PROCEEDINGS OF PUBLIC HEARINGS: PLUTONIUM AND THE OTHER TRANSURANIUM ELEMENTS

VOLUME 2
PROCEEDINGS OF HEARINGS
IN DENVER, COLORADO
JANUARY 10, 1975

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation Programs

PROCEEDINGS OF PUBLIC HEARINGS: PLUTONIUM AND THE OTHER TRANSURANIUM ELEMENTS

VOLUME 2
PROCEEDINGS OF HEARINGS IN
DENVER, COLORADO
JANUARY 10, 1975

Environmental Protection Agency
Region V, Library
230 South Dearborn Street
Chicago, Illinois 60604

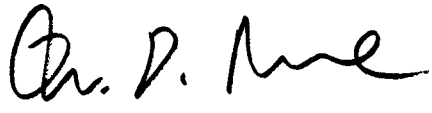
U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation Programs
Criteria and Standards Division
Washington, D.C. 20460

FOREWORD

Production and use of plutonium and the other transuranium elements is projected to increase rapidly. Because of the long half-lives and high radiotoxicity of many nuclides of these elements, public and technical concern has been expressed regarding the possible environmental and health impact of releases of these elements to the environment. For this reason the Environmental Protection Agency has embarked on a program to evaluate the environmental impact of the transuranium elements and to consider whether further guidelines or standards are needed to assure adequate protection of the general ambient environment and of the public health from potential contamination of the environment by radionuclides of these elements.

As a part of this program public hearings were held in Washington, D.C., and Denver, Colorado, to gather information regarding the public and social implications of plutonium utilization; the factors involved in the balancing of costs vs. benefits; dosimetry, health, and environmental effects; environmental levels and pathways; applications using plutonium; and control and cleanup technology.

This Agency believes that the information resulting from these hearings constitutes a significant contribution to the public awareness and knowledge of this problem and that wide dissemination of these proceedings will be valuable.



W. D. Rowe, Ph.D.
Deputy Assistant Administrator
for Radiation Programs

PREFACE

Information was presented both orally and in written form at the hearings and, in addition, a number of letters were submitted directly to the Office of Radiation Programs of The U. S. Environmental Protection Agency for inclusion in the hearing record. This information is being published in three volumes: Volume 1 contains the proceedings of the hearing in Washington, D.C.; Volume 2 the proceedings of the hearing in Denver, Colorado; and Volume 3 the additional material submitted. Where written submittals are more complete, these are printed in lieu of the oral testimony.

CONTENTS

Page

Opening Remarks

Mr. John A. Green 1
Dr. William D. Rowe 5
Dr. William A. Mills 12

U. S. Atomic Energy Commission
(Energy Research and Development Administration)

Dr. William W. Burr, Jr. 17
Mr. Earl W. Bean 25

The Colorado Department of Health

Mr. Albert J. Hazle 183

City of Boulder, Colorado

Ms. Ruth Correll 203

Jefferson County Health Department

Dr. Carl J. Johnson 208

Colorado Medical Society

Dr. John C. Selner 224

Lamm-Wirth Rocky Flats Task Force

Dr. John C. Cobb 235

Colorado American Friends Service Committee

Miss Susan Carpenter 267

Dr. Eric Eisenbud, Hospital Physician 282

Prof. Donald P. Geesaman, University of Minnesota 291

Dr. Edward A. Martell, National Center for
Atmospheric Research 407

Mr. George Pelton, Natural Hygienist 458

Page

Dr. Frank W. Anders, University of Northern Colorado 465

Environmental Action of Colorado

Mr. Albert Nunez 479
Mr. Morey Wolfson 484

People for Rational Energy Sources

Mr. Carl Lehrburger 517

St. Mary's Episcopal Church

Ms. Nina Conant 523

South High School, Denver

Mr. Mike Tryen 532

Mr. Rick Speed 543

P R O C E E D I N G S

9:07 a.m.

CHAIRMAN MILLS: This is a public hearing on plutonium and the transuranium element. This particular hearing was announced in the Federal Register on December 24, 1974, to be held here in Denver.

For some opening remarks, I would like to call on Mr. John Green, who is the Regional Administrator in Region VIII located here in Denver for some comments from the Environmental Protection Agency. Mr. Green?

MR. GREEN: First of all I would like to welcome everyone to Denver, anyone who is not from the vicinity here. Welcome to the panel, welcome to our EPA headquarters people, and I want to thank them for the opportunity of allowing people in our Region to have some input into these hearings. As you realize, the original hearings were in Washington. This is more or less an extension of those. We do have significant problems in this area out here, and I do want to express my appreciation to the EPA headquarters people, to Bill Rowe, especially, who heads it in allowing us to have it here.

THE AUDIENCE: We can't hear.

MR. GREEN: What I just did is welcome everybody.

Now, as we all know, as Dr. Mills said, this is an information-gathering hearing to better enable us to assess the requirements for standards, regulations, and this type of

thing. EPA intends to evaluate the environmental impact of the transuranium elements and to determine whether guidelines or standards are allowed under our authority to promulgate are really needed. I am hopeful that these determinations will assure that there is adequate protection of the general environment and the public health, especially, that is from the potential contamination of the radioactive elements that we are addressing today.

During the course of the day, we will be interested in any information and all information pertinent to the development of such standards and, with that in mind, the rules that the Chairman will address later are a very flexible and very informal type of meeting.

Now, for some specifics of the problem before us. The elements which we are considering here are plutonium, neptunium, americium, curium, and all the others up through Atomic Number 103. These elements, as we all know, are man-made elements. Forty years ago they were unknown for man. Today, however, they are produced in large quantities, and they form a central part of our national defense, nuclear power industry, and our space research program. These elements are also beginning to appear in consumer items such as smoke detectors, as we use in our air pollution business, and static eliminators. Research and development is also underway on such items as heart pacemakers and heart pumps. So, as we go

on and on, this list is expanding as larger quantities of these materials become available.

While the environmental contamination levels are certainly a topic of great interest to us here, I think it is worthwhile at this time to put this problem in a perspective. There is already a large existent worldwide inventory of plutonium, fairly uniformly distributed, that is on the order of 300,000 to 500,000 curies throughout the universe. This is the result of fallout from various atmospheric weapons tests and from the burnup of a space nuclear power generator on its reentry to the earth's atmosphere here on the earth.

Local contamination levels also are something that we are concerned with, like for example in the vicinity of Rocky Flats, but we feel these contaminations and locations of atomic test sites in areas such as Rocky Flats are relatively small when you look at the total overall levels throughout the world. For example, the total release from the Rocky Flats facility over the entire period of operation is reported to be about 15 curies, with about one-third of this being off-site. This is not to minimize the importance of environmental contamination, but rather to emphasize that this is both a global and local problem.

Now, we feel at this time there is a good reason for EPA to consider the subject of standards of elements now, especially at this time. Earlier decisions concerned with

plutonium were predicted solely on the basis of national security considerations inasmuch as plutonium produced was destined for weapons programs. The Rocky Flats plant and the Nevada test site are examples of this phase of our development. Only a recent growth of the nuclear power industry has brought this problem into the national area.

Plutonium and other transuranium elements are produced in substantial quantities during the operation of light water reactors, for example. The materials are contained in fuel rods and cannot escape except in extremely unlikely event of a catastrophic event. However, there is a finite possibility for a small release, and this does exist in certain operations such as fuel reprocessing, fabrication, and transportation operations. Such releases are expected to occur under normal conditions, but will require careful control and surveillance. The nuclear power industry is now embarking on a growth period, and the problems of today may be very, very more significant tomorrow.

One significant item is the persistance of these elements in the human time scale. Plutonium-239, for example, has a radioactive half-life of over 24-thousand years. Therefore, remedial measures are difficult to apply to these elements, and only preventive action is completely satisfactory. The time to think about this preventive action is right now, and that is our purpose for being here today to study this, to look

at it, and to get inputs, and to determine whether preventive action is necessary; whether it is in the form of a joint regulation, whether it is in the form of various types of standards, and whatever can be developed to assure that we do prevent any future increase, significant increase in the level of these radioactive lives in the environment.

Thank you.

CHAIRMAN MILLS: Thank you very much, Mr. Green. Now I would like to call on Dr. William Rowe, who is the Deputy Assistant Administrator for Radiation Programs in the Environmental Protection Agency.

DR. ROWE: We are pleased to be in Denver to continue our public hearings on plutonium and the other transuranium elements. As John Green has said, the purpose of these hearings is to give both the scientific community and the general public a forum for discussion of all the issues pertinent to the development of standards designed to limit the environmental dispersion of these elements to levels both realistic and safe. We are soliciting such information now, prior to the time when the Environmental Protection Agency is ready to write such standards, in order to give the maximum opportunity for all participants to have their opportunity to talk early in the standards development process.

The Environmental Protection Agency is keenly aware of the potential for both use and misuse of plutonium and the

other transuranium elements. Some of the major decisions leading to our current environmental contamination levels, such as decisions on atmospheric testing of nuclear devices, were made long ago and must be considered as past history. However, because of the very long persistence of these elements in the environment, the consequences of such decisions continue on and must be part of any realistic assessment of current and future activities. What we can do now is to make the best assessment of the consequences of current and future activities and develop such standards as may be required to best protect our population. The development of such standards requires a broad range of detailed information and of informed viewpoints. Our purpose here today is to help us gather as much of such information as possible from the total spectrum of opinion in order for us to do the best possible job.

The establishment of regulatory standards and radiation guidance involves three different types of judgment which must be clearly recognized. It is information which will permit us to make such judgments that we desire here today.

First, we have the technical judgment. Groups of related facts may on occasion be given different interpretation by the experts, and result in different conclusions. The rationale and validity of these conclusions then needs to be examined from the viewpoint of their influence on standard setting. In addition, there are always areas where the results

may not be definitive and uncertainties remain. While it may be possible to conduct scientific experiments to reduce such uncertainties, the time to carry out these experiments may preclude the necessary information being available at the time action is needed. Therefore, experts in the technical problem area often must make collective value judgments on the interpretation of available information. I want to say that the technical expert panels that we use in EPA are usually not part of EPA, but are various scientific groups such as the National Academy of Science, National Committee of Radiation Protection, and other scientific groups who advise EPA on these technical matters and judgments. In this vein, we seek information which will help EPA and external technical bodies upon whom EPA relies to make these technical judgments.

The second type of judgment is the one where the best technical information as to risks, costs and benefits is considered and balanced to achieve equitable standards for society as a whole. In making a regulatory balance of this type, not only must costs and benefits be balanced as a whole, but inequities where cost and risk impact on those who do not directly receive benefits must be considered in terms of the total and ultimate impact of this activity. In the case of plutonium and the actinides this involves consideration of potential health effects committed for long periods. This type of value judgment must be made by society as a whole and

not by the technical community alone. We seek information today which help us to make these risk-cost-benefit judgments.

The third type of value judgment is in that arena that when standards are set they must be capable of being implemented and enforced in a way that is visible, traceable and reportable, and can be substantiated in an evidentiary manner in the courts. These judgments of a managerial nature as to the best means of implementing a standard certainly affect the form of a standard. We here also seek information which will help us to make judgments on implementation.

It is not by chance that the Environmental Protection Agency's Office of Radiation Programs has selected plutonium and the other transuranic elements as the first problem to be considered in this type of forum. The toxicity and long life of plutonium and the transuranium elements, totally man-made elements, provide us with the need for making value judgments which will now have long-term significance.

The objective of these hearings is to provide a forum where all existing information on plutonium and transuranic elements which affects radiation protection activities can be aired and can be considered in a meaningful way, where all points of view and all who wish to provide input can have an opportunity to be heard in a studied manner. It is our opinion at EPA that this information can be best derived by the type of hearing format we are using here -- where the

procedures are informal and a panel of technical experts is used to assure that the information presented is sufficiently clear for public recognition of all viewpoints. The information that we seek at these hearings is to provide a baseline of technical information on radiation protection aspects of the transuranics, but also can be addressed to any one or all of the value judgments that I have described.

At the close of the hearings today, the record will remain open for 30 days, and any further information can be presented to EPA, Office of Radiation Programs, 30 days from today, will be included in the record.

This will not be the only source of information that we use as we set standards. We will be talking with other bodies as well, but this will become a very important portion of our standards setting information base. The standards we seek to set for plutonium are all inclusive.

In many cases the particular authorities and jurisdictions that set these standards is not totally within the EPA, and in some cases not even clear where the responsibility lies. We are undertaking to do this in an overall proceeding with the cooperation of all those Federal agencies who will have anything to do with plutonium. This includes the AEC, the successor bodies, the NASA Department of Defense, HEW, and all other people who are using plutonium or transuranium elements. We have formed an interagency

committee where these matters will be discussed and studied, and determinations of what kinds of standards and who will set them will be determined.

Through its Federal guidance authority, EPA has responsibility for looking as an overview of plutonium as well as setting generally applicable environmental standards. In doing this, EPA will come forth and set standards, but we hope that the philosophy that is used not only for EPA will be done consistently across the board by all agencies involved. Certainly EPA's standards will be EPA's standards promulgated by standard procedures. However, we feel that this cooperation between agencies which has already been demonstrated by the hearings in Washington will lead to a straight-forward proceeding where all matters can be taken.

Let me now introduce the Hearing Panel.

First, we have Walter S. Snyder: Dr. Snyder was born in Mansfield, Ohio, and obtained his Ph.D. from Ohio State University. He was a Professor of Mathematics at the University of Tennessee for many years. From 1959 until quite recently he held important posts with Union Carbide at Oak Ridge. He is a specialist in internal dosimetry and a former editor of Health Physics.

Melvin First: Dr. Melvin First was born in Boston and received his Doctorate of Science in Industrial Hygiene from Harvard. He has served with the Michigan Department of

Health and is now on the faculty of the Harvard School of Public Health. He is well known for his many contributions in air and gas purification.

John Garner: Dr. John Garner was born in the United Kingdom where he was educated, majoring in biochemistry and received his doctorate in Veterinary Science at Liverpool. After serving in several assignments in Africa and the United Kingdom, he came to the United States in 1965. He served as the Director of the Collaborative Radiological Health Laboratory at Colorado State University from 1965 to 1972. He is now Director of the Experimental Biology Laboratory of the Environmental Protection Agency at Research Triangle Park in North Carolina.

Karl Z. Morgan: Dr. K. Z. Morgan was born in Kannapolis, North Carolina, obtaining his Ph.D. in Physics from Duke University. He became Director of the Health Physics Division at Oak Ridge National Laboratory in 1943. He is a member of the NCRP, as well as the ICRP, and is presently the Neeley Professor in the Nuclear Engineering Department at Georgia Tech.

Lauriston S. Taylor: Dr. Lauriston S. Taylor was born in Brooklyn, New York, obtaining a Doctor of Science degree from the University of Pennsylvania in 1960. He worked at the National Bureau of Standards for many years starting in 1927, becoming Chief of the Radiation Physics Division in

1960. He now serves as the President of the National Council on Radiation Protection and Measurement.

Dr. William A. Mills: Dr. William A. Mills was born in Lynchburg, Virginia, received his Ph.D. in Biophysics from the Medical College of Virginia. He is a Commissioned Officer U. S. Public Health Service, current rank Scientist Director. His past employment includes Oak Ridge National Laboratory, the Southeastern Radiological Health Laboratory, Bureau of Radiological Health, and is currently the Director of Criteria and Standards Division, Office of Radiation Programs, Environmental Protection Agency. His field of specialization is the Bioeffects of Radiation.

Dr. Mills is the Chairman of the Panel, and he will be the Hearing Officer for this meeting. Dr. Mills?

CHAIRMAN MILLS: Thank you very much, Dr. Rowe and Mr. Green, for those opening remarks.

I need to take about a two-minute break here for just a moment.

(Whereupon, a short recess was taken.)

CHAIRMAN MILLS: We are ready to resume.

On behalf of the Panel, let me welcome you to this hearing. It is going to be a very long day, and we have got a full schedule. We will run late this afternoon and into the evening probably. I ask for your cooperation in abiding by the procedures that have been established.

Let me briefly review some of those procedures which were announced in the October 24th Federal Register notice for the hearing which we conducted in Washington. We referenced those rules in the Federal Register notice of December 24th, which pertained to this hearing.

The hearings will be conducted informally. The technical Rules of Evidence will not apply. Discovery and cross-examination of participants will not be permitted. The Hearing Panel appointed by Dr. Rowe will consist of a Chairman and three or more experts in the field of radiation protection. The Panel will conduct the hearings. The Chairman of the Hearing Panel is impowered to conduct the meeting in a manner that in his judgment will facilitate the orderly conduct of business, to schedule presentations by participants, and to exclude materials which is irrelevant, extraneous, or repetitious. In arranging this schedule, persons wishing to present an oral statement shall give a written notice no later than January 3, 1974, in order to be placed on the agenda. The time allotment for such oral statements shall be at the discretion of the Chairman, and which shall not ordinarily exceed twenty minutes. Persons wishing to submit written statements regarding the agenda items may do so either in abeyance or during the hearings. Such persons may also request an opportunity to request an oral statement.

Oral presentation may be presented by panel discussion of technical experts chosen to present a particular viewpoint if notice is given. The time allotment for such panel discussion shall be at the discretion of the Chairman, which shall not ordinarily exceed 60 minutes.

Requests at the time of the hearings for the opportunity to make oral statements with no previous notice shall be ruled on by the Chairman who is impowered to apportion the time available, but not ordinarily to exceed five minutes.

Questions may be propounded only by members of the Hearing Panel. I have requested that such questions be submitted to Dr. Gordon Burley -- Gordon, will you stand?

(Whereupon, Dr. Gordon Burley stood.)

CHAIRMAN MILLS: For referral to the Panel for their decision.

There was one other condition we had in the Federal Register notice which in the public interest we have chosen to eliminate, and that is the use of cameras and so on is permitted only before and after the hearing and during the inner recess, but not during the hearing session. We have waived that procedural rule.

As Dr. Rowe indicated, a transcript of the hearing will be made and a copy of the transcript, together with copies of all documents presented at the hearing, will constitute the

record of the hearing. A copy of the transcript of the hearing will be available for public inspection and in copy within 30 days after the conclusion of the hearings today. These will be available at the U. S. Environmental Protection Agency. We will as soon as available get copies of such in the Regional Office here in Denver.

With regard to the speakers, as I indicated, we will have a full schedule, and I ask for your full cooperation in trying to make that schedule. To assist the Recorder and the audience, I ask that the speakers and the Panel members avail themselves of the microphone.

For those speakers who may have not registered to participate, please insure that Dr. Burley has a copy of your full mailing address for these hearings.

With those remarks, I would now like to call on Dr. William Burr from the Atomic Energy Commission in Washington, D. C.

Testimony By
William W. Burr, Jr., M.D.
Deputy Director
Division of Biomedical and Environmental Research
U.S. Atomic Energy Commission

Environmental Protection Agency
Plutonium Standards Hearing
Denver, Colorado, January 10, 1975

I am Dr. William W. Burr, Jr., Deputy Director of the Division of Biomedical and Environmental Research, U.S. Atomic Energy Commission. We appreciate the opportunity to participate in these hearings in Denver as we did in the EPA hearings held last month in Washington, D. C. At that time, the AEC presented approximately four hours of testimony which, with questioning from the hearing panel, extended to nearly six hours. Recognizing the interest and concerns of the people of the Western States, and recognizing the fact that societal decisions of the type considered in these hearings must be based at least in part upon scientific data, we would like to review and very briefly summarize our testimony in Washington.

This material covered the sources of plutonium and other transuranium elements, control measures with respect to those sources, worldwide environmental levels of these elements, biomedical effects observed to date in experimental work, followup studies of exposed humans, and the implications of all of this information with respect to radiation protection criteria. In fact, it covered a great deal of factual information resulting from scientific investigation. Although the entire hearing proceedings,

including this testimony, is part of the public record, the AEC, in order to make its testimony more readily available to interested persons, has published the complete AEC testimony as a separate document. A limited number of copies of this material are available here today for the participants in today's hearings.

The hearing panel has already had extensive opportunity to question those who presented the AEC testimony, and we have not requested all of the speakers to be present today.

Dr. Liverman, in his introductory testimony, pointed out that concern regarding plutonium is based upon several facts:

1) Increasing quantities of transuranics are being and will continue to be produced as nuclear power provides a growing fraction of our national energy requirements.

2) A number of these radioisotopes are similar to naturally occurring alpha-emitting radioisotopes in that they have extremely long half-lives and, once released, will persist and accumulate in the environment for time periods extending over many human generations.

3) These naturally occurring alpha-emitting radioisotopes are known to produce cancer of the lung, bone and liver in humans exposed to large concentrations.

4) Comparable concentrations of alpha-emitting transuranic elements are known to produce cancer of the lung, bone and other organs in experimental animals.

These considerations make it mandatory that bioenvironmental health and safety considerations be of primary concern with respect to activities involving the production and use of the transuranic elements. More than

thirty years of research have produced a substantial body of knowledge and understanding regarding the health and safety aspects of such operations. Through application of this knowledge, experience and understanding, it has been possible to establish health and safety procedures which have permitted many thousands of kilograms of plutonium to be produced and processed, and we have yet to identify successfully a major health consequence attributable to its radiotoxicity. This record contrasts sharply with that for the commercial use of radium earlier in this century where manufacture and use of a few grams of material resulted in extensive occupational exposures and many cases of cancer.

Meaningful judgments on the adequacy of current standards, criteria and guidelines must be based in part on the knowledge and understanding acquired in the course of nuclear development including the research in the life sciences. This knowledge is extensive; Nuclear Science Abstracts alone contains over 10,000 references on all aspects of plutonium and other transuranic elements. These and other bibliographic data are available at a number of sites throughout the country. Numerous scientific meetings have been held to promote the exchange of information; authoritative monographs are periodically prepared by those most competent to do so.

This body of available information is continually analyzed by various national and international groups including the International Atomic Energy Agency (IAEA), the United Nations Scientific Committee on

the Effects of Atomic Radiation (UNSCEAR), and various past and present committees of the National Academy of Sciences: Biological Effects of Atomic Radiation (BEAR Committee), Biological Effects of Ionizing Radiation (BEIR Committee), and the current committee established to examine the "hot particle" issue. It is also analyzed and used in establishing exposure limits by organizations independent of any governmental agencies. These organizations include the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP). It is essential that the objectivity which these organizations represent continues to be involved in this process.

Despite the thousands of scientific references, information on the biomedical and environmental behavior of plutonium and other transuranics is not complete. Accordingly, the AEC continues to maintain a major research program on the biomedical and environmental aspects of the transuranics. This program focuses on those areas where additional information is most likely to critically influence developmental programs, operations and regulations. Such information is needed to make more refined estimates of potential health and environmental hazards of transuranium elements. The results of this research are published regularly and are readily accessible.

I shall now very briefly discuss the several topics identified on the slide; detailed information may be obtained from the AEC testimony previously presented at the hearings in Washington.

Since the discovery of plutonium there have been releases to the environment; these have been reported. The overwhelming portion of plutonium in the environment, over four hundred thousand curies, was placed there as a result of military activities; some was also released as a result of the burn-up of a space thermoelectric generator. If releases due to military and space activities are not included, the amount released as a fraction of what is handled is very small indeed. For example, routine off-site releases during the six-year period 1967-1973 amounted to approximately 1.5 curies. We anticipate that in the future releases from all government facilities through normal discharge systems will not exceed 0.1 Ci/yr. That is, at present release rates, less than three additional curies of plutonium will be discharged to the environment by the year 2000.

I would like to mention at this time with respect to release levels that the AEC operates under the "as low as practicable" philosophy, and that values associated with "as low as practicable" have continually decreased with increasing operating experience and improved control technology.

Those few sites where releases and accidents have occurred are extremely dissimilar in their environmental conditions, the physical and chemical form of the radioisotopes involved and current and projected land use. Our experience suggests that each of these may exert an important influence on the practicability, including cost-effectiveness,

of possible remedial actions. Since the number of contaminated sites is small and is likely to remain small, and since these sites are so diverse in character, it appears to be more effective to deal with these situations on a case-by-case basis using current standards than to attempt to develop additional standards and guidance generally applicable to all of them. However, if additional guidance is developed, it would be essential that it include the flexibility necessary to assure effective application under widely varying circumstances.

The fact that plutonium has been dispersed into the atmosphere provides us with a means of tracing globally distributed plutonium. Monitoring studies have been carried out for many years, tracing the fate of this plutonium. These data were previously reported, along with concentrations at a more local level in the vicinity of those sites where releases have occurred. We continue to follow the transuranic elements dispersed globally and to study the behavior of plutonium in the quite diversified environments near weapons test areas in the United States and the Pacific and around operating facilities in the United States.

Monitoring of the plutonium content of food, air, water and tissue has been carried out to determine the relative quantity of that potentially available which is finally incorporated into man. Based on a limited number of tissue measurements, a very rough estimate of the total amount of plutonium in individuals living in the United States is perhaps 3.5 picocuries or about 10^{-17} per person of that in the global biosphere.

Many years of research and many millions of dollars have been and are being devoted to understanding how plutonium is metabolized by the body, what the ultimate biomedical effects of plutonium--and other transuranics--might be, and what actions might be taken to minimize those effects. These studies extend over decades and include administration of a range of quantities of transuranic radioisotopes in a variety of chemical and physical forms to several animal species by inhalation, ingestion and injection. These studies also have provided direction for additional research, such as determining the consequences of inhaling small quantities of aerosolized transuranics, the effects of chronic inhalation exposures, and quantitating the effects of "hot particles."

Although we are in a sense fortunate that so much of our biomedical information thus far comes from experimental work, man is the primary subject of our concern. Consequently, persons who have been occupationally exposed to plutonium at some time in their careers are of particular interest. Despite the fact that numerous persons have been occupationally exposed during the past 30 years, to date there has been no serious health consequence observed which has been successfully shown to be related to plutonium. Some of these persons have been followed medically for nearly 30 years with periodic medical examinations.

What all of these data mean in the context of establishing environmental and general public exposure limits was also discussed in the testimony. As was pointed out there, man today is an evolutionary product evolved under

constant exposure to radiation. In this process, man did not develop means to insulate himself from either external or internal naturally occurring radiation. Consequently, if additional exposures are kept to a small fraction of that occurring naturally, our own development and existence says that unacceptable biological risks would not be anticipated.

This completes the summary. I wish to thank the Board for the time to present this brief summary so that those not present at the hearings in Washington might be aware of what was discussed in AEC testimony, and, if they are interested, to avail themselves of the opportunity to examine that portion of the record more closely.

In addition, since this part of the EPA hearings are in Colorado, we feel that the Board might find it useful to have information on the AEC's Rocky Flats Plant, which is northwest of Denver. A member of the AEC staff, Mr. Earl Bean, Assistant Area Manager for Operations at Rocky Flats, will present this material.

Should the Hearing Board wish to direct any further questions to the Atomic Energy Commission during or at the close of this hearing, we will be happy to attempt to respond either orally, if we have the information available, or in writing. To that end, we have a limited number of staff and contractor personnel present.

Testimony By
Earl W. Bean
Assistant Area Manager for Operations
Rocky Flats Area Office
U.S. Atomic Energy Commission

Environmental Protection Agency
Plutonium Standards Hearing
Denver, Colorado, January 10, 1975

Members of the Panel, Ladies and Gentlemen, I am pleased to have the opportunity to present a very brief summary of the Rocky Flats plant history, what is done at the plant, the effects of plant operations and the AEC concern for health, safety and the environment.

Construction of the Rocky Flats plant was completed and operations started in 1953. By the end of fiscal year 1974, the acquisition costs for the plant totaled $222 million. This includes about $91 million for equipment and $131 million for land, buildings and facilities. Over 90 major structures containing approximately 1.7 million square feet of building area are included on the plant site. About 2900 people are employed at the plant. The plant is situated on about 2500 acres of Government owned property approximately 15 miles north and west of Denver. The Government has purchased approximately an additional 4000 acres around the perimeter of the original plant site to act as a buffer zone in order to minimize the types of problems which often arise from the proximity of industrial facilities to residential communities.

The plant is part of the AEC nuclear weapon production complex. It has been operated from the onset by the Dow Chemical Company. Effective July 1, 1975, Rockwell International Corporation will operate the plant.

The primary function of the plant includes metal working and chemical recovery. Plutonium is one of the primary materials handled at the plant. Since the plant operation began, extensive control techniques have been utilized to insure that plutonium in liquid and gaseous effluents leaving the plant site are below allowable standards and at the minimum practical level. Improvements have continually been made in these control techniques so that plutonium concentrations in air and water leaving the plant site have been reduced and have been substantially below currently accepted concentration guides.

Small amounts of plutonium have been released in the air and water due to normal plant operations and due to accidental releases. Two major fires occurred at the plant site, in 1957 and 1969, during which small amounts of plutonium were released. Essentially all of the off-site contamination resulted from the plutonium released over a period from 1958 to 1968 due to leakage from 55 gallon drums containing plutonium-contaminated lathe coolants. Soil samples have been collected both on and off-site to describe the distribution and amount of plutonium from the plant. These findings have been published and can be made available to the Panel. We will be happy to answer questions concerning these areas or any other area of local concern.

An extensive environmental monitoring program is conducted to insure that all plant discharges are well within applicable AEC and EPA standards. Air, water and soil are routinely and repetitively sampled and analyzed

for plutonium within the plant site, at the plant boundary, and in the communities surrounding the plant. All water discharged from the plant is held in ponds on the plant site and analyzed prior to release.

In addition, vegetation and wildlife are sampled periodically and analyzed for plutonium. The results of the environmental monitoring are reviewed monthly with the EPA, Colorado Department of Health, and other state and local officials. These data are published semi-annually.

Background radiation measurements are made at various locations up to 20 miles from the plant. The maximum measured background concentrations of plutonium in water was .03% of the maximum allowable levels. During 1974, the average plutonium concentration in water leaving the plant site was .05% of the standard. In the same year, plutonium in Great Western Reservoir, which is the drinking water supply for the city of Broomfield, averaged .002% of the standard. The maximum measured background concentration of plutonium in air was 0.4% of the maximum allowable concentrations. In 1974, the plutonium in the air at the downwind site of the buffer zone was less than .4% of the currently accepted standard and plutonium in the Broomfield air averaged .4% of the standard. Both values are the same as found for background. In general, plutonium concentrations in plant effluents have been less than 1% of the allowable standards.

In addition to monitoring the surrounding communities, an extensive monitoring program is conducted at the plant. This program includes monitoring the air in all of the work areas; multiple samplers and

continuous alarms at gaseous release points; periodic soil, vegetation and animal analysis; monitoring of ground water through a series of wells; employee monitoring, and periodic employee health examinations. An extensive quality control program is included as part of all monitoring activities.

Several long term research studies are under way to determine the movement and effect of plutonium in the eco-system. Several studies are being conducted by the University of Colorado and Colorado State University to understand the behavior of plutonium in the aquatic and terrestrial environment. Other studies conducted by the USGS, AEC laboratories, and private consultants have been concerned with resuspension and disposition of plutonium, the meteorology of the Rocky Flats area, and possible movement of plutonium through ground water and soil. In addition there are data available from extensive environmental studies of plutonium which have been conducted elsewhere; this information is being utilized to the degree it is applicable to the Rocky Flats areas.

In the past several years significant improvements have been made to the physical facilities and operations in the areas of environmental protection, fire safety, occupational safety, and handling of radioactive wastes. These include:

--Improved packaging of solid radioactive wastes.

--100 specific improvements to plant fire protection as recommended by an outside consulting fire protection association.

--A new waste treatment facility which, when completed in 1976, will recycle all process waste water.

--A new tertiary treatment facility for sanitary sewage to comply with the most restrictive state and EPA standards for water quality.

--A new plutonium recovery facility which is being constructed to stringent design criteria for new plutonium handling facilities.

--An expanded environmental monitoring and sampling program.

In summary, the AEC is aware of the environmental aspects of its Rocky Flats operation and continuously monitors the effluents (both air and water) that leave the plant site. Actual releases measured are substantially below existing standards.

Thank you.

Chairman Mills: Mr. Bean, I have a quick question and the Panel may have some also.

This recent purchase of land surrounding the Rocky Flats Plant, can you say something about what this land has been used for in the past, and what you propose to do with it from the standpoint of controlling access to the land itself?

Mr. Bean: The land in the past has been strictly agricultural, principally grazing. We certainly have no plans to do any development on the land. It will be held as an undeveloped buffer zone around the plant site.

Chairman Mills: Does the Panel have any questions? Dr. First?

Dr. First, First, I am sure this will be clear when I get your written comments. But, we went through a lot of numbers in a hurry, and I am a little confused. Perhaps you might clarify the relationship between the measurements in the environment, which I gather from your discussion are at or close to background, and the relative percentage of allowable emissions as measured in the stacks, etc., and water discharges from the plant. Can we relate those two figures in any way?

Mr. Bean: Your question is concerning the amount in the stack versus what is in the background air?

Dr. First: No, is the percentage of emissions from your measured effluents in the same relation as the environmental measurements to background?

Mr. Bean: Dr. Milton Thompson from Dow Chemical is present. Milt, why don't you come up and use the microphone?

Dr. Thompson: Let me try from here. I am not sure I understand the question, but the releases from our plant at the plant boundary in general are like 1% or less than the currently allowable standard. Now, that is true for both air and water at the plant boundary. The measurements in the communities near the plant are essentially background measurements.

Dr. First: As I understand, you are saying that you are measuring environmental concentrations at the plant boundary. My question referred to the measurement in the effluent streams before release into the environment?

Dr. Thompson: The material in the effluent stream leaving the plant site, whether it is water or air, are in general less than 1% of the currently allowable standards.

Dr. First: Thank you.

Dr. Taylor: By way of perspective, I would like to ask Dr. Burr if he could tell us approximately how much natural alpha-emitting radioactive material do we find in the normal environment? You mentioned that we will get 0.1 curies, a

tenth of a curie per year emitteed from the AEC operation. Do you happen to know roughly the amount of alpha-emitting radioactive material per square mile of earth a foot deep, let us say?

Dr. Burr: I do not have the figure, Dr. Taylor, at hand. We certainly can supply it, or perhaps you could supply it?

Dr. Taylor: I will supply it. It is of the order of one curie of radium and several curies of the -- I think it totals something a little bit less than 10 curies of the alpha-emitting part of the radium series per square mile a foot deep. (Note: see letter from Dr. Taylor at the end of the questioning.)

Dr. Snyder: I would like to ask a question of Mr. Bean. Does your monitoring program include monitoring for foodstuffs that might reach human consumption, and are we to infer that the levels seen in these, perhaps milk or meat or brook trout, I am not sure, are comparably small to what your effluent releases are?

Mr. Bean: I think the answer is generally that that is true - the same order of magnitude as our effluent releases are. We have done some aquatic studies on minnows in the stream. We do not have large rivers, we just have very small streams that have some minnows living in them. There does not seem to be any concentration mechanism in those

minnows. The levels in them are --

Dr. Snyder: Second, may I ask, could you summarize very briefly the experience on transportation of these things, the plutonium particularly, from the plant? Have there been a significant number of accidents in which there was breach of containment or at least threatended?

Mr. Bean: So far, in our transportation experience with both the plutonium material coming to the plant and the product leaving and the waste material, we have never had an accident, transportation accident, that I know of where there has been any release of material.

Dr. Morgan: I would like to ask Mr. Bean first, you indicate that in general the releases have been less than 1% of the allowable levels. How much plutonium do you allow, that is what is the allowable level for plutonium per year in curies?

Mr. Bean: I do not know the number offhand. We use the per cubic meter standard for air and the per liter standard for water, and we would have to -- how about you, Dr. Thompson? Do you know the exact number?

Dr. Thompson: I do not have the total allowable number, but the standard that we use is the most restrictive standard for the general population which for air is .02 picocuries per liter, for water is .1667 picocuries per liter.

Dr. Morgan: My question I think implies, we would be concerned about the total number of curies released with a long half-life in addition to the concentration in the air and water?

Dr. Thompson: I think we can provide you with that number, but we do not have it now.

Mr. Bean: We can give you our annual environmental monitoring reports which have those numbers in them; we will provide those to the Panel. (Note: material is attached to the end of the questioning.)

Dr. Morgan: I have a question of Dr. Burr. I believe you indicated that there would be less than three additional curies of plutonium released from all Government facilities to the environment by the year 2000. I have then three comments on this, or questions. First of all, does this include the releases by plant accidents? Second, does it include releases by accident with military planes? We have had two such accidents that have been widely publicized. Third, does it include releases of all plutonium? You said that for plutonium there would be more Pu-241 and 238. Does it include the others too?

Dr. Burr: First of all, let me address the accident. This is from routine release and not accidental releases; it does not include accidents.

Dr. Morgan: This is assuming that you have no accidents

in this period?

Dr. Burr: That is assuming there is not an accident.

Dr. Morgan: What about the military?

Dr. Burr: Likewise for the military. In regard to whether it includes all the transuraniums, I would like Dr. Yoder to comment on that.

Dr. Yoder: It includes all of the plutonium isotopes.

Dr. Morgan: And the military, does it include all of that?

Dr. Yoder: No, sir.

Dr. Garner: Is that figure predicated upon the development of a fast breeder program?

Dr. Burr: I would like Dr. Yoder to respond to that.

Dr. Yoder: I did not hear the question.

Dr. Burr: Is this predicated on the development of a fast breeder? Do we have a figure?

Dr. Yoder: I think it does, yes.

Dr. Burr: We believe it does, but we can verify that.

Dr. Morgan: Does this include the MOX Program, mix oxide uses in light-water reactors?

Dr. Burr: This is a part of Dr. Yoder's Washington testimony; that is why I am referring to him. I would like Dr. Yoder to respond to that. Dr. Yoder?

Dr. Yoder: Those numbers refer to AEC plant operations, those operations in Government facilities. MOX, if it is

done at commercial facilities, is not included in those numbers.

Dr. Morgan: So Barnwell operations, if they get in operation, will not be included, although this may be the principal contributor to the environment?

Dr. Yoder: That is correct, Barnwell is not included.

Chairman Mills: Mr. Bean, for the record, we would like to have a copy of your annual monitoring report.

Mr. Bean: We will be pleased to provide them for the past 4 years. (Note: Material follows.)

Chairman Mills: Thank you, Dr. Burr and Mr. Bean.

NCRP

National Council on Radiation Protection and Measurements

7910 WOODMONT AVENUE, SUITE 1016, WASHINGTON, D. C. 20014 AREA CODE (301) 657-2652

LAURISTON S TAYLOR, *President*
E DALE TROUT, *Vice President*
W. ROGER NEY, *Executive Director*

January 22, 1975

Dr. William Mills
Director
Division of Criteria and
Standards (AW-560)
Radiation Office
Environmental Protection Agency
Waterside Mall, E-635
401 M Street, S.W.
Washington, D.C. 20460

Dear Bill:

You may recall that during the hearings, I questioned Dr. Burr about the amount of naturally-occuring radioactive material in the soil of the earth. When he did not know the answer, I provided it, but I have now discovered that I was grossly incorrect in some of the numbers that I gave him. Since I believe this is important to the overall hearings, I would like to have the material below included as a correction statement.

The average concentration of some radioactive materials in the earth's soil is as follows:

Uranium -- 2×10^{-12} curies per gram
Thorium -- 1.3×10^{-12} curies per gram
Radium -- 2×10^{-12} curies per gram

As to actual amounts of radioactive material, the following quantities would be contained in a surface of earth 1 foot thick and 1 mile square:

Radium -- 1 gram
Uranium -- 3 tons
Thorium -- 6 tons

In addition to these materials, there are varying amounts of carbon-14 and potassium-40.

The source of this information and the references are contained in "Radiation Hygiene Handbook," by H. Blatz, page 4-7 (1959).

Sincerely yours,

Lauriston S. Taylor

ROCKY FLATS EMERGENCY PREPAREDNESS PROGRAM

It is the policy of the AEC* to develop and maintain appropriate Emergency Preparedness Programs for each of its facilities. Rocky Flats has a comprehensive emergency program which is integrated and coordinated with the Emergency Preparedness Programs of other Federal, state, and local governmental agencies. The program is designed to cope with all types of emergencies which might involve the plant. These include radiological, operational, natural, civil and national disasters or emergencies. The responsible agencies, including the AEC, have both written and informal plans which cover those emergencies which occur on-site but have an effect off-site, as well as off-site emergency situations which may have an effect on-site. It is these plans which comprise the Rocky Flats Emergency Preparedness Program. The program provides for the systematic, orderly handling of emergencies in such a manner as to minimize any adverse effects which could result from them. Lines of authority are delineated and responsibilities for immediate and continuing action are assigned to specific agencies and individuals. Emergency procedures and action levels are established and clearly stated. Response team rosters and 24 hour radio and telephone contacts are maintained in a current status. Repeated test exercises and real time experience have demonstrated the effectiveness and capability of these response forces.

The principal agencies whose emergency plans make up the Rocky Flats Emergency Preparedness Program are the Office of Preparedness; the Defense Civil Preparedness Agency; the Interagency Radiological Assistance Committee; the Atomic Energy Commission; the Federal Bureau of Investigation; the State of Colorado Health Department; the State of Colorado Department of Military Affairs, Civil Defense Division; the counties of Jefferson, Adams, Boulder, Arapahoe; and, the communities of Broomfield, Boulder, Golden, and Denver. The recognition by these Federal, state, and local agencies of their involvement in the Rocky Flats Emergency Preparedness Program can best be indicated by a synopsis of their plans.

FEDERAL

The Office of Preparedness and the Defense Civil Preparedness Agency have the overall responsibility for civil defense and survival in the event of enemy attack, major natural disaster, or catastrophic man-caused emergency. They plan the response training, warning systems, evacuation, shelter, care, hospitalization, feeding and rehabilitation of the community following a disaster. Exercises are held testing coordination between governmental agencies, communications, response efforts, facilities, transportation, logistics, critical supplies and the like. The Region 8

* To avoid confusion the AEC is referred to throughout this paper. However, effective January 19, 1975, the AEC was abolished by PL 93-438 and its functions transferred to two new independent federal agencies, the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission. The Rocky Flats plant is under ERDA's jurisdiction.

Headquarters for DCPA is located in a hardened underground facility at the Denver Federal Center. By agreement between the AEC, the DCPA, and OP, the AEC Area Office at Rocky Flats has assigned liaison representatives to this Regional Emergency Operating Center as the official AEC representatives at the Region 8 Federal Relocation Center. Continuous liaison is maintained between these federal agencies and in the event of national attack, a severe natural disaster or emergency involving Rocky Flats, AEC will have representation at that facility for the duration of the emergency, and coordinate any response and assistance efforts related to the Rocky Flats Plant. The Regional Office has been thoroughly briefed on the Rocky Flats operation and has the authority and responsibility to assist both the plant and the community in the event of any major disaster involving Rocky Flats.

The Interagency Radiological Assistance Plan of 1961 provides that each of the twelve signatory Federal government agencies will assist one another in the event of a radiological incident. The agencies are the AEC, Department of Agriculture, Department of Commerce; Department of Defense; Department of Health, Education, and Welfare; Department of Labor; Department of Transportation; Environmental Protection Agency; Interstate Commerce Commission; National Aeronautics and Space Administration; Defense Civil Preparedness Agency; and the Postal Service. The AEC coordinates response activities under the plan and in the event of a serious emergency at Rocky Flats, almost unlimited technical and logistic assistance could be obtained from the participating agencies.

The Atomic Energy Commission has a Radiological Assistance Plan which assigns nationwide and regional responsibilities, establishes lines of communication, identifies resources, and provides general guidance for the handling of radiological accidents. The objectives of the plan are:

a. To develop and maintain plans, resources, guidelines, arrangements, and procedures necessary to provide a ready capability to respond effectively to radiological emergencies, including cooperation and coordination with other agencies as needed.

b. To make radiological assistance available when the AEC believes it is needed or when requested by anyone cognizant of an incident suspected to involve the misplacement or loss of control of:

   (1) source, byproduct, or special nuclear materials;

   (2) ionizing radiation sources where such sources have been used in connection with AEC-supported work, including radium and other naturally occurring radionuclides and particle accelerators.

c. To encourage State and local governments, private industry, and other organizations to develop their own radiological emergency capabilities and plans for coping with radiological incidents.

Rocky Flats is located in Radiological Assistance Region 6. The Idaho Falls Operations Office is the Regional Coordinating Office for Region 6. In the event of a radiological emergency at Rocky Flats the total resources of the AEC and its contractors could be called upon under this plan. The plan and implementing instructions issued by Idaho have been coordinated with representatives of the State of Colorado.

As the result of a "Joint Department of Defense and AEC agreement in Response to Accidents Involving Radioactive Material," dated May 9, 1966, the AEC and the DOD have agreed to mutually assist one another in the event of an accident involving radioactive materials. To provide such assistance they have established a Joint Nuclear Accident Coordinating Center. Located in Albuquerque, New Mexico, this facility is manned by the AEC and the DOD. Records are maintained of the specialized capabilities and equipment of each agency, wherever located, which could be used in the event of an emergency. The center is manned 24 hours a day and has telephone contacts with over 300 AEC and DOD radiological assistance teams. In the event of a radiological accident at Rocky Flats, these teams are available through the JNACC to provide whatever assistance is appropriate.

STATE

The State of Colorado has a "Radiological Response Plan for Fort St. Vrain Nuclear Generating Station and Rocky Flats Plant." This plan provides notification channels in the event of an emergency involving possible off-site contamination and for mutual evaluation by AEC and the Colorado State Department of Health of what action should be taken to protect public health and property in the event of a release.

The State of Colorado Department of Military Affairs, Civil Defense Division has developed a "Rocky Flats Plan" for operating procedures in the event of a radiological incident at the Rocky Flats Plant. It sets forth the responsibilities of the AEC's contractor at Rocky Flats, the Colorado Department of Health, the State Civil Defense Division of the Department of Military Affairs, the Jefferson County Sheriff, and the Radiological Assistance Teams of the AEC. The plan provides for the Emergency Operating Center of the State Civil Defense to effect emergency notifications to the State agencies that might be affected. Communication channels are listed for the EOC, the State Health Department, the counties of Adams, Boulder, Jefferson, and Denver City and County. Task assignments are established for each organization should an emergency develop.

The "City and County of Denver Response Plan for a Rocky Flats Plant Incident" further specifies the responsibilities of various departments and offices under these political entities in case of off-site contamination resulting from an incident at the Rocky Flats Plant.

The Metropolitan Emergency Telephone System (METS) is a private line telephone connecting the State Emergency Operating Center with the Office of Civil Defense, National Warning Centers and State warning points, with additional outlets at Rocky Flats and AEC offices, and municipal fire departments, weather bureaus, and emergency operating centers. A ring-down circuit exists which immediately signals all the subscribing parties.

A plan for the care of Radiation Accident victims at the University of Colorado Medical Center has been developed and is in draft form. It provides guidance for any area organization which may have need to send a patient to the center for treatment following exposure to radioactive materials in those instances where the injuries which attend the exposure cannot be treated at the Plant.

Dow* has discussed these procedures with representatives of the Colorado General Hospital and the parties concluded that the procedures would provide the required medical services in the event of an accident at Rocky Flats as the result of which injured persons were contaminated.

LOCAL

The State of Colorado Department of Military Affairs Civil Defense Division Rocky Flats Plan mentioned above directs the participating government agencies: Boulder County, Adams County, Denver City/County, Jefferson County, State Health Department, Colorado State Patrol, and the Rocky Flats Plant to develop emergency plans consistent with the Department of Military Affairs Plan. Numerous meetings and orientation tours of the plant site have been held with representatives of various political entities. Emergency communication channels have been established and the responsible individuals identified in each agency. Although formal written plans have not been formulated in every case, an understanding of the responsibilities of each agency has been achieved. There is a good spirit of cooperation among county and community officials regarding site emergency preparedness.

* The Dow Chemical Company, Rocky Flats Division, is currently AEC's operating contractor at the Rocky Flats Plant.

THE ROCKY FLATS PLANS

A most significant part of the Rocky Flats Emergency Preparedness Program are the emergency plans prepared by the AEC's Rocky Flats Area Office and the AEC's contractor at Rocky Flats. The "Emergency, Defense, and Mobilization Plan for Rocky Flats" is one of the principal documents. It expresses the basic philosophy of Rocky Flats Emergency Plans that the plant should be self-sufficient in the handling of on-site emergencies. The objectives are: (1) to take necessary measures to prevent any disasters that can possibly be averted; (2) to mitigate the effects of a disaster, and (3) to specify plans and to provide guidelines for actions to be taken in an emergency.

Other Rocky Flats Emergency Planning documents are as follows:

Emergency Manual - Dow Rocky Flats Division

This manual contains information to be used in the event of a plant-wide emergency such as fire and/or explosion; on-site major radioactiv contamination; on-site release of chemicals, gases, or toxic materials; on-site hazardous chemical, radioactive, or oil spill which may be discharged off-site via waterways; transportation accident; on-site criticality emergencies; mass casualties and serious injuries; sabotage; major structural failure; bomb threat; civil defense; civil disturbance; forces of nature; utilities interruptions; and telecommunication failure. The manual has a section on each of the above emergencies which includes an immediate action checklist to be used during the emergency. In addition to this checklist, the section includes a description of the alarms signaling the emergency, a brief discussion of the emergency, and references for additional information.

Response Plan for Accidental Discharge of Oil or Hazardous Substances

This document outlines the actions to be taken in responding to accidental discharges of oil or hazardous substances on the plant site.

Building Rules for Process Area Buildings

Each manual contains a large section called, "Emergency Procedures." This section discusses each type of alarm system, what each indicates, and what type of action is required. It gives procedures for emergency shutdown and for actions to be undertaken in civil defense or disaster situations.

Communications

Communications play a vital role in emergency planning. Systems available to the plant are:

> National Warning System (NAWAS), Metropolitan Emergency Telephone System (METS), two-way radio system with Jefferson County Sheriff's Department, monitoring capability of the Colorado State Patrol radio frequency, and AEC radio frequencies operable throughout the Metropolitan area. The METS capability permits immediate contact between the greater Denver area emergency organizations and offices such as the Governor's office and the State of Colorado Emergency Operating Center.

In summary, it seems clear that a satisfactory emergency preparedness program exists in connection with the Rocky Flats facility. Plans and procedures to cope with natural and operational hazards have been developed and coordinated between all responsible agencies. These include Federal, State, and local government plans, as well as plans developed at the Rocky Flats Plant.

TABLE

RADIOACTIVE MATERIALS RELEASES FROM ROCKY FLATS
(μCi)

	Loss Mechanism					
	Airborne[a]			Waterborne[a,b]	Fires	Spills
Year	^{238}U	^{235}U	Pu			
1953			1.5	1126		
1954			65	1226		
1955			72	1099		
1956	(b)	127	229	1653		
1957	38	230	270	1863	18,000	
1958	51	308	3144	2796		500,000[d]
1959	34	540	1435	5800		
1960	58	863	1321	5900		
1961	523	483	1457	6110		
1962	368	249	2974	5500		
1963[c]	339	277	3903	2360		
1964[c]	236	193	230	2620		
1965[c]	277	186	6518	2630		
1966	143	233	323	4227		
1967	139	112	397	2765		
1968	138	161	488	2982		
1969	167	51	718	4384	880	
1970	190	64	379	3369		
1971	58	41	74	6723		
1972	42	4	59	10412		
1973	63	11	77	8990		
1974	30	10	1000	1800		
1975 (Estimated)	30	10	1000	1800		
Total (thru 1974)	2898	4143	25085	87335	18,880	500,000
TOTAL						638,341 μCi

TABLE

(Continued)

(a) All results were obtained from monitoring for total long-lived alpha emitters prior to mid-1973. The specific isotopes listed refer to predominant material processed in various areas. From mid-1973 to present, plutonium releases are from specific isotopic analyses for ^{238}Pu, ^{239}Pu and ^{240}Pu.

(b) Buildings 444-447 began operations in 1956 and should be included in the ^{238}U column. However, results of monitoring do not become from this area until 1960.

(c) Records of total uranium releases did not separate ^{235}U and ^{235}U from 1963-1965. Results reported here are derived from approximate ratios from other reporting periods.

(d) Beginning in July 1958, a drum storage area was established. From that time until November 1969, when an asphalt cover was completed, it is estimated by Rocky Flats sampling that 0.5 Ci of plutonium was lost off site resulting from leakage of these drums. HASL report 849 estimates 3.06 Ci as the amount lost from the spills. The difference in estimates results from use of larger areas in the HASL calculations.

PREVIOUSLY PUBLICLY RELEASED

RFP-ENV-71A 47

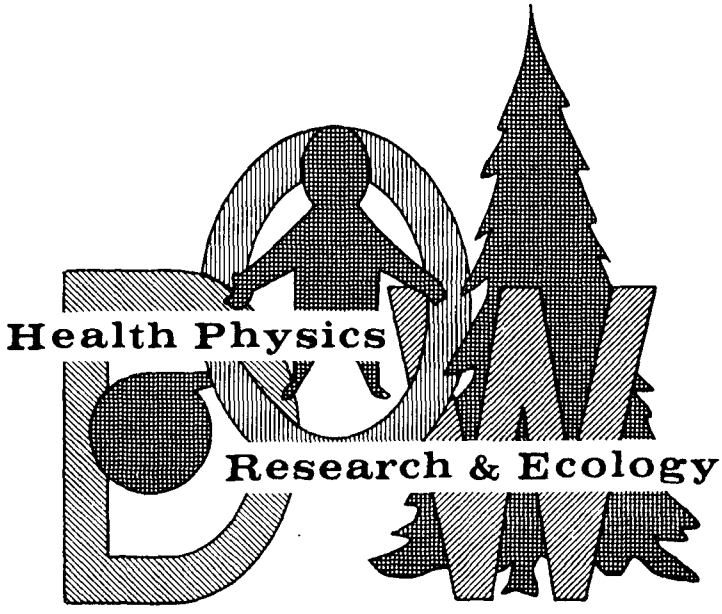
November 1, 1971

SEMIANNUAL REPORT: ENVIRONMENTAL SAFEGUARD '71

RADIOACTIVE MONITORING AND ENVIRONMENTAL SURVEILLANCE

JANUARY THROUGH JUNE 1971

Protective measures and radioactive levels
in the vicinity of the Rocky Flats Plant,
Golden, Colorado



DOW CHEMICAL U.S.A.
Rocky Flats Division

November 1, 1971

Publication Date

RFP-ENV-71A 9

SEMIANNUAL REPORT: ENVIRONMENTAL SAFEGUARD 1971

Radioactive Monitoring and Environmental Surveillance, January Through June 1971.

Protective measures and radioactive levels in the vicinity of the Rocky Flats Plant, Golden, Colorado

M. R. Boss
L. M. Steward

Prepared by Product and Health Physics Research and
Ecology Group, Rocky Flats Division, Dow Chemical U.S.A.
S. E. Hammond, Industrial Hygiene and Bioassay
J. R. Seed, Director; Product and Health Physics Research
J. F. Willging, Director; Research and Ecology
H. E. Bowman, Assistant General Manager for Operations
L. M. Joshel, Rocky Flats Division General Manager

DOW CHEMICAL U.S.A.
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401

Prepared under Contract AT(29-1)-1106
for the
Albuquerque Operations Office
U. S. Atomic Energy Commission

ENVIRONMENTAL SURVEY – JANUARY - JUNE 1971

Dow Chemical U.S.A.
Rocky Flats Division
Post Office Box 888
Golden, Colorado
80401

The Rocky Flats Division of Dow Chemical U.S.A. is located approximately 16 miles northwest of downtown Denver. The Government-owned reservation occupies about 2600 acres. The inhabited portion of the plant, occupying about 425 acres, is located in the center of the property.

Primary controls are exercised at the emission source, i.e., stacks for airborne contaminants, and at the process waste treatment plant for liquid effluents. Ideally, emissions are controlled to below the recommended concentration guide levels for the general population, regardless of dilution from external sources.

The environmental survey data contained in this report have been released on a monthly basis to the Colorado Department of Health.

STACK EFFLUENT SAMPLING

The exhaust ducts in the buildings engaged in operations involving processing of radioactive material are continuously monitored using isokinetic* sampling techniques. The samples are analyzed for total long-lived alpha activity. The total activity released to the atmosphere is calculated from the total effluent volume. Table 1 summarizes both the plutonium and uranium stack sampling results.

The most restrictive concentration guide for plutonium in air is 0.06×10^{-12} μ Ci/ml averaged over one year to an individual in the general population. The measured concentrations from the plutonium operations, *including natural long-lived alpha activity*, average 0.011×10^{-12}** μ Ci/ml or 18.2% of the standard.

The most restrictive concentration guide for uranium in air is 3×10^{-12} μ Ci/ml averaged over one year to an individual in the general population. The measured concentrations from the uranium operations, *including natural long-lived alpha activity*, average 0.011×10^{-12}† or 0.4% of the uranium standard.

*Air moving into the sample tubes is at the same velocity as that inside the duct being sampled. This prevents turbulence at the mouth of the sample tube and provides better trapping for particulate matter.

**Monthly average of total emissions from all Pu Operations during reporting period.

AIR SAMPLING

Air filters from 12 on-site air-monitoring stations, sampling at 2 ft^3/min, are collected and analyzed daily for total long-lived alpha concentrations. Table 2 summarizes these air sample results. The concentrations reported include activity due to natural long-lived alpha emitters.

Air samplers programmed to sample 10 min. each hour are located in Boulder, Broomfield, Coal Creek Canyon, Denver, Golden, Lafayette, Marshall, Wagner Site, and Westminster (see map). These air filters are collected weekly and are analyzed for total long-lived alpha activity. These air sample results are Tabulated in Table 3 and also include activity due to natural long-lived alpha emitters. The on-site concentrations range from 0.0041×10^{-12} μ Ci/ml to 0.0323×10^{-12} μ Ci/ml, while samples collected off site show a range of concentrations from 0.0035×10^{-12} μCi/ml to 0.0185×10^{-12} μCi/ml.

An additional network of 12 high-volume air samplers began operating on February 11, 1971. These samplers are located 2 to 3 miles from the plant perimeter. Samples are collected on a 4-inch-diameter filter paper at an average flow rate of 18 ft^3/min. The air filters are collected daily, composited into a weekly sample and analyzed specifically for plutonium. Sample volumes typically average about 5000 m^3. Additional high-volume samples of 4-6 hours duration are collected each week from Wagner Site (S-18), located 2.5 miles southeast of the plant and Coal Creek Canyon (S-11) 3 miles west-southwest of the plant. These samples vary in size but average about 200 m^3. Table 4 summarizes the plutonium concentrations found in the high-volume air samples. For

†Monthly average of total emissions from all uranium operations during the reporting period.

convenience in reporting, monthly averages are given for each sample location. The concentrations from the air sampling network range from 0.00006×10^{-12} μCi/ml to 0.00267×10^{-12} μCi/ml. Samples collected from Wagner Site and Coal Creek Canyon show somewhat higher concentration levels. The concentrations shown in Table 4 are influenced by the sample size and indicate the particulate nature of the plutonium being collected. The concentrations found in the large-volume air samples are a better indicator of possible chronic exposure levels.

DUSTFALL SAMPLING

Dustfall sample collection trays are mounted on all the off-site, low-volume air sample stations. Sample collection trays are also located at standby stations in Arvada, Eastlake, and Superior. Dustfall samples are collected bimonthly and analyzed specifically for plutonium content. Dustfall samples from Castle Rock and Berthoud are collected less frequently. The results, which include plutonium fallout from atmospheric weapon testing in addition to plutonium of plant origin, are summarized in Table 5. There are no established concentration standards for plutonium in dustfall. The values reported are of the same order of magnitude as are reported for plutonium from worldwide fallout.

WATER SAMPLING

The Rocky Flats plant is drained by three streams that flow through the reservation; North and South Walnut Creeks located north of the plant, and Woman Creek to the south. Treated sanitary and process waste waters are released to South Walnut Creek through a series of four holding ponds. Effluents released through the sewage treatment plant meet the Water Quality Standards for Colorado and the U.S. Public Health Service Drinking Water Standards (1962). The overflow from the pond system flows into Great Western Reservoir. Flow into Great Western Reservoir from Walnut Creek is comprised largely of liquid wastes from the plant. Holding ponds located on North Walnut Creek and Woman Creek also exist; however, no effluents are discharged directly into these ponds.

Daily water samples are collected from the holding ponds, composited into a weekly sample and analyzed for gross alpha (uranium plus plutonium) activity. The plutonium contribution to the sample activity is measured by alpha spectrometry. Daily chemical analyses are also performed on these water samples. Table 6 summarizes the results of the holding pond analyses. Gross alpha concentrations range from 4.58×10^{-9} to 36.64×10^{-9} μCi/ml. Plutonium concentrations range from 0.25×10^{-9} to 7.23×10^{-9} μCi/ml. The gross alpha concentrations reported in Table 6 include naturally occurring uranium activity. Water in use at the Rocky Flats plant is obtained from Ralston reservoir. Water samples collected at the reservoir range up to about 29×10^{-9} μCi/ml in gross alpha activity as shown in Table 8. Some degree of decontamination of liquid waste effluents released to the holding ponds is affected in the sewage treatment plant. Guides do not exist for gross alpha concentrations in water. The recommended concentration guide for soluble plutonium-239 in water is 5×10^{-6} μCi/ml averaged over one year to an individual in the general population. This concentration guide is 100-1000 times greater than the gross alpha concentrations reported in Table 6. Total activity released to Walnut Creek via liquid effluents is based on flow rates through the holding ponds.

Tap water samples from the surrounding communities and water samples from the major reservoirs in the area are collected bimonthly. Tables 7 and 8 summarize the tap and reservoir water sample results. Plutonium analyses are made on the sample if sufficient gross activity is present.

Concentrations in tap water samples reported in Table 7 range from 0.11×10^{-9} to 18.58×10^{-9} μCi/ml for gross alpha activity. Concentrations in reservoir water samples range from 0.26×10^{-9} to 28.79×10^{-9} μCi/ml for gross alpha activity.

Weekly grab samples from Walnut Creek, below the confluence of the north and south branches, are analyzed for gross alpha and plutonium activity. Gross alpha concentrations in Walnut Creek average 11.71×10^{-9} μCi/ml while plutonium concentrations average 2.58×10^{-9} μCi/ml.

SOIL AND SEDIMENT SAMPLING

Soil samples have been collected for a number of years, and the program was recently expanded.* Surface soil samples at distances of 1, 2, and 5 miles from the plant are now collected twice a year and analyzed for plutonium content.

*Prior to May 1969, soil samples were analyzed for gross alpha content which includes the contributions from Pu as well as other alpha emitters and not for plutonium specifically.

Sediment samples from the four major reservoirs in the area are collected semiannually. Monthly sediment samples are collected from each of the six holding ponds located on the plant site. Additional monthly sediment samples are collected from Walnut and Woman Creeks. Soil sample results from 1970, incomplete in the last report, are shown in Table 9. *Sediment sample results from the reservoirs,* holding ponds, and creeks, are shown in Table 10. No concentration standards exist for plutonium in soil or sediment.

VEGETATION SAMPLES

Vegetation samples are collected twice a year from 63 locations to a radius of about 20 miles from the plant. These samples are analyzed specifically for plutonium content. The results from the latest vegetation sampling are incomplete at this time.* No concentration standard exists for plutonium in vegetation.

*These results will be reported in the 1971 annual report.

Table 1. Total Long-Lived Alpha Concentrations in Stack Effluents.

Source	Average Concentration (μCi/ml $\times 10^{12}$)						Average Monthly* Percent of Standard for 6-Month Reporting Period	Total Long-Lived Alpha Release (μCi)
	January	February	March	April	May	June		
Plutonium Operations								
Bldg. 771	0.005	0 005	0.005	0 015	0.007	0.012	13.6	12.852
Bldg 774	0.015	0.010	0.011	0.014	0 060	0 013	34 2	4 551
Bldg 776	0.004	0.095	0.033	0.006	0 018	0.011	46 4	29.069
Bldg. 779	0.007	0.002	0 002	0.002	0.002	0.002	4 7	0 248
Bldg. 559	0.003	0.002	0.002	0.002	0 003	0 003	3 3	0 411
Bldg. 707	0.003	0.002	0.005	0.003	0.005	0.004	6.1	1 091
Uranium Operations								
Bldg 444	0 009	0.005	0.002	0.002	0.002	0 002	0.12	4 61
Bldg. 447	0.071	0.070	0.029	0.033	0.040	0.023	1 48	18.92
Bldg 881	0 004	0 017	0.018	0 049	0 005	0.005	0 54	30.11
Bldg 883-A	0.010	0.008	0.010	0.012	0.041	0 034	0.64	13.12
Bldg. 883-B	0.010	0.006	0.003	0.004	0.008	0 005	0 20	4 26
Bldg. 886	0.003	0.001	0.002	0.002	0.002	0 002	0 07	0.06
Bldg. 889	0.003	0.002	0 002	0.002	0.002	0.002	0.07	0 07
Bldg. 865	0.002	0.001	0.002	0.002	0.002	0 002	0.06	0 45
Bldg. 991	–**	0.002	0.002	0.001	0.001	0.002	0.05	0.02

*Based on the soluble Pu standard of 0.06×10^{-12} μCi/ml or the soluble natural uranium standard of 3×10^{-12} μCi/ml. It is important to note that these existing standards are in terms of averages for a one-year period.

**Plenum installed February 1971.

Table 2. Average On-Site Air Sample Concentrations.*

Location	Number of Samples	Total Long-Lived Alpha Concentrations (μCi/ml $\times 10^{12}$)						Monthly Percent of Standard**	
		January	February	March	April	May	June	Average	Maximum
S-1	124	0.0051	0.0049	0.0056	0.0051	0.0060	0.0045	8.7	10.0
S-2	124	0.0054	0.0054	0.0058	0.0054	0.0054	0.0045	8.9	9.7
S-3	124	0.0047	0.0043	0.0049	0.0062	0.0062	0.0062	9.0	10.3
S-4	123	0.0041	0.0054	0.0058	0.0071	0.0060	0.0047	9.2	11.8
S-5	124	0.0043	0.0056	0.0047	0.0051	0.0054	0.0058	8.6	9.7
S-6	124	0.0051	0.0049	0.0051	0.0049	0.0066	0.0047	8.7	11.0
S-7	124	0.0086	0.0073	0.0068	0.0092	0.0054	0.0051	11.8	14.3
S-8	124	0.0071	0.0073	0.0083	0.0323	0.0094	0.0094	20.5	53.8
S-9	124	0.0054	0.0049	0.0056	0.0051	0.0054	0.0049	8.7	9.3
S-10	116	0.0060	0.0060	0.0060	0.0066	0.0049	0.0060	9.9	11.0
S-50	124	0.0054	0.0051	0.0056	0.0092	0.0056	0.0073	10.6	15.3
S-51	124	0.0058	0.0060	0.0051	0.0071	0.0054	0.0049	9.5	11.8

*Concentrations include activity due to natural long-lived alpha emitters.

**Based on the soluble ^{239}Pu standard of 0.06×10^{-12} μCi/ml, which is stated in terms of yearly averages.

Table 3. Average Off-Site Air Sample Concentrations.*

Location	Number of Samples	Total Long-Lived Alpha Concentrations (μCi/ml $\times 10^{12}$)						Monthly Percent of Standard**	
		January	February	March	April	May	June	Average	Maximum
Boulder (S-15)	25	0.0056	0.0050	0.0051	0.0062	0.0077	0.0064	9.8	12.8
Broomfield (S-17)	25	0.0049	0.0075	0.0069	0.0068	0.0056	0.0057	10.4	12.5
Coal Creek Canyon (S-11)	25	0.0045	0.0055	0.0049	0.0075	0.0051	0.0064	9.4	12.5
Denver (S-23)	25	0.0041	0.0035	0.0088	0.0080	0.0060	0.0067	10.3	14.7
Golden (S-20)	25	0.0047	0.0049	0.0073	0.0074	0.0071	0.0048	10.1	12.2
Lafayette (S-16)	25	0.0064	0.0085	0.0066	0.0071	0.0096	0.0077	12.8	16.0
Marshall (S-13)	25	0.0050	0.0045	0.0046	0.0046	0.0054	0.0050	8.1	9.0
Wagner Site (S-18)	25	0.0062	0.0042	0.0050	0.0173	0.0088	0.0133	15.2	28.8
Westminster (S-25)	23	0.0060	0.0042	0.0054	0.0090	0.0049	0.0185†	13.3	30.8

*Concentrations include activity due to natural long-lived alpha emitters.

**Based on the soluble ^{239}Pu standard of 0.06×10^{-12} μCi/ml, which is stated in terms of yearly averages.

†It is believed that these data are the result of analytical error.

Table 4. Plutonium Concentrations in High-Volume Air Samples.

Location	Number of Samples	Average Plutonium Concentration (μCi/ml $\times 10^{12}$)						Monthly Percent of Standard*	
		January**	February	March	April	May	June	Average	Maximum
S-26	107	–	0.00007	0.00024	0.00018	0.00027	0.00026	0.34	0.45
S-27	107	–	0.00006	0.00020	0.00012	0.00029	0.00038	0.35	0.63
S-28	107	–	0.00012	0.00018	0.00012	0.00022	0.00036	0.33	0.60
S-29	107	–	0 00014	0.00014	0.00011	0.00026	0.00062	0.42	1.03
S-30	107	–	0.00009	0.00015	0.00010	0.00030	0.00046	0.37	0.77
S-31	106	–	0.00006	0.00019	0.00019	0.00036	0.00037	0.39	0.62
S-32	107	–	0.00014	0.00031	0.00015	0.00030	0.00267	1.19	4.45
S-33	107	–	0.00019	0.00031	0.00018	0.00037	0.00051	0.52	0.85
S-34	106	–	0.00015	0.00021	0.00016	0.00034	0.00070	0.52	1.17
S-35	108	–	0.00012	0.00023	0.00012	0.00030	0.00043	0.40	0.72
S-36	107	–	0.00009	0.00033	0.00018	0.000 28	0.00038	0.42	0.63
S-37	107	–	0.00012	0.00074	0.00029	0.00030	0.00042	0.62	1.23
S-11	14	–	0.0039	0.0015	0.0021	0.0016	0.0218†	10.30	36.33
S-18	23	0.0008	0.0022	0.0012	0.0031	0.0014	0.0034	3.36	5.67

* Based on the soluble ^{239}Pu standard of 0.06×10^{-12} μCi/ml, which is stated in terms of yearly averages.

**This air sampling program was started in February 1971.

† It is believed that these data are the result of analytical error.

Table 5. Plutonium Concentrations in Dustfall Samples.*

Location	Number of Samples	Sample Days	Average Concentration (pCi/m^2/month)
Arvada	10	169	4.25
Broomfield	9	155	1.59
Boulder	9	141	15.02
Coal Creek Canyon	8	127	0.98
Denver	10	169	6.30
Eastlake	10	169	4.38
Golden	10	169	2.46
Lafayette	10	169	3.75
Marshall	10	169	13.00
Superior	9	155	4.80
Wagner Site	7	120	4.71
Westminster	10	169	4.41
Castle Rock	5	179	0.75
Berthoud	3	222	0.51

*Concentrations include background due to worldwide plutonium fallout.

**For averaging purposes, sample results that were less than the minimum detectable concentration were assumed to be at the minimum detectable concentration. Minimum detectable concentration is <0.50 pCi/m^2.

Table 6. Radioactivity and Chemical Concentrations in Effluent Waste Water.

Sample Period	Volume (M liters)	Number of Samples	Gross Alpha Concentrations* (μCi/ml $\times 10^9$)			Total Gross Alpha Release (mCi)	Plutonium Concentrations** (μCi/ml $\times 10^9$)			Total Plutonium Release (mCi)
			Avg.	Min.	Max.		Avg.	Min.	Max.	
January	36.01	4	14.33	4.58	36.64	0.516	2.29	0.25	4.01	0.082
February	34.85	4	24.74	21.24	27.73	0.856	2.92	0.28	7.23	0.101
March	49.18	4	13.15	9.91	19.29	0.647	2.86	1.27	4.32	0.141
April	41.21	5	14.75	10.84	19.98	0.608	2.99	1.15	5.23	0.123
May	32.36	4	12.54	8.17	19.06	0.406	2.63	0.81	4.59	0.085
June	28.15	5	8.33	5.09	10.30	0.234	1.60	0.32	2.61	0.045
Summary	221.76	26	14.64	9.97	22.17	3.267	2.55	0.68	4.67	0.577

*Gross alpha concentrations refer to uranium and plutonium activity only and include natural background.

**Although most plutonium processed at the Rocky Flats plant is insoluble, the more restrictive soluble ^{239}Pu standard (5×10^{-6} μCi/ml) is used as the concentration guide.

Sample Period	Number* of Samples	Average pH	Average Concentration (ppm)					
			NO_3^-	PO_4^{-3}	F^-	BOD†	Total Solids	Cr^{+6}
January	20	7.7	16.7	10.9	0.5	5.4	400	<0.005
February	20	7.6	6.2	9.2	0.4	9.9	681	<0.005
March	22	7.5	9.4	6.3	0.4	4.5	406	<0.005
April	19	7.5	8.4	4.3	0.4	6.4	392	<0.005
May	19	8.0	5.5	12.5	0.4	5.8	456	<0.005
June	22	8.1	3.8	13.3	0.5	7.3	368	<0.005
Guide	–	–	45.0	–§	2.4	30.0	500	0.05

†Biological Oxygen Demand. That amount of oxygen required to stabilize a sample or an effluent i.e., allow biological oxidation of organic matter.

§No Federal Guidelines exist for PO^{-3} concentrations.

Table 7. Community Tap Water Sample Results.

Sample Locations	Gross Alpha Concentrations* (μCi/ml $\times 10^9$)			Plutonium Concentrations (μCi/ml $\times 10^9$)			
	Number of Samples	Avg.	Min.	Max.	Number of Samples	Avg.†	Min.	Max.**
Arvada	12	7.64	0.56	16.20	2	0.45	0.12	0.77
Boulder	12	2.34	0.66	6.93	10	<0.29	<0.0004	0.97
Broomfield	12	2.54	0.11	18.58	6	0.98	0.09	5.03
Denver	12	5.73	0.53	17.19	11	<0.44	<0.0004	2.79
Golden	12	3.40	0.17	8.79	11	<0.14	<0.0004	0.45
Lafayette	12	1.40	0.50	3.23	6	<0.27	<0.0004	0.77
Louisville	12	1.24	0.25	2.45	3	0.31	0.04	0.52
Thornton	12	9.29	3.07	17.48	3	0.18	0.05	0.30
Westminster	12	2.26	0.43	6.49	9	0.27	0.08	0.60

*Gross alpha concentrations refer to uranium and plutonium activity only and include natural background.

**The most stringent standard, based on soluble ^{239}Pu is 5×10^{-6} μCi/ml, in terms of yearly averages. These values represent concentrations of 1000 to 10,000 times less than that allowable by the Standard.

†For averaging purposes, sample results that were less than the minimum detectable concentration were assumed to be the minimum detectabl concentration. (Minimum detectable concentration is 0.0004×10^{-9} μCi/ml.)

Table 8. Reservoir Water Sample Results.

Location	Gross Alpha Concentrations* (μCi/ml $\times 10^9$)				Plutonium Concentrations** (μCi/ml $\times 10^9$)			
	Number of Samples	Avg.	Min.	Max.	Number of Samples	Avg.	Min.	Max.
Baseline	12	3.25	0.26	6.06	11	0.33	0 07	1 68
Great Western	12	3.12	1.70	6.29	10	0.17	0.04	0 64
Ralston	12	20.50	6.01	28.79	10	–†	–†	–†
Standley	11	5.22	1.61	17.44	9	0.30	0 08	0 95
Walnut Creek	25	11.71	2.85	30.06	25	2.58	0.67	8.47

*Gross alpha concentrations refer to uranium and plutonium activity only and include natural background.

**The most stringent standard, based on soluble ^{239}Pu is 5×10^{-6} μCi/ml, in terms of yearly averages. These values represent concentrations of 1000 to 10,000 times less than that allowable by the Standard.

†Below detectable limits.

Table 9. Plutonium Concentrations in Soil Samples.

Location	Number of Samples	Total Plutonium (dpm/gram) Avg.	Min.	Max.
1 mile	19	5.97	<0.06	60.51
	16	11.79	0.09	67.86
2 miles	19	3.95	<0.06	26.80
	16	2.10	<0.06	17.73
5 miles	15	0.46	<0.06	1.10
	13	0.88	0.11	5.26

Table 10. Plutonium Concentrations in Sediment Samples.

Location	Number of Samples	Total Plutonium (dpm/gram) Avg.	Min.	Max.
Baseline	1	1.31	–	–
Great Western Reservoir	2	0.70	<0.06	1.33
Ralston Reservoir	1	0.67	–	–
Standley Reservoir	2	2.04	<0.06	4.01
Walnut Creek	8	16.11	4.0	36.0
Woman Creek	5	1.31	0.09	2.54
Pond A	6 (composite)	27.0	–	–
Pond 1	6 (composite)	216.0	–	–
Pond 2	6 (composite)	124.00	–	–
Pond 3	6 (composite)	27.0	–	–
Pond 4	6 (composite)	32.0	–	–
Pond 5	6 (composite)	2.9	–	–

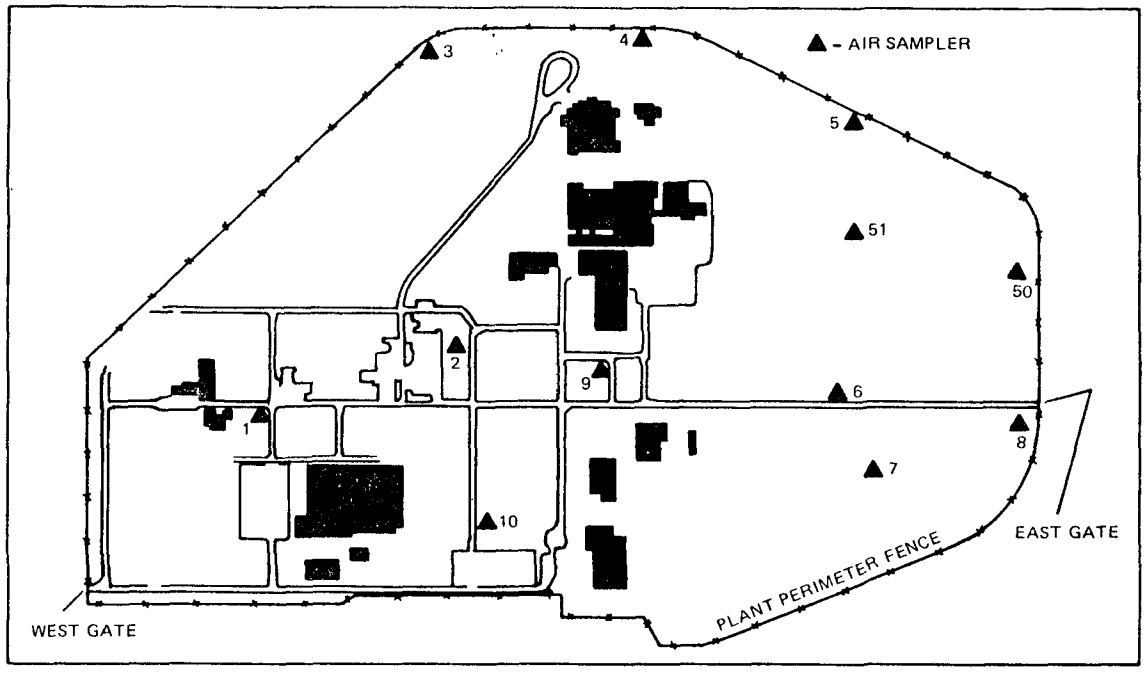
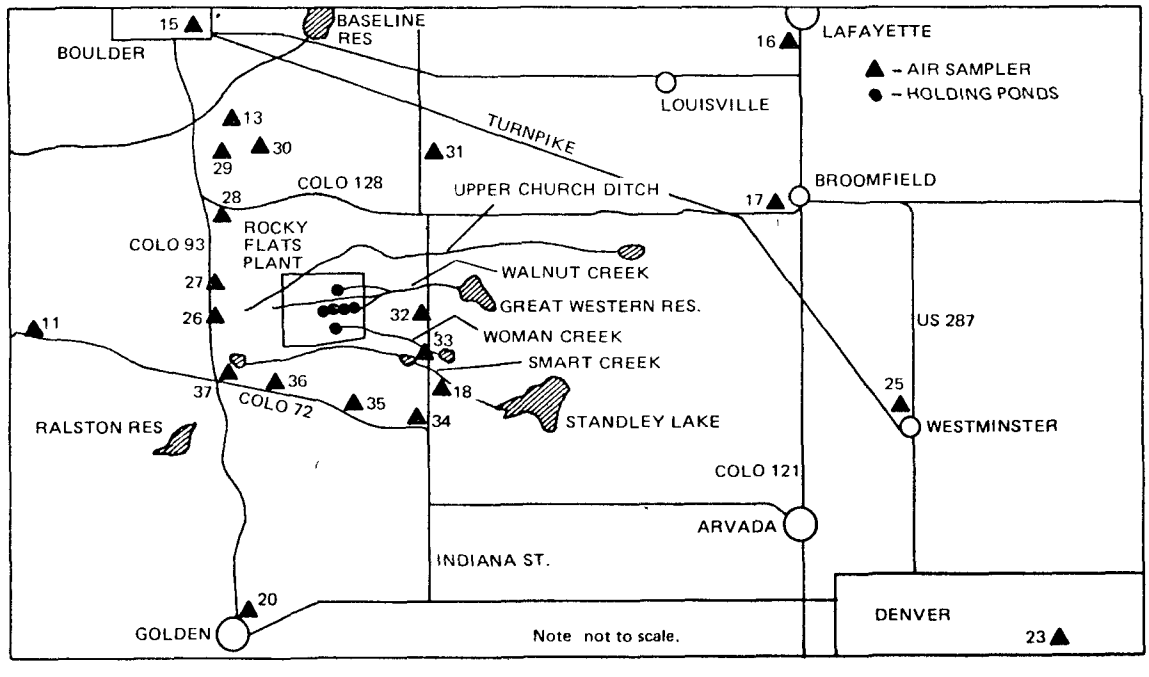


Figure 1. On-Site Air Sampling Locations.

Figure 2. Rocky Flats Plant Environmental Air-Sampling Off-Site Network.



PREVIOUSLY PUBLICLY RELEASED

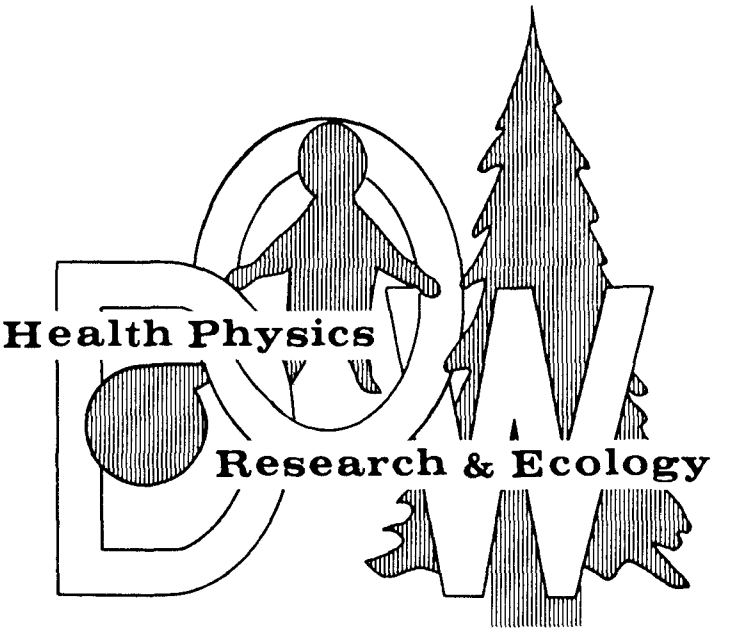
RFP-ENV-71B

March 10, 1972

ANNUAL REPORT: ENVIRONMENTAL SAFEGUARD '71

Protective measures and radioactive levels in the vicinity of the Rocky Flats Plant, Golden, Colorado

JANUARY – DECEMBER 1971



DOW CHEMICAL U.S.A.

Rocky Flats Division

U.S. ATOMIC ENERGY COMMISSION CONTRACT AT(29-1)-1106

Printed
March 10, 1972

RFP-ENV-71B

ANNUAL REPORT: ENVIRONMENTAL SAFEGUARD 1971

Radioactive Monitoring and Environmental Surveillance January Through December 1971

Annual report on radioactive monitoring procedures, and radioactive levels in the vicinity of the Rocky Flats Plant, Golden, Colorado

L. M. Steward
M. R. Boss

Prepared by Product and Health Physics Research and Ecology Group,
Rocky Flats Division, Dow Chemical U.S.A.

J. H. Hanes, Rocky Flats Division General Manager
H. E. Bowman, Assistant General Manager for Operations
J. F. Willging, Director; Research and Ecology
J. R. Seed, Director; Product and Health Physics Research
S. E. Hammond, Industrial Hygiene and Bioassay

DOW CHEMICAL U.S.A.
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401

Prepared under Contract AT(29-1)-1106
for the
Albuquerque Operations Office
U. S. Atomic Energy Commission

"It is our belief that the nuclear industry can serve the needs of the public without undue risk to our health or to our environment. But we also believe that we have the important responsibility of assuring that this continues to be the case in the future."

Joseph A. Liberman
Deputy Assistant Administrator
Radiation Programs
Environmental Protection Agency
July 1971

CONTENTS

I. Abstract 1

II. Introductions
- Rocky Flats 1
- Radiation 2
- Radiation Standards 4

III. Standards
- Air: Radioactive 6
- Non-Radioactive 6
- Water: Radioactive 7
- Non-Radioactive 7
- Other Standards 10

IV. Sample Collection and Analysis Summary
- Stack Effluents 10
- Air Samplers 11
- Dustfall Samples 12
- Water Samples 12
- Sediment Samples 14
- Soil Samples 14
- Vegetation Samples 15

V. Tabular Data and Maps 15

VI. Summary and Conclusions 32

VII. Bibliography 36

VIII. Appendix A. 37

FOREWORD

This report was prepared for submission to the U. S. Atomic Energy Commission by the Health Physics Research and Ecology Department of the Rocky Flats Division, Dow Chemical U.S.A. The analyses of all samples described within this report were performed by the Health Physics Bioassay Laboratory and the Service Laboratories at Rocky Flats.

All effluents with potential adverse health and safety or environmental effects have been monitored, evaluated and appropriately controlled.

The AEC has initiated more comprehensive procedures for more complete reporting of environmental impact information. Due to the new reporting procedures and format, the data contained within this report are not directly comparable with previous reports in this series. This is the first report to be prepared under the new AEC guidelines.

ANNUAL REPORT: ENVIRONMENTAL SAFEGUARD 1971

Radioactive Monitoring and Environmental Surveillance
January Through December 1971

L. M. Steward
M. R. Boss

I. ABSTRACT

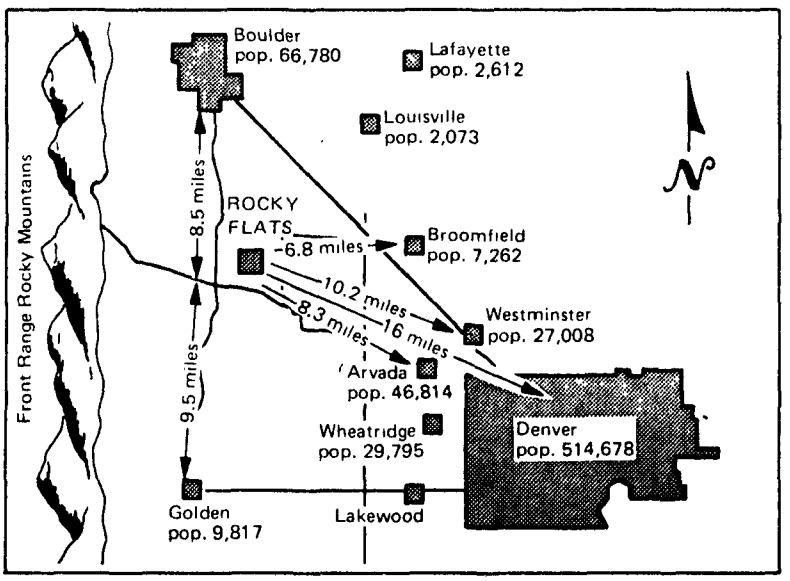
The Rocky Flats Plant maintains an extensive environmental surveillance program to assess effluent levels and to determine if any accidental release of environmental contaminants has occurred. Analyses of over 50,000 air, water, vegetation, soil, sediment and effluent samples for the year indicated that; in no manner did Rocky Flats contribute significant quantities of environmental contaminants to the surrounding environs; all radioactive and nonradioactive effluent levels were below the most stringent and/or restrictive standards established by regulatory agencies; and, that radioactive levels in the environs of Rocky Flats have not changed significantly, either on or off site in the past year.

II. INTRODUCTIONS

Rocky Flats

The Rocky Flats Division of Dow Chemical U.S.A. manages a plutonium processing facility for the U.S. Atomic Energy Commission. It is located on a gently sloping plain on the eastern edge of the front range of the Rocky Mountains and is situated about halfway between Golden and Boulder, Colorado. To the east lie the beginnings of the Great Plains of Colorado and a panorama of Denver, about 16 miles to the southeast. The grassy, gently rolling hills surrounding the plant provide grazing grounds and winter shelter for deer, local livestock, and small animals.

Rocky Flats Plantsite Located about Halfway between Golden and Boulder, Colorado



The climate for which the State of Colorado is so justly famous favors Rocky Flats with about 300 days of sunshine a year. Rainfall averages just under 14 inches a year and the average temperature is 50 degrees.

The plant handles both plutonium and uranium as well as other potentially hazardous materials as part of its normal function within the AEC complex. Rocky Flats maintains a constant surveillance program which continuously monitors the control of effluents and releases from the plant site and its operations.

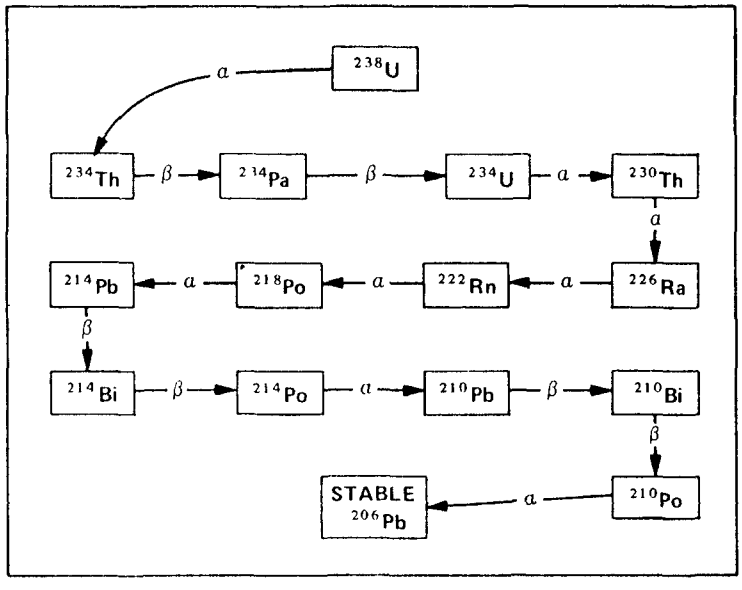
Rocky Flats Handles Plutonium and Uranium as Processing Facility for U.S.AEC

Radiation

There are many naturally occurring, unstable, radioactive nuclides among the elements with atomic numbers from 81 (thallium) to 92 (uranium). The majority of these can be grouped into the uranium series, the actinium series, and the thorium series. Each decay series begins with a very long-lived nuclide (parent) as the first member. These parents transform by radioactive disintegration into intermediate members (daughters) until a final, stable, nonradioactive isotope of lead results. Where found in nature, the uranium and naturally occurring members of the actinide series are always found together.

Where ^{239}plutonium comes from: ^{238}uranium is bombarded by neutrons in a reactor to produce ^{239}plutonium by the following steps:

1. $^{238}_{92}U + ^{1}_{0}n \longrightarrow ^{239}_{92}U$
2. $^{239}_{92}U \xrightarrow{2.3\ \text{minute}} ^{0}_{-1}\beta + ^{239}_{93}Np$
3. $^{239}_{93}Np \xrightarrow{2.3\ \text{days}} ^{0}_{-1}\beta + ^{239}_{94}Pu$

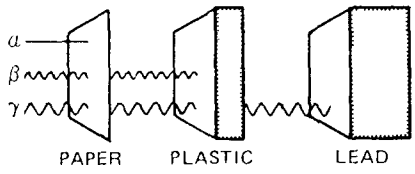


The series of disintegrations is known as radioactive decay. The new elements formed from the original or "parent" atoms are called "daughters." When a nucleus undergoes this decay process to form a daughter, energy is emitted in the form of particulate or electromagnetic radiation. The most common types of radiation are alpha and beta particles, gamma rays, x-rays, and neutrons. The alpha particle is the positively charged nucleus of a helium atom ($^{4}_{2}He^{+2}$) and is very stable. The beta particle is a negatively charged, high-speed electron that originates in the nucleus. Gamma and x-rays are electromagnetic radiations similar to ordinary radio waves and visible light waves except their frequencies are higher and they are not visible to the human eye. Neutrons are neutrally charged particles of mass 1. Of these types of radiation, the high energy gamma ray and the neutron have the greatest range

Radioactive Decay: "Parent" Elements Decay to Form New "Daughter" Elements

Alpha, Beta, and Gamma are the Most Common Types of Radiation.

Alpha and Beta Both Particulate Radiations. Gamma is Electromagnetic like X-Ray.



and penetrating ability, easily penetrating several inches of steel. Beta particles, although less penetrating than gamma, still have enough penetrating ability to penetrate the skin of man. The alpha particle, that of most concern at Rocky Flats, has the least penetrating power. In fact, the alpha particle is unable to penetrate an ordinary sheet of paper or the relatively thick skin of man. Since both plutonium and uranium are primary alpha emitters, the alpha particle receives the most attention in this report.

Alpha Radiation has Least Penetrating Ability: Will not Normally Penetrate Skin of Man. This is the primary Radiation of Concern to Rocky Flats.

Before delineating standards, the actual measurement criteria should be explained. In relating measured values to the predicted or actual biological effects, two separate units have arisen.

Two Units for Measuring Radioactivity.

The first is based on the number of radioactive disintegrations per unit of time and is thus a quantitative measure of the radioisotope present. Based on radium-226, the first naturally occurring radioisotope to be isolated in any quantity, the curie (Ci) became the unit used for expressing quantities of all isotopes. In 1950 this unit was standardized and is now defined as that quantity of any radioactive nuclide undergoing 3.7×10^{10} disintegrations per second.[1] [Disintegrations per unit time are usually abbreviated as dps (second) or dpm (minute).]

Curie (Based on Disintegrations per Unit Time) is Measurement of Quantity of Isotope Present.

Disintegrations per Minute (dpm) and per Second (dps) are Usual Notations.

The curie is a very large unit, especially for reporting minute quantities such as found in environmental radiation measurements. Therefore, subunits of the curie are usually used. These are the millicurie (mCi; 10^{-3} Ci), the microcurie (μCi, 10^{-6} Ci), the nanocurie (nCi; 10^{-9} Ci), and the picocurie (pCi; 10^{-12} Ci).

Curie Very Large Unit (37,000,000,000 dps) so Subunits Usually Used.

1 curie = 37,000,000,000 dps (16.3 g Pu^{239})
1 millicurie = 37,000,000 dps (0.016 g Pu^{239})
1 microcurie = 37,000 dps (0.000016 g Pu^{239})
1 picocurie = 0.037 dps (0.0000000000163 g Pu^{239})

It must be emphasized that these units express only quantities of isotopes present and not the radiation does these quantities could produce.

The interaction of radiation with matter creates ions by imparting energy to orbital electrons and stripping them from atoms. The ions thus produced have either a positive or negative electrical charge. It is this phenomenon that allows us to detect the presence of radiation, and also determines the amount of biological damage that a given radiation dose can produce.

Radiation Produces Ions. Amount of Ionization is Deciding Factor in Biological Damage so Unit of Dose Must be in Terms of Ionization.

Since radiation effects on organisms are due to ionization, the only quantitative measurement of radiation dose that can be directly related to biological effects must be stated in terms of this ionization and the amount of energy absorbed by that organism.

The basic measurement unit, as described by the International Commission on Radiological Units and Measurements (ICRU), is the roentgen (R). This was established in 1928, a time when only x-ray or gamma radiations were considered important. It is defined in terms of energy transfer or ionization to a specific volume of air as the result of an exposure dose of x or gamma radiation.[2] Thus, it is not directly relatable to other types of radiation in tissues or biological systems.

Basic Unit is Roentgen, Based on the Ionization Produced by X-Ray and Gamma-Radiation Only; Not Directly Relatable to Other xnits of Radiation.

This shortcoming in the definition of the roentgen has led to the introduction of another unit, the roentgen equivalent (for) man, or the rem. This unit is that quantity of ionizing radiation which, when absorbed by man, produces an effect or biological response equivalent to the absorption of one roentgen of x or gamma radiation.[3] Since the biological effects due to radiation are known to vary, a quality factor ranging from one to twenty is included in the rem * A primary subunit of the rem, the millirem(mrem) or 0.001 rem, is very often used in describing biological radiation exposures.

Modified Unit is Roentgen Equivalent, Man (REM), which Includes Modification Factor to Account for Differences in Types of Radiation.*

Radiation Standards

In 1928, an international group was convened to establish standards for ionizing radiation and formed the International Commission on Radiological Protection (ICRP). The committee charged with establishing those standards was composed of scientists from Great Britain, the United States, Germany, and Sweden. Later, they were joined by members from France and Italy.

International Commission on Radiological Protection (ICRP) Formed in 1928.

To establish unanimity among representatives to the ICRP, it was decided that each member nation should have one official representative. Thus, in 1929, what became the National Committee on Radiation Protection and Measurements was established under the auspices of the National Bureau of Standards.[5]

U. S. Representative to ICRP is National Council on Radiation Protection and Measurements (NCRP).

In 1964, this national committee was granted an independent status and charter by Congress and changed its name slightly to become the National Council on Radiation Protection and Measurements (NCRP). The NCRP, in conjunction with its international counterpart, the ICRP, has, since 1929, provided the basic standards and guidance in the field of radiation protection.[5]

NCRP, an Independent, Objective Organization has Provided Basic Guidanc in Radiation Protection Since 1929.

In 1959, the Federal Radiation Council (FRC) was formed to provide a federal policy on human exposures to ionizing radiation. The FRC, whose responsibilities were absorbed in 1970 by the new Environmental Protection Agency (EPA), adopted those guidelines recommended by both the NCRP and ICRP. These guidelines were based on five principles in determining permissible levels:[6]

Federal Radiation Council Functions Absorbed by Environmental Protection Agency in 1970.

1. It is appropriate to set different standards for different sources of emissions and exposures.

2. Exposure to radiation should always be as low as possible.

*"Whereas all radiations produce the same types of biological effects, the magnitude of response per unit of absorbed dose is not the same The inverse ratio of the absorbed dose from one radiation type to that of a reference radiation required to produce the same degree of a stipulated effect is referred to as Relative Biological Effectiveness (RBE) There is actually no one RBE for a given type of radiation, the value depends on the total dose, dose rate, tissue, cell, and/or the biological effect being studied."[4]

3. No exposure should be allowed without expectation of benefit.

4. That all radiation is assumed to be harmful or potentially so.

5. And, that the biological risk associated with higher levels of exposure is proportional to those risks at lower levels.

   (Since these lower levels refer to exposures due to or comparable with natural background radiation, this assumption of proportionality provides a most conservative guideline.)[6]

Both FRC and EPA Followed Five Basic Premises in Establishment of Radiation Protection Guidelines.

The U.S. Atomic Energy Commission has incorporated the guidelines and recommendations of the NCRP, ICRP, and the FRC into its own operational procedures for AEC installations and those of contractors and licensees.[7,8]

The entire history of the derivation of radiation standards has been one of objective, conservative evaluation of the best data available. Guidelines have been internationally derived, accepted, and endorsed.[5]

Entire History of Present Standards is One of Objective, Conservative Evaluation.

The permissible dose of occupationally exposed individuals, 5 rem per year to the whole body, is defined by the National Council on Radiation Protection and Measurements as:[4]

> ". . . that dose, accumulated over a long period of time or from a single exposure, which in the light of present knowledge, carries a negligible probability of severe somatic or genetic injuries. . ."

Occupational Dose is 5 REM Per Year Limit to Whole Body.*

Based on all present technical knowledge, authorities have concluded that this level can be absorbed per year by a man throughout his working lifetime[4] without his sustaining any measurable damage.*

In contrast to this controlled group (i.e., the occupationally exposed), individual members of the general public include persons of all ages and degrees of health. The established standards reflect this prudent, conservative attitude toward exposures to the general public.

Since General Population is Uncontrolled Group (i.e. contains all ages, health, etc.) General Standards Far More Conservative

For an *individual* in the general population the whole body radiation exposure guide is given as 0.5 rem per year, one tenth that of the occupational expsoure level When a group of individuals is at risk, the whole body radiation exposure for the average of a suitable sample of the group must be less than 0.17 rem.[4]

Standards are in Terms of Group, Portio of Body Irradiated, and Period of Time Over Which Dose Delivered.

It must be noted then that the established standards, accepted by international authorities, are in terms of portions of the body irradiated and the period of time over which that dose is delivered.

Important too is the relatively low penetration power of the alpha particle. Alpha particles must be taken into the body to do any radiation damage to man; i.e., in the foods we eat (ingestion), the air we breathe (inhalation), or through a wound or break in the skin.

Alpha Particles Must Be Taken Into Body to Do Any Radiation Damage to Man.

*For perspective, it should be emphasized that the NCRP believes that its recommendations provide ". . .a system that offers far lower occupational risk than is found in many occupations normally considered not to be extra hazardous."[4]

III. STANDARDS

Air

Radioactive

The short range alpha particle will be completely absorbed by a small amount of tissue when taken into the body. This complete absorption represents a greater dose or exposure than that received from a gamma ray having the same energy. The gamma ray, with its higher penetration power, can pass completely through the body and thus transfer only a portion of its energy to the body tissue.

Most Restrictive Standards are for *Alpha Emitters in Air.*

Therefore, when alpha particles are inhaled, they can stay in one portion of the lung and irradiate one small area of tissue quite heavily.* To prevent this effect, the most restrictive standards are those for plutonium in air.

The current established standard for soluble plutonium in air is 0.06×10^{-12} μCi/ml of air in terms of exposure to an individual in the population and 0.02×10^{-12} μCi/ml to a suitable sample of the population[7,8,9] in terms of yearly averages.

STANDARDS FOR SOLUBLE Pu^{239} IN AIR.
Radiation Workers 2.0×10^{-12} μCi/ml
General Populace: Individual 0.06×10^{-12} μCi/ml
Total Population (suitable sample) 0.02×10^{-12} μCi/ml
Source: NBS Handbook, 69, USAEC Manual, Chapter 0524

For uranium (soluble-238), the applicable standards are 3×10^{-12} μCi/ml for an individual and 1×10^{-12} μCi/ml for a suitable sample of the total population.[7,8,9] These standards are based on the soluble materials, are stated in terms of yearly averages above the levels of naturally occurring alpha activity and apply at the plant boundary, the point of public access.[4,9]

STANDARD FOR URANIUM IN AIR:
INDIVIDUAL: 3×10^{-12} μCi/ml
TOTAL POP.: 1×10^{-12} μCi/ml

Total population standard for soluble plutonium-239 is 0.02×10^{-12} μCi/ml. This is equivalent to about 3.3×10^{-19} (0.00000000000000000033) gram of plutonium, or 1.2×10^{-20} (0.000000000000000000012) ounce of plutonium per milliliter of air. Based on the specific activity of plutonium-239, this would be just one particle about 3/1000 micron (0.00000013 inch) in diameter/ml of air.

Non-Radioactive

The standard most applicable to nonradioactive operations at Rocky Flats is that for beryllium. In terms of monthly averages, this standard is 1×10^{-5} milligrams per cubic meter (mg/M^3) of effluent air. This standard was established by action of the American Conference of Governmental Hygienists and modified by an Advisory Committee to the AEC.[10]

Beryllium Standard in Air = 0.01 μgrams Per Cubic Meter (1×10^{-5} mg/M^3).

*It must also be noted that since fewer cells are involved, this possibility might, in effect, do even less damage than originally presumed.

The EPA used these guidelines in their proposed beryllium standards as published in the December 7, 1971 Federal Register. The proposed standard states that total beryllium releases shall not result in outplant concentrations that exceed 10 grams in any 24-hour day, or concentrations of greater than 0.01 micrograms/cubic meter (1×10^{-5} mg/M^3) as averaged over 30 days.[11]

EPA 1971 Standard is Same as AEC Beryllium Standard for its Contractors and Licensees.

The Rocky Flats self-imposed internal goal for beryllium in air is one-half the official standard or 5×10^{-6} mg/M^3.

Water

Radioactive

The most restrictive recommended guideline for plutonium-239 (soluble) in water is 1.67×10^{-6} μCi/ml to a suitable sample of a population on a yearly average. For an individual within that population, that guideline is given as 5×10^{-6} μCi/ml on a yearly average.[7,8,9]

STANDARDS FOR SOLUBLE Pu^{235} IN WATER: Radiation Workers 100×10^{-6} μCi/ml. General Populace: Individual 5×10^{-6} μCi/ml. Total Population (suitable sample) 1.67×10^{-6} μCi/ml.

The most restrictive standard for uranium, that for the uranium-235 isotope, is 3×10^{-5} μCi/ml in terms of an individual in the population, or 1×10^{-5} μCi/ml for a suitable sample of the total population on a yearly basis.[7,8,9]

Most Restrictive Standard for Uranium in Water (Soluble U^{235} Is: 3×10^{-5} μCi/ml for Individ., 1×10^{-5} μCi/ml for Total Population (suitable sample).

In addition, gross alpha and gross beta guidelines to limit total radioactive nuclide content have also been established by the NCRP,[4] the AEC[7,8] the Colorado Department of Health[12] and U.S. Public Health Service.[13] Those standards adopted by the latter two agencies are based primarily on the recommendations of the Federal Radiation Council and thus the NCRP. Gross alpha standards for Rocky Flats effluents would be the same as the given standard for plutonium since it is one of the constituents of the mixture and has the most restrictive limit. Where the identity and concentration of both uranium and plutonium are known, a somewhat more complex derived standard is applicable.[7,8,9]

U.S. Public Health Service and Colorado Department of Health Guidelines are Based on NCRP Recommendations.

Established standards for soluble americium-241 in water are 4×10^{-6} μCi/ml for individual and 1.33×10^{-6} μCi/ml for a suitable sample of a population in terms of yearly averages.[7,8,9]

Non-Radioactive

The U.S. Public Health Service Drinking Water Standards (1962) are the primary guidelines followed at Rocky Flats. The Water Pollution Control Commission of the Colorado Department of Health is, however, the agency to which Rocky Flats is directly responsible. That agency is responsible for the administration of the USPHS guidelines and, in some cases, has established standards of its own. In addition, the Water Pollution Control Commission has compiled classifications for the major water sources of Colorado according to uses. Although Walnut Creek has not been classified, the most restrictive classifications (A, B_1, C, and D_1) are those adhered to. The basic Colorado Standards were revised effective September 1, 1971.[12] These new standards for Class A, B_1, C, and D_1 water sources are summarized below. Also summarized are those chemical guidelines delineated by the U. S. Public Health Service in the Drinking Water Standards of 1962.[13]

For Chemical Contaminants in Effluent Waste Waters, Rocky Flats Responsible to Colorado Department of Health.

Rocky Flats Effluents Discharged into Walnut Creek.

WATER QUALITY STANDARDS

Water Pollution Control Commission Colorado Department of Health

I. Basic (Non-Radioactive) Standards Applicable to All Waters of the State

A. All waters capable of treatment or control prior to discharge into any waters of the state shall receive secondary treatment with disinfection or its industrial waste equivalent.

Waters shall be free from substances attributable to municipal, domestic, or industrial wastes that:

B. Will either settle to form unsightly, putrescent or odorous bottom deposits or will interfere with the classified use of the water;

C. Create unsightly floating debris such as oil, grease, or scum;

D. Will produce objectionable odor, color, taste, or turbidity, or objectionable aquatic life;

E. May, in sufficient levels, concentrations, or combinations prove deleterious to human or animal life.

II. Additional Water Quality Standards (most restrictive from Class A, B_1, C, and D_1)

A. General (Colorado Department of Health)

Parameter	Limits	Classification
Fecal Coliform Bacteria	<1000/ml	A, B_1
Dissolved Oxygen	6 mg/l	B_1
pH	6.5-8.5	B_1
Turbidity	Not to impair natural and developed fisheries	B_1
Total Dissolved Solids	Less than 500 mg/l (annual volume-weighted average)	A, B_1
Toxic Materials (Biocides, Pesticides, etc.)	Free From	All
Temperature (°F)	70	B_1
Sodium Adsorption Ratio	Review of Commission	C, D_1
Taste & Odor	Free From	A, B_1

B. Chemical

Parameters	Limits (mg/l) CDH A, B_1	Suggested Maximum (USPHS)	Grounds for Rejection (USPHS-CDH)
Alkyl Benzene Sulfonate	–	0.500	–
Arsenic	0.05	0.010	0.05
Barium	1.00	–	1.00
Cadmium	0.01	–	0.01
Chloride	–	250.	–
Cr^{6+}	0.05	–	0.05
Copper	0.05	1.00	–
Carbon Chloroform Extract	–	0.200	–
Cyanide	0.20	0.010	0.20
Fluoride	–	1.200	2.40
Iron	–	0.300	–
Lead	0.05	–	0.05
Manganese	–	0.050	–
Nitrate	–	45.0	–
Phenols	–	0.001	–
Selenium	0.01	–	0.01
Sulfates	–	250.	–
Silver	0.05	–	0.05
Zinc	–	5.00	–

A Colorado guideline for the Biochemical Oxygen Demand (BOD) – the amount of oxygen needed to allow for natural, biological oxidation of organic matter – has been established, primarily as a measurement of sewage treatment effectiveness. The BOD guideline for Rocky Flats is 30 mg/l.

Measure of Success of Secondary Waste Treatment is BOD.

No standards have been established for phosphate levels.

Other Standards

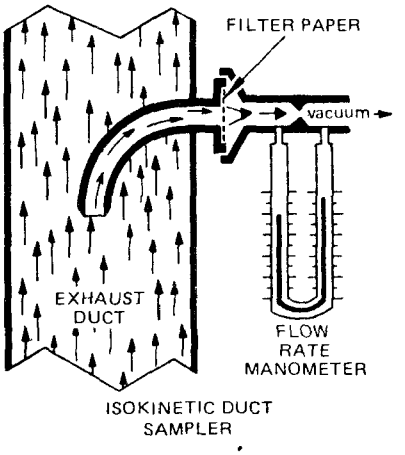
Although no directly applicable standards currently exist for plutonium and/or uranium levels or non-radioactive materials in soil, sediments, vegetation, or dustfall samples, the guide at Rocky Flats has always been to maintain these levels as low as is practicable in accordance with the guidelines of the National Council on Radiation Protection and Measurement.[4]

No Applicable Standards for Soil, Sediments, Vegetation, or Dustfall, so Guideline is that of the NCRP: Maintain Levels as Low as Practicable.

IV. Sample Collection and Analysis Summary

Stack Effluents

Exhaust ducts from buildings involved with processing of plutonium, uranium, and/or beryllium are continuously sampled. An iso-kinetic technique is used whereby the air moving into the sample device is at the same velocity as the air inside the duct. This technique allows improved trapping of particulate matter by eliminating turbulence at the mouth of the sample tube. Samples are taken continuously and analyzed for total long-lived alpha activity (including natural, long-lived alpha emitting materials) and/or beryllium where applicable. Total activity released is then calculated from total effluent volumes.



Exhaust Ducts of Process Buildings Continously Sampled Using Isokinetic Device for Better Particulate Trapping.

Samples Analyzed for Gross Alpha and/or Beryllium Where Applicable.

Since most standards apply to concentrations measured at the point of public access (plant boundaries),[4,9] measurements taken at the stack discount any dilution effect and thus provide an additional safety factor. The guides for effluents are for contributions (above naturally occurring activity) after dilution by the atmosphere in terms of timed averages. *The values obtained at Rocky Flats are taken at the stack and include natural activity before any atmospheric dilution.* These results, summarized in Tables IA and IB indicate a maximum (one-month average) long-lived alpha concentration of 0.095×10^{-12} μCi/ml for all plutonium operations.

Standards Apply at Plant Boundaries . . . Samples Taken and Results Reported at the Stack Before Appropriate Atmospheric Dilution.

Results Summarized in Tables IA and IB.

The yearly average (the pertinent value in terms of the guidelines) was 0.009×10^{-12} μCi/ml, about 15% of the standard.

Maximum Concentration for All Plutonium Releases Occurred During Filter Change.

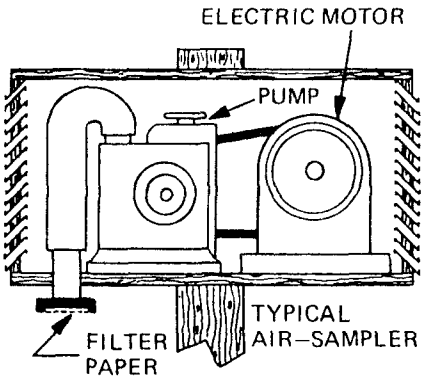
The maximum (one-month average) total emission from all uranium operations (Table IC and ID) was 0.05×10^{-12} μCi/ml. The yearly average was 0.008×10^{-12} μCi/ml, which is about 0.3% of the applicable (population) standard.

Maximum (one-month average) beryllium emission was 1.5×10^{-5} mg/cubic meter (before atmospheric dilution). The 12-month average stack release for all beryllium operations was 1.3×10^{-9} milligrams per cubic meter or about 13% of the standard. Beryllium results are tabulated in Tables IIA and IIB.

Air Samplers

To provide further detection and measurement of any accidental release of any contaminated effluents, Rocky Flats maintains an extensive network of continuously operating air sampling devices to monitor contamination levels in the surrounding atmosphere.

Extensive Network of Air Samplers Maintained to Detect Levels and Accidental Releases



Continuous samples are obtained from 12-on-site air sampling stations (Map 1) which sample about 82 cubic meters of air per day (the equivalent of 2 cubic feet per minute). These samples are collected and analyzed daily for *total long-lived alpha concentrations* (which would include plutonium, uranium, and other long-lived alpha emitters) and specifically for beryllium (see Map 1).

12 (Continuous Operation) Air Samplers on Plantsite; Sample About 2 Cubic Feet Per Minute. Samples Analyzed for *Long-Lived Alpha.*

Twelve high-volume air samplers are located at a radius of about 2 miles from the plant perimeter (Map 2). These samples are collected on a 4-inch filter paper, which is changed daily, composited and analyzed specifically for *plutonium.* The 437 composite samples for 1971 represent volumes of over 2,000,000 cubic meters (about 70,000,000 cubic feet) of air actually filtered in 1971.

12 High Volume Samplers Offsite, Surrounding Plant at About 2 Mile Radius. Samples Analyzed for *Plutonium.*

High-volume samples are also taken weekly from Wagner Site (S-18, Map 2) and from Coal Creek Canyon (S-11, Map 2), about 2.5 miles southeast and 3 miles west southwest of the plant, respectively. For 1971, the 77 samples taken represent volumes of about 17,000 cubic meters of air (nearly 600,000 cubic feet). These were analyzed specifically for *plutonium.*

Special High Volume Samplers Also Taken Onsite and at Two Offsite Locations on Regular Basis, Analyzed for *Plutonium.*

Results for the year indicated a maximum of 0.06×10^{-12} μCi/ml. High-volume grab samples were also taken to the east of an asphalt pad covering some contaminated soil (former drum storage area in the southwest corner of the plant-site proper) The 180 samples taken in 1971 represent over 40,000 cubic meters of air actually filtered and were analyzed for *total plutonium content.* The results varied from a single sample maximum of 0.049×10^{-12} μCi/ml to a yearly average of 0.0030×10^{-12} μCi/ml.

Nine low-volume air samplers, programmed to sample for 10 minutes of each hour, are located in Boulder, Broomfield, Denver, Coal Creek Canyon, Golden, Lafayette, Westminster, and Marshall (Map 3). These samples are collected weekly and analyzed for total *long-lived alpha activity.* The low-volume samplers represent about 44,000 cubic meters of air during 1971.

Low-Volume, Programmed Samplers Located in Surrounding Communities.

Weekly-Samples Analyzed for Total Long-Lived Alpha (Nearly 10,000 Samples Per Year).

This complex of air samplers produces nearly 10,000 samples per year. These are analyzed to make certain that effluent levels as well as any re-distribution effects are kept well below guideline concentrations. Summaries of these results for 1971 are presented in Tables III, IV, and V. On-site air samples varied from a maximum average *long-lived alpha concentration* (one-month average) of 0.0128×10^{-12} μCi/ml with a 12-month average of 0.0049×10^{-12} μCi/ml, about 24.5% of the standard.

Low-volume, off-site air sample results were also quite low. The programmed samplers indicated a maximum *long-lived alpha concentration* (one-month (average) of 0.01 X 10^{-12} μCi/ml with a yearly average of 0.0044 X 10^{-12} μCi/ml, about 66% of the guidelines. The high-volume, off-site samplers, much more indicative of chronic exposure levels, revealed much lower concentrations. The maximum (one-month *plutonium* average) was 0.004 x 10^{-12} μCi/ml whereas the average for the year was 0.0003 x 10^{-12} μCi/ml, about 1.3% of the guideline.

Average Concentrations Below Established Guidelines.

Data from the air-sampling network indicate that the average contaminant concentrations in air effluents from Rocky Flats were below the established standards.

Beryllium Results Also Below Guidelines.

Beryllium sample results were also far below guideline concentrations (Table VI). Nearly 12,000 analyses of these air samples indicate that in no case did off-site beryllium concentrations exceed 1.87 x 10^{-5} milligrams per cutib meter* and that the yearly average was 2.8 x 10^{-6} mg/M^3, roughly 30% of the applicable standard. On-site results were considerably lower, ranging from a maximum of 2.3 x 10^{-6} mg/M^3 to a yearly average of 1.2 x 10^{-6} mg/M^3 indicating that cross contamination occurred in an analysis of the off-site samples.

Dustfall Samples

Dustfall Collection Trays Mounted Atop all Offsite Air Samplers.

In addition to the air samples obtained, specially designed trays atop all the off-site air stations collect dustfall samples for specific plutonium analysis. In addition, more remote samples are collected from locations near Berthoud and from Castle Rock. Table VII tabulates these results for the year. All samples are collected on a bi-monthly basis, and represent fallout from atmospheric weapons testing, and, of course, any contribution from Rocky Flats. Castle Rock and Berthoud samples are collected to provide an indication of plutonium in dustfall samples from background. The values obtained in this extensive sampling program are on the same order of magnitude as reported for world-wide fallout measurements.[14] These levels represent no health or safety hazard. There is possibly some insignificant but nonetheless real contribution from Rocky Flats. Studies are now underway to determine what (if any) contribution is directly attributable to Rocky Flats.

Dustfall Results Same Order of Magnitude. as Worldwide Fallout, But Possibly Some Contribution From Rocky Flats. This Under Intensive Study.

Levels Represent No Health or Safety Hazard.

Water Samples

Three Drainage Streams: North Walnut Creek (A), South Walnut Creek (B), Woman Creek (C). (Discharges Made Only to South Walnut Creek (B) Through Four Holding Ponds.)

Rocky Flats is drained by three streams; North and South Walnut Creeks to the north of the plant-site, and Woman Creek to the south. For reference, North Walnut Creek is classified as the plant's "A" drainage, South Walnut Creek as the "B" drainage, and Woman Creek as the "C" drainage.

Sanitary and process waste waters are released after treatment to South Walnut Creek through a series of four holding ponds (Ponds B-1, B-2, B-3, B-4). Effluents released through the sewage plant meet all Water Quality Standards as established by the Colorado Department of Health[12] or the U.S. Public Health Service Drinking Water Standards Act (1962).[13] The overflow from the pond system (Ponds B-1 through B-4) flows into Great Western Reservoir.

*Although these data are believed to be the result of analytical error due to their high deviation from the average, it is felt that it would be far better to err on the conservative side and they are thus presented as maximums.

Continuous flow into this reservoir is comprised mainly of liquid wastes from Rocky Flats and makes up a small portion of the drinking water for the community of Broomfield.

Holding Ponds Also Located on (A) and (C) Drainages.

Holding ponds are also located on North Walnut Creek (Pond A) and on Woman Creek (Pond C), but no effluents are discharged directly into these holding ponds.

Daily water samples are collected from Pond B-4, and three times weekly from the Ponds A and C. These samples are composited into a weekly sample and analyzed for their gross alpha (uranium and plutonium) content as well as specifically for plutonium and for americium.

Water Samples Collected Daily From B-4, Three Times Each Week From (A) and (C).

Tap water samples from the surrounding communities (Arvada, Boulder, Broomfield, Denver, Golden, Lafayette, Lousiville, Thornton, and Westminster) and water samples from four reservoirs in the area are collected every 2 weeks, and analyzed specifically for gross alpha and plutonium. Standley and Great Western Reservoir water samples are also analyzed for americium.

Tap Water Samples Taken From Surrounding Communities Every 2 Weeks, Along with Four Reservoirs in Area.

Weekly grab samples are taken from Walnut Creek below the confluence of the North and South branches and analyzed for gross alpha and specifically for plutonium and americium content. As a further safeguard, nearly all waters in the immediate vicinity are surveyed semi-annually and analyzed for gross alpha (uranium and plutonium) and for plutonium content. There are 34 such bodies of waters surveyed, 18 within 5 miles of the plant site and 16 at distances greater than 5 miles.

Most Waters in Area Sampled for Gross Alpha and Plutonium.

The most restrictive standard, that for soluble plutonium-239, is 1.67×10^{-6} μCi/ml in terms of yearly averages to a suitable sample of a population. *Gross alpha concentrations* in samples from B-4 pond had a maximum of 36.6×10^{-9} μCi/ml, and a yearly average of 11.69×10^{-9} μCi/ml. These gross alpha concentrations are contributions from both plutonium and uranium. All other naturally occurring long-lived alpha emitters are removed from the samples during the analytical procedure.

Total *maximum plutonium concentration* in Pond B-4 was 7.23×10^{-9} μCi/ml with a yearly average of 2.06×10^{-9} μCi/ml. *Americium-241 maximum* was 3.07×10^{-9} μCi/ml with a yearly average of 1×10^{-9} μCi/ml.

Average Gross Alpha, Americium and Plutonium Concentrations Below Guidelines.

Grab samples from Pond A showed a maximum *gross alpha concentration* of 17.65×10^{-9} μCi/ml, with a yearly average of 7.28×10^{-9} μCi/ml. Pond C showed similar low concentrations with a yearly maximum (gross alpha) of 23.64×10^{-9} μCi/ml and a yearly average of 6.14×10^{-9} μCi/ml.

Those grab samples taken at the confluence of North and South Walnut Creeks showed a maximum gross alpha of 49.34×10^{-9} μCi/ml. Maximum *plutonium* concentration found was 8.47×10^{-9} μCi/ml, and maximum americium was about one-half that amount. *Average gross alpha was 11.55, average plutonium 2.56 and average americium 0.80, all x 10^{-9} μCi/ml.*

Tap water results averaged 3.33×10^{-9} μCi/ml with a maximum of 18.58×10^{-9} μCi/ml *gross alpha activity.* Gross alpha concentrations in the reservoirs averaged 6.38×10^{-9} μCi/ml with a maximum of 28.8×10^{-9} μCi/ml in Broomfield.

Tap Water From Surrounding Communities and Reservoir Samples Below Gross Alpha (U + Pu) Guidelines.

Average plutonium concentrations, summarized in Tables VIIIA and B, show that all water samples, from tap water, reservoirs, and holding ponds were 1000 to 10,000 times less than the most restrictive standard for soluble plutonium.

Average *Plutonium* Content of Tap Water and Reservoir Samples 1000 to 10,000 Times Less Than Guidelines.

In addition to the radionuclide analyses performed on these effluents, the daily chemical analyses of the B holding ponds, sanitary and process waste effluents, and weekly grab samples taken from Ponds A and C, show them to be within both State and Federal specifications (Table VIIID and VIIIE.)

Chemical Analyses Also Below USPHS and Colorado Guidelines.

Sediment Samples

Sediment samples from the four major reservoirs are collected semi-annually and more frequent sediment samples are taken from each of the six holding ponds. Additional samples are also taken from Walnut and Woman Creeks. These samples are taken to a depth of 4 centimeters. No specific standard now exists for plutonium in sediment samples. The results, tabulated in Table IX indicate a maximum of 0.641×10^{-3} μCi/gram (dry) within the controlled area. The yearly average within the controlled area was 0.03×10^{-6} μCi/gram (dry). The maximum concentration found outside the controlled access area of the plant site was 7×10^{-6} μCi/gram with a yearly average of 7×10^{-9} μCi/gram.

No Standards for Sediment Samples.

No analyses are performed for nonradioactive materials in sediment samples.

Soil Samples

The Rocky Flats Health Physics Department has maintained an extensive soil sampling program on a routine basis since mid-1969. Previous to that time, samples were taken on a random basis and analyzed for gross alpha content. Although this gross alpha analysis would include plutonium and uranium as well as naturally occurring radionuclides, no specific plutonium analyses were routinely performed on these soil samples prior to that time.

Routine Soil Sampling Since Mid-1969.

The current program draws samples from a rough grid at 1, 2, and 5-mile distances from the center of the plant. About 75 locations, predominantly east and south of the plant site (corresponding to prevailing wind directions) but covering all areas between the perimeter and cattle fences, are sampled twice each year. In addition, locations along public right-of-way are also sampled, and samples are taken from Denver, Arvada, Westminster, between Boulder and Fort Collins, between Leyden and Golden, along 104th Avenue and in Coal Creek Canyon. All samples are to a depth of 1 centimeter. In all, 159 soil samples were collected in 1971 and analyzed specifically for plutonium.

Current Program Uses 1, 2, and 5-Mile Grids. 159 Samples in 1971 Analyzed Specifically for Plutonium.

No specific standard has been set for plutonium in soils. The levels obtained in this sampling program are summarized in Table X.

No Standard for Plutonium in Soils.

All evidence gathered to date by the Rocky Flats Health Physics Department and other official agencies indicate that the plant has made some contribution to plutonium soil concentrations in the immediate vicinity of the site. There is, however, no evidence to indicate that there has been any measurable or significant contribution to the Greater Denver Metro areas surrounding the plant. Nor is there any evidence that the levels found closer to the plant represent any health hazard.

Plant Made Some Contribution to Pu Soil Concentrations in Immediate Vicinity. No Evidence of Any Measurable or Significant Contribution to Greater Denver Metro Areas, nor Any Evidence That Levels Found Represent Health or Safety Hazard.

Vegetation Samples

Vegetation samples are collected from 75 locations within a radius of 20 miles from the plant site. These are taken from public right-of-way twice each year, and are confined to those plants normally consumed by grazing domestic animals. The various samples are analyzed specifically for plutonium.

Vegetation Samples Collected Twice Yearly from 75 Locations, Analyzed Specifically for Plutonium.

Results for 1971 (Table XI) show that plutonium levels were a maximum of 2.54×10^{-6} μCi/gram (dry). One notable aspect of this sampling program is that the plant is analyzed without any prior washing. Thus, the plant becomes a form of dustfall collector as well as a measurement of the amount of plutonium physically incorporated into the plant through normal growth activities. Although no specific standard has been established for plutonium in or on plants, these levels are considered by most experts to be insignificant, especially in light of empirically derived dilution factors.[15]

No Standard for *Plutonium* In Vegetation. Levels Found Are Considered Safe.

No specific *routine* analyses are performed at Rocky Flats on food or biological samples. Specific studies are now under way on vegetation and biological samples by Rocky Flats and by C.S.U.

Rocky Flats has contracted with the Radiobiology Department of Colorado State University to make ecological studies of the flora and fauna in the immediate environs of the plant. This will be a continuing project.

C.S.U. Ecology Studies of Plant Site, A Continuing Project.

V. Tabular Data, 1971

Map 1. On-site high-volume air sampling stations and weather summary.

Map 2. Off-site high-volume air sampling stations.

Map 3. Programmed environmental sampling network.

Map 4. Rocky Flats effluent water flow.

Table I. Radioactive stack effluent releases.

- A. Plutonium concentrations.
- B. Yearly summation, plutonium concentrations.
- C. Uranium concentrations.
- D. Yearly summation, uranium concentrations.

Table II. Non-radioactive stack effluent releases.

- A. Beryllium concentrations.
- B. Yearly summation, beryllium concentrations.

Table III. Average monthly air sample concentrations, on-site, radioactive.

- A. Long-lived alpha concentrations.
- B. Yearly summation, long-lived alpha concentrations.

Table IV. Average monthly air sample concentrations, off-site, radioactive.

- A. Low-volume, programmed samplers.
  1. Long-lived alpha concentrations.
  2. Yearly summation, long-lived alpha concentrations.
- B. High-volume off-site samplers.
  1. Plutonium concentrations.
  2. Yearly summation, off-site plutonium concentrations.

Table V. Special high-volume air samples, radioactive.

- A. On-site grab samples and summation.
- B. Off-site grab samples and summation.

Table VI. Average monthly beryllium concentrations in air samples, on- and off-site.

Table VII. Dustfall sample summary.

Table VIII. Water surveys.

- A. Radioactivity in holding ponds and effluent waste waters.
  1. Pond B-4.
  2. Grab samples, Ponds A and C.
  3. Walnut Creek at Indiana (confluence).
- B. Radioactivity in reservoir and tap water samples.
  1. Reservoir water samples.
  2. Community tap water samples.
- C. Semi-annual water collection.
- D. Chemical concentrations in holding ponds and effluent waste waters.
  1. Pond B-4.
  2. Pond B-4 summary.
  3. Pond B-4 elemental analyses.
- E. Chemical concentrations in holding ponds and effluent waste waters.
  1. Grab samples, Ponds A and C.
  2. Yearly summary, Pond A.
  3. Yearly summary, Pond C.

Table IX. Sediment samples.

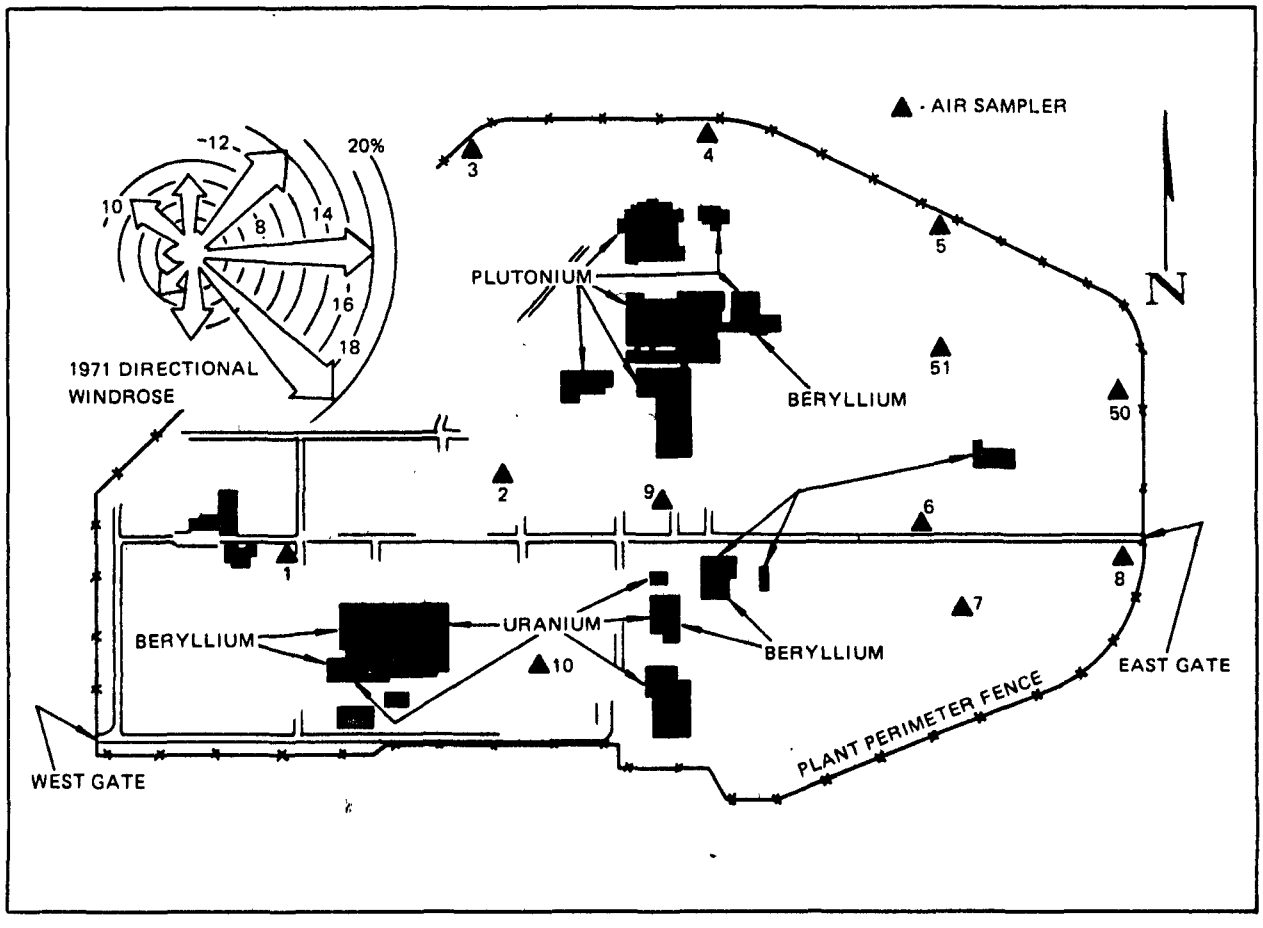
Table X. Semi-annual surface soil analyses - off-site contours.

Table XI. Vegetation samples.

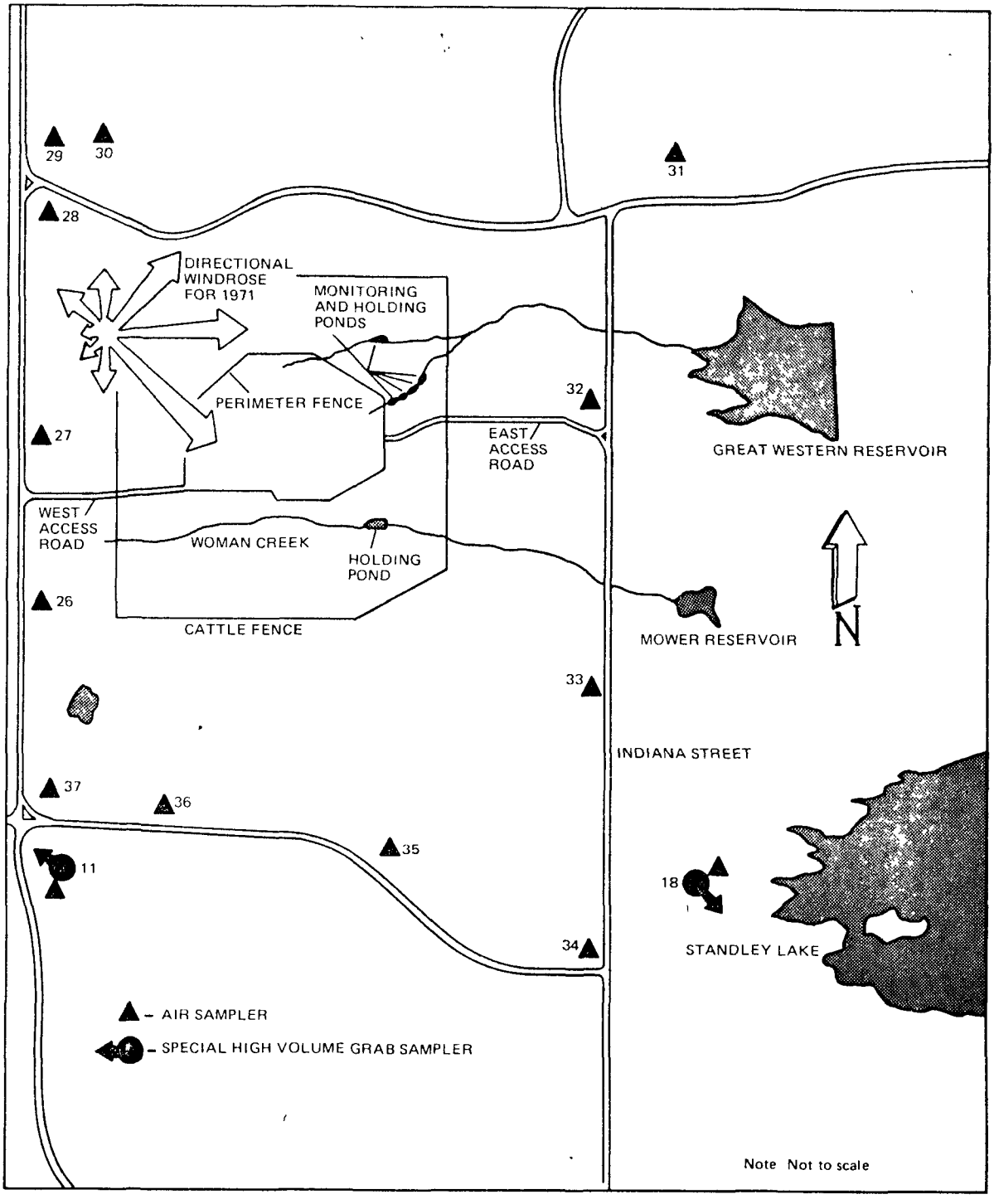
Analytical Note: For all samples below detection limits, a value was assigned. This value is a fraction of the detection limit; i.e., the number of samples above the detection limit divided by the total number of samples that were analyzed.

Weather Summary, 1971

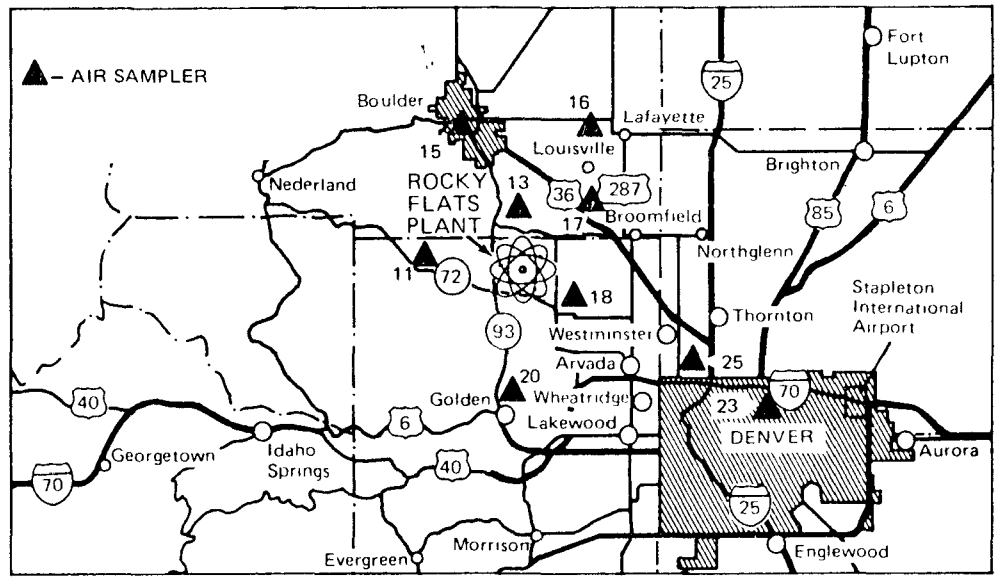
For 1971, weather records show that the average temperature was 50.2 degrees Fahrenheit, and ranged from minus 2 to 102 degrees. The average relative humidity was 48.1%. Monthly precipitation ranged from 0.15 inch in November to a maximum 3.78 inches in April. The average precipitation for the year was about 1.2 inches per month, with a total for the year of 14.3 inches. Although winds at Rocky Flats averaged only 8.7 miles per hour, peak wind velocities exceeded 40 miles per hour in all 12 months, ranging from 43 miles per hour in May 1971, to 95 in January. Average peak velocity for all 12 months was 31 miles per hour. The prevailing winds below from the northwest 20% of the time and from the west about 18% of the time. (A directional wind rose is included with Map 1.)



Map 1. On-Site Air Sampler Locations and Material Areas.



Map 2 Off-Site High-Volume Environmental Air Sampling Network



Map 3. Programmed Environmental Air Sampling Network.

Map 4. Rocky Flats Effluent Water Flow.

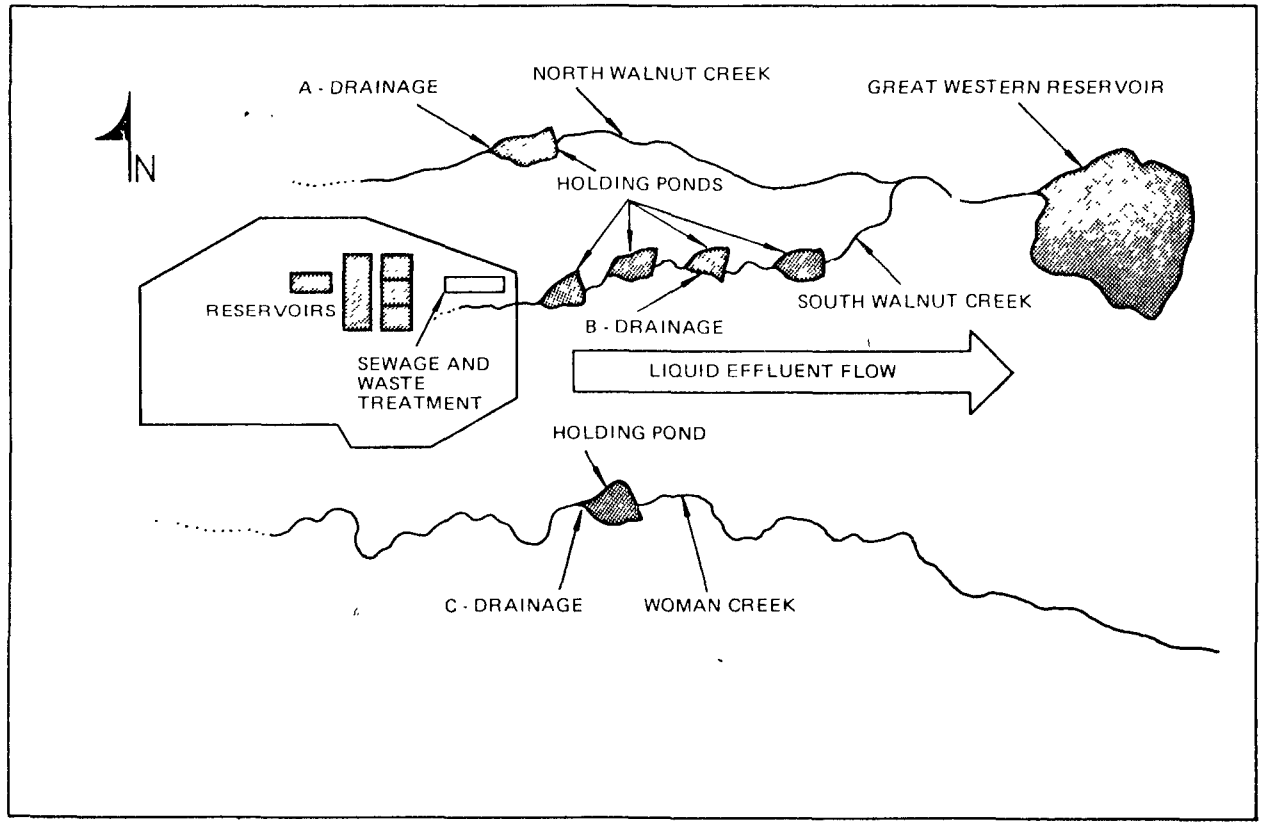


Table I. Radioactive Stack Effluent Releases, 1971.

(A) Plutonium

Monthly Concentrations ($\times 10^{-12}$ μCi/ml)

Building	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
771	0.005	0.005	0.005	0.015	0.007	0.012	0.007	0.006	0.015	0.012	0.004	0.006
774	0.015	0.010	0.011	0.014	0.060**	0.013	0.008	0.007	0.012	0.010	0.013	0 015
776	0.004	0.095*	0.033	0.006	0.018	0.011	0.003	0.003	0.002	0.009	0.002	0.002
779	0.007	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
559	0.003	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002
707	0.003	0.002	0.005	0.003	0.005	0.004	0.003	0.004	0.003	0.002	0.080***	0.004
Total Releases by Month (μCi)	2.852	17.240	8.017	5.989	8.286	5.838	2.671	2.680	5.096	5.270	7.884	2.546

Applicable Standard: (Soluble ^{239}Pu) = 0.06×10^{-12} μCi/ml.

(B) Yearly Summary – Plutonium

Concentrations ($\times 10^{-12}$ μCi/ml)

Building	January – June: Maximum Concentration (Single Sample)	January – June: (Monthly) Average Concentration	July – December: Maximum Concentration (Single Sample)	July – December: (Monthly) Average Concentration)	Total Year: Concentration Max. (Bldg)	Total Year: Concentration Av. (Bldg)	Total Year: % Std. (Av. Conc.)	Total Year: Total Release (μCi)
771	0.015	0.008	0.008	0.002	0.015	0.008	13.3	26.427
774	0.109	0.021	0.013	0.011	*0.109	0.016	26.7	6.034
776	0 087	0.028	0.009	0.004	0.087	0.016	26.7	33.052
779	0.006	0.003	0.002	0.002	0.006	0.002	3.3	0.344
559	0.004	0.003	0.004	0.002	0.004	0.002	3.3	0.766
707	0.004	0.004	0.080	0.016	0.080	0 010	16.7	7.726
			Total Plutonium Operations, Yearly Summation:		0.109	0.009	15%	74.349

*The maximum monthly average emission (which occurred during filter changing operations in Building 776 in February) was 0.095×10^{-12} μCi/ml. The maximum single sample emission (0.10×10^{-12} μCi/ml) was from Building 774. It must be noted that these values are taken at the stack, BEFORE appropriate atmospheric dilution. The standards apply at the plant perimeter and are in terms of averages of up to one year. The annual average Pu emission from ALL Pu operations was 0.009×10^{-12} μCi/ml, about 15% of the applicable standard (0.06×10^{-12} μCi/ml).

**Filter changing operations.

***Effluents leaking around one stage of filter plenum. Discovered and corrected.

(C) Uranium

Monthly Average Concentrations ($\times 10^{-12}$ μCi/ml)

Building	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
444	0.009	0.005	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.017	0.002
447	0.071*	0.070	0.029	0 033	0.040	0.023	0.002	0.017	0.030	0 018	0 007	0.021
881	0.004	0.017	0.018	0.049	0.005	0.005	0.005	0.006	0.002	0.002	0.003	0.002
883 (A)	0.010	0.008	0.010	0.012	0.041	0.034	0.008	0.013	0.013	0.010	0.015	0.011
883 (B)	0.010	0.006	0.003	0.004	0.008	0.005	0.003	0.003	0.002	0.002	0.003	0.002
886	0.003	0.001	0.002	0.002	0.002	0 002	0.002	0.002	0.001	0.001	0.003	0.003
889	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.003	0.002	0.003
865	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
991-T	–	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.001
Total Release by Month (μCi)	11.264	12.148	8.959	21.935	10.052	7.270	2.976	6.149	4.405	3.151	6.801	3.741

Applicable Standard:*** (Soluble ^{238}U) 3×10^{-12} μCi/ml

(D) Yearly Summary – Uranium

Concentrations ($\times 10^{-12}$ μCi/ml)

Building	January – June: Maximum Concentration (Single Sample)	January – June: (Monthly) Average Concentration	July – December: Maximum Concentration (Single Sample)	July – December: (Monthly) Average Concentration	Total Year: Concentration Max. (Bldg)	Total Year: Concentration Av. (Bldg)	Total Year: % Std. (Av. Conc.)	Total Year: Total Release (μCi)
444	0.009	0.004	0.017	0.004	0.017	0.004	0.1	9.960
447	0.077	0 044	0.033	0.016	**0.077	0.030	1.0	25.756
881	0.050	0.016	0.006	0.003	0.050	0.010	0.3	35.440
883A	0.040	0.019	0.014	0.012	0.040	0.016	0.5	20.680
882B	0.012	0.006	0.003	0.002	0.012	0.004	0.1	5.740
886	0.004	0.002	0.004	0.002	0.004	0.002	0.1	0.132
889	0.005	0.002	0.003	0.002	0.005	0.002	0.1	0.146

Table I. Radioactive Stack Effluent Release, 1971 (continued).

(D) Yearly Summary – Uranium (continued)

Concentrations ($\times 10^{-12}$ μCi/ml)

Building	January – June Maximum Concentration (one month average)	January – June (Monthly) Average Concentration	July – December Maximum Concentration (one month average)	July – December (Monthly) Average Concentration	Total Year Concentration Max. (Bldg)	Total Year Concentration Av. (Bldg)	Total Year % Std. (Av. Conc.)	Total Year Total Release (μCi)
895	0.004	0.002	0.001	0.001	0.004	0.002	0.1	0.803
991-T	0.007	0.002	0.007	0.001	0.007	0.002	0.1	0.033
Total Uranium Operations, Yearly Summation:					0.077	0.008	0.3	98.690

*Maximum monthly average emission 0.071×10^{-12} μCi/ml (Building 447, January)

**Maximum single sample concentration. Both maximums associated with filter changes in the plenums of this building.

***Although Rocky Flats effluents would include several isotopes of uranium, the guideline for soluble-238 is the most restrictive in air. It must be noted that this standard applies at the plant boundary and is in terms of yearly averages to an individual in the general population. The values here, all well below that standard, are taken at the stack before any atmospheric dilution.

Table II. Non-Radioactive Stack Effluent Releases, 1971.

(A) Beryllium

Monthly Average Concentrations ($\times 10^{-6}$ mg/M^3)

Building	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
444-447	2.2	5.1	3.0	2.2	1.8	0.7	15.0	2.0	2.8	1.2	0.2	14.1
883A	1.0	3.2	0.5	0.2	0.2	0.2	0.5	0.2	1.1	0.2	0.2	0.2
779	0.3	0.7	0.3	0.3	0.3	0.3	0.3	0.5	0.2	0.6	3.6	0.6
774	0.8	0.6	0.6	0.5	0.5	0.5	0.4	0.6	0.2	0.4	0.8	0 8
865	0.5	2.0	0.4	0.2	0.5	0.5	0.2	0.2	0.2	1.1	0.2	0.2
Total Monthly Release (grams)	0.8226	2.0923	1.2391	0.6988	0.6192	0.3700	4.4909	0.8021	0.8809	0.5191	0.0940	4 2010

(B) Annual Summary

Beryllium Stack Effluent Releases ($\times 10^{-6}$ mg/M^3)

Building	January – June Maximum Single-Sample Concentration	January – June Average Concentration	July – December Maximum Single-Sample Concentration	July – December Average Concentration	Totals for Year Max. Conc.	Totals for Year Av. Conc.	Totals for Year *% Std	Totals for Year Total Release (g)
444-447	45.0	2.6	209.2	5.8	209.2	4.2	42	15.1879
883A	25.2	0.6	1.2	0.5	25.2	0.6	6	0.0793
779	5.1	0.4	7.7	0.9	7.7	0.6	6	0.0262
774	2.4	0.7	0.4	0.2	2.4	0.5	5	0.8146
865	9.8	1.0	7.0	0.4	9.8	0.7	7	0.7220
Total Beryllium Operations, Yearly Summation:					209.2	1.3	13.0	Total 16.8301

*Applicable Standard is 10×10^{-6} mg/M^3 (Division Internal Goal is 5×10^{-6} mg/M^3).

Table III. Average Monthly Air Sample Concentrations, On-Site, Radioactive.

(A) Total Long-Lived Alpha Concentrations (U, Pu, and naturally occurring alpha emitters)

Monthly Average Concentrations ($\times 10^{-12}$ μCi/ml)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S-1	0.0044	0.0033	0.0046	0.0036	0.0057	0.0052	0.0034	0.0040	0.0045	0.0049	0.0035	0.0038
S-2	0.0045	0.0044	0.0039	0.0046	0.0050	0.0027	0.0025	0.0055	0.0029	0.0044	0.0040	0.0047
S-3	0.0033	0.0028	0.0033	0.0059	0.0052	0.0048	0.0054	0.0066	0.0057	0.0052	0.0046	0.0043
S-4	0.0021	0.0044	0.0047	0.0067	0.0042	0.0040	0.0046	0.0041	0.0035	0.0034	0.0034	0.0034
S-5	0.0017	0.0040	0.0032	0.0036	0.0047	0.0060	0.0053	0.0026	0.0034	0.0058	0.0069	0.0034
S-6	0.0031	0.0030	0.0028	0.0037	0.0052	0.0034	0.0145	0.0020	0.0032	0.0021	0.0068	0.0030
S-7	0.0082	0.0066	0.0054	0.0082	0.0043	0.0047	0.0026	0.0034	0.0022	0.0034	0.0012	0.0045
S-8	0.0058	0.0069	0.0078	0.0324	0.0090	0.0103	0.0096	0.0110	0.0056	0.0128	0.0114	0.0071
S-9	0.0043	0.0040	0 0041	0.0039	0.0036	0.0042	0.0043	0.0036	0.0026	0.0028	0.0013	0.0049
S-10	0.0046	0.0052	0.0041	0.0072	0.0047	0.0073	0.0029	0.0030	0.0040	0.0062	0.0040	0.0038
S-50	0.0042	0.0026	0.0045	0.0085	0.0048	0.0078	0.0052	0.0086	0.0059	0.0076	0.0064	0.0036
S-51	0.0044	0.0051	0.0036	0.0067	0.0046	0.0037	0.0024	0.0020	0.0041	0.0054	0.0044	0.0056

Applicable Standard (Soluble Plutonium-239) = 0.02×10^{-12} μCi/ml

(B) Summary: Total Long-Lived Alpha, On-Site, 1971

Concentration ($\times 10^{-12}$ μCi/ml)

Location	No. of Samples	<Det.	$C_{Max.}$	$C_{Avg.}$	% of Std.
S-1	243	125	0.0218	0.0043	21.6
S-2	241	140	0.0420	0.0040	20.0
S-3	245	124	0.0218	0.0047	23 6
S-4	244	142	0.0333	0.0040	20.0
S-5	245	132	0.0228	0.0042	21.2
S-6	245	161	0.2723	0.0043	21.5
S-7	245	136	0.0822	0.0046	22.8
S-8	245	81	0.1884	0.0104	52.0
S-9	244	146	0.0368	0.0036	17.9
S-10	237	112	0.0228	0.0047	23.4
S-50	244	120	0.1436	0.0058	28.8
S-51	244	135	0.0341	0.0043	21.5
Yearly Summation, Total Averages:	2922	1554	0.2723	0.0049	24.5

*This sampler (S-8) is located within the strongest, most frequent wind vector, and is adjacent to the asphalt pad covering some contaminated soil. The large volumes of dirt thus seen by this sampler may be indicative of resuspension mechanisms. It is worthy of note that this, the highest-concentration-location, is still less than 40% of the applicable standard when stated in terms of yearly averages.

Table IV. Average Monthly Air Sample Concentrations, Off-Site, Radioactive.

(A) Low-Volume Programmed Samplers

1. Total Long-Lived Alpha Concentrations, 1971 (U, Pu, and naturally occurring alpha emitters)

Monthly Average Concentrations ($\times 10^{-12}$ μCi/ml)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Boulder (S-15)	0.0036	0.0039	UD	0.0049	0.0074	0.0061	0.0044	0.0056	0.0077	0.0078	0.0036	0.0034
Broomfield (S-17)	0.0041	0.0060	0.0066	0.0056	0.0026	0.0031	UD	0.0044	0 0046	UD	0.0031	0 0035
Coal Creek (S-11)	0.0031	0.0041	0.0022	0.0062	0.0022	0.0036	UD	UD	UD	0.0027	0.0029	0.0023
Denver (S-23)	0.0022	0.0014	0.0085	0.0068	0.0029	0.0055	0.0024	0.0069	0.0059	0.0032	0.0030	0.0024
Golden (S-20)	0.0039	0.0047	0.0061	0.0062	0.0052	UD	UD	UD	0.0040	0 0118	UD	0.0037
Lafayette (S-16)	0.0063	0.0079	0.0055	0.0068	0.0078	0.0065	0.0034	0.0033	0.0073	0.0031	0.0025	0.0083
Marshall (S-13)	0.0042	0.0024	UD	UD	0.0023	UD	0.0023	0.0022	0.0036	0.0021	UD	UD
Wagner (S-18)	0.0053	UD	UD	0.0105	0.0080	0.0130	0.0083	0.0033	0.0082	0.0032	0.0029	0 0050
Westminster (S-25)	0.0050	UD	0.0026	0.0085	UD	0.0137	0.0052	0.0063	UD	0.0060	0.0024	0.0038

Applicable Standard (unidentified alpha emitters) = 0.0067×10^{-12} μCi/ml

Table IV. Average Monthly Air Sample Concentrations, Off-Site, Radioactive. (continued).

(A) Low-Volume Programmed Samplers

2. Yearly Summary, Long-Lived Alpha Concentrations (U, Pu, and naturally occurring alpha emitters)

Concentrations ($\times 10^{-12}$ µCi/ml)

Location	No. of Samples	<Det.	January – June		July – December		CY-1971	
			C_{Max}	C_{Avg}	C_{Max}	$C_{Avg.}$	$C_{Avg.}$	% of Std
Boulder (S-15)	46	22	0.0128	0.0044	0 0174	0.0056	0 0049	73.1
Broomfield (S-17)	46	29	0.0134	0 0045	0 0128	0.0027	0.0036	54.3
Coal Creek (S-11)	46	37	0.0129	0.0034	0.0099	0.0013	0.0024	36 2
Denver (S-23)	46	27	0.0160	0 0035	0.0098	0.0039	0.0037	55.0
Golden (S-20)	46	32	0 0134	0 0044	0 0368	0.0033	0.0039	58.0
Lafayette (S-16)	46	22	0.0112	0 0068	0.0163	0 0048	0.0058	86.8
Marshall (S-13)	45	36	0 0082	0 0017	0 0070	0 0018	0.0018	26.3
Wagner (S-18)	46	27	0.0197	0.0061	0.0167	0 0053	0.0057	85.5
Westminster (S-25)	42	29	0 0270	0 0037	0.0298	0.0043	0.0039	58.2
Summary:	409	261	0.0270	0.0052	0.0368	0.0036	0.0044	65.7

(B) High-Volume Offsite Samplers

1. Plutonium Concentrations

Monthly Concentrations ($\times 10^{-12}$ µCi/ml)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S-26	–**	*0.00010*	*0.00019*	*0.00013*	*0.00023*	*0.00021*	*0.00005*	0.00025	0.00024	0.00011	0.00016	0.00001
S-27	–	0.00003	0.00023	0.00010	0.00024	0.00026	0.00011	0.00032	0.00006	0.00036	–***	0.00180
S-28	–	0.00012	0.00019	0.00012	0.00020	0.00027	0.00009	0.00030	0.00038	0.00012	–***	–**
S-29	–	0.00014	0.00015	0.00009	0.00022	0.00040	0.00025	0.00085	0.00022	0.00011	0.00014	0.00022
S-30	–	0.00008	0.00016	0.00011	0.00020	0.00030	0.00016	0.00026	0.00011	–***	–***	–***
S-31	–	0.00006	0.00013	0.00024	0.00032	0.00028	0.00019	0.00040	0.00024	0.00012	0.00015	0.00031
S-32	–	0.00014	0.00033	0.00017	0.00028	0.00131	0.00010	0.00039	0.00021	0.00193	–***	UD*
S-33	–	0.00019	0.00033	0.00022	0.00031	0.00031	0.00018	0.00028	0.00022	0.00014	0.00010	0.00014
S-34	–	0.00014	0.00026	0.00014	0.00029	0.00040	0.00008	0.00023	UD	–***	–***	–***
S-35	–	0.00012	0.00020	0.00015	0.00025	0.00030	0.00014	0.00023	0.00010	0.00019	UD	0.00050
S-36	–	0.00008	0.00034	0.00018	0.00023	0.00027	0.00010	0.00025	0.00016	0.00020	0.00014	0.00015
S-37	–	0.00012	0.00092	0.00032	0.00021	0.00030	0.00008	0.00030	0.00010	0.00464	UD	–***

Applicable Standard (Soluble ^{239}Pu) is 0.02×10^{-12} µCi/ml.

(B) High-Volume Off-site Samplers

2. Yearly Summary, Plutonium

Concentrations ($\times 10^{-12}$ µCi/ml)

Location	**February – June		July – December		Totals for Year			
	Max. Conc./ Single Sample	Average	Max. Conc./ Single Sample	Average	Average Conc.	% of Std.	Total No. Samples	No. Below Detection Limit
S-26	0.00038	0.00018	0.00041	0.00012	0.00014	0.7	40	10
S-27	0.00038	0.00016	0.00343	0.00035	0.00026	1.3	34	6
S-28	0.00044	0.00018	0.00073	0.00021	0.00020	1 0	32	2
S-29	0.00068	0.00020	0.00132	0.00028	0.00025	1.2	44	5
S-30	0.00050	0.00017	0.00043	0.00017	0.00017	0.9	30	3
S-31	0.00064	0.00021	0.00059	0.00023	0.00022	1 1	43	2
S-32	0.00428	0.00045	0.00193	0.00058	0.00051	2 6	32	2
S-33	0.00063	0.00027	0.00045	0.00018	0.00022	1 1	44	4
S-34	0.00092	0.00025	0.00028	0.00010	0.00019	1.0	28	3
S-35	0.00043	0.00020	0.00066	0.00017	0.00018	0.9	36	5
S-36	0.00070	0.00022	0.00087	0.00017	0.00018	0.9	42	5
S-37	0.00222	0.00036	0.00464	0.00068	0.00065	3.2	32	6
Yearly Summation, Total Averages:					0.00026	1.3%	437	53

*Undetectable (below detection limits).

**This network of samplers began operation in February 1971.

***Air Samplers inoperative due to pump failure.

Table V. Special High Volume Air Samples, On- and Off-Site, Radioactive.

(A) On-site Grab Samples*

Plutonium Concentrations (X 10^{-12} μCi/ml)

Location of Grab	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
903-20	0.00039	0.00109	0.00055	0.00158	0.00135	0.00234	0.00054	0.00313	0.00373	0.00161	0.00216	0.00508
903-15	0.00004	0.00192	0.00029	0.00307	UD**	0.00220	0.00324	0.00962	0.00852	0.00123	0.00019	UD
903-10	0.00039	0.00176	0.00109	0.00162	0.00018	0.00132	0.00090	0.00060	0.00120	UD	0.00111	0 00272
903-5	0.00011	0.00175	0.00030	0.00088	0.00042	0.01370	0.00067	0.00218	0.00051	NA***	0.00325	0.00196

Yearly Summation:

Location	Single Sample Maximum	Average Concentration	Percent of Standard****	Number of Samples	Number Less Than Detection Limits
903-20	0.001800	0.000200	3.3	48	12
903-15	0.002970	0.000261	4 4	46	18
903-10	0.001110	0.000104	1.7	44	13
903-5	0.004960	0 000187	3 1	42	12
Totals (averages)		0.00013	2.2%	180	55

*Taken just to east of asphalt pad covering contaminated soil on plant site.
**Undetectable (below detection limits).
***No analysis.
****Standard for these on-site samples is taken as 0.06 X 10^{-12} μCi/ml.

(B) Off-site Grab samples

Concentrations (X 10^{-12} μCi/ml).

Location of Grab	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wagner	0.00038	0.00220	0.00120	0.00306	0.00145	0.00340	0 00214	0.00375	0.00743	0 01827	0.00040	0.00185
Coal Creek	NA	0.00390	0.00153	0.00213	0.00078	0.01455	0.00141	0.00318	0.00510	0.00015	0.00091	0.00278

Yearly Summation:

Location	Single Sample Maximum	Average Concentration	Percent of Standard	Number of Samples	Number Less Than Detection Limits
Wagner	0.00570	0.000345	17.2	42	7
Coal Creek	0.06020	0.000344	17.2	35	8
Totals (averages)		0.000266	13.3	77	15

Table VI. Beryllium Concentration in Air Samples.

Concentration (X 10^{-5} mg/M^3)

	Location		% of Standard*	
	On-Site	Off-Site	On-Site	Off-Site
Jan	.009	.010	9	10
Feb	.012	**.187	12	**187
Mar	.012	.011	12	11
Apr	.010	.012	10	12
May	.020	.015	20	15
Jun	.010	.012	10	12
Summary	.012	.041	12%	41%
Jul	.007	.017	7	17
Aug	.010	.011	10	11
Sep	.023	.009	23	9
Oct	.014	.025	14	25
Nov	.010	.011	10	11
Dec	.010	.011	10	11
Summary	.012	.014	12%	14%

*Beryllium standard in ambient air is 1 X 10^{-5} mg/M^3 -- Rocky Flats self imposed standard is ½ that or 0.5 X 10^{-5} mg/M^3.
**This concentration represents cross contamination in the analytical laboratory.

Table VII. Dustfall Samples, 1971 Yearly Summary.

(Plutonium)

	No. Samples Taken	No. Samples Less Than Detection Limit	Sample Days	1971 Maximum (Single Sample) Concentration (pCi/M²)	Total Deposition (pCi/M²)	Deposition Rate (pCi/M²/month)
Arvada	23	4	362	16.11	77.44	5.30
Broomfield	22	11	348	28.88	74.48	3.21
Boulder	18	14	334	28.59	85.69	1.71
Coal Creek	19	11	292	21.66	50.76	2.20
Denver	22	11	341	53.87	118.27	5.20
Eastlake	23	11	362	6.00	49.84	2.15
Golden	*22 (21)	8	*348 (334)	*(174.16)	*219.55 (45.39)	*12.04 (2.65)
Lafayette	22	13	348	11.77	46.26	1.63
Marshall	23	10	362	67.70	149.04	6.98
Superior	21	8	334	16.11	74.20	4.13
Wagner	20	6	292	13.17	9.61	0.69
Westminster	22	7	341	17.30	41.36	2.48
Summary	*257 (256)	114	*4064 (4050)	*(174.16) (67.70)	*996.50 (822.34)	*4.09 (3.38)
Berthoud	7	2	310	5.58	12.98	0.90
Castle Rock	9	7	358	2.46	7.73	0.14
Summary	16	9	668	5.28	20.73	0.41

*Based on highly suspect data. The removal of one single-aliquot sample reduces the total deposition at Golden to 45.39 pCi/M² and the total (summary) deposition rate to 3.38 pCi/M²/month.

Table VIII. Water Surveys.

(A) Radioactivity in Holding Ponds and Effluent Waste Water

1 Pond B-4 (Effluent Waste Water)

Concentrations (X 10^{-9} μCi/ml)

Sample Period	No. Samples	* Effluent Volume (million liters)	U + Pu Concentrations Max.	U + Pu Concentrations Avg.	U + Pu Release (mCi)	Pu Concentrations Max.	Pu Concentrations Avg.	Pu Release (mCi)	Am Concentrations Avg.	Am Concentrations Max.	Am Release (mCi)
January	4	36.01	36.64	14.33	0.516	4.01	2.29	0 082	3.07	–	0.112
February	4	34.85	27.73	24.74	0.862	7.23	2.92	0.101	1 20	1.36	0 042
March	4	49.18	19.19	13.15	0.647	4.32	2.86	0.141	1.89	2.67	0.093
April	5	41.21	19.29	14.75	0.608	5.23	2 99	0.123	1.51	2.39	0.062
May	4	32.36	19.98	12.54	0.406	4.59	2.63	0.085	0.94	2.26	0.030
June	5	28.15	10.30	8.33	0.234	2.61	1.60	0.045	1.37	2 18	0.039
July	5	23.95	8.95	6.14	0.147	6.09	2.92	0.070	1.03	1.29	0 025
August	4	30.47	18.75	11.34	0.346	2.77	1.05	0.032	0.42	0.52	0.013
September	5	33.69	11.19	7.14	0.241	7.04	2.72	0.092	0.65	1 08	0.022
October	4	42.64	5.75	5.61	0.239	1.59	1.01	0.043	0 06	0 16	0.003
November	4	47.61	(15.08)	10.67	0.508	0.98	0.59	0.028	NA	NA	NA
December	5	53.79	(28.89)	11.48	0.618	1.56	1.09	0.059	NA	NA	NA

( ) denotes suspect data. NA – No Analysis

2. Yearly Summation Pond B-4 (Effluent Waste Water: Total Volume 1971 = 232,150,000 Liters)

Concentrations (X 10^{-9} μCi/ml)

Sample Period	U + Pu Number Samples Taken	U + Pu Concentrations Max.	U + Pu Concentrations Avg.	U + Pu Release (mCi)	Pu Number Samples Taken	Pu Concentrations Max.	Pu Concentrations Avg.	Pu Release (mCi)	Am Concentrations Max.	Am Concentrations Avg.	Am Release (mCi)
Jan-Jun	26	36.64	14.64	3.273	26	7.23	2.55	0.577	3.07	1.50	0.378
Jul-Dec	27	(28.89)	8.73	2.098	27	6.09	1.56	0.324	1 29	0.53	0.063
Summary	53	36.64	11.69	5.371	53	7.23	2.06	0.901	3.07	1.00	0.441

Table VIII. Water Surveys (continued).

(A) Radioactivity in Holding Ponds and Effluent Waste Waters

3. Grab Water Samples – Ponds A and C (Holding Ponds)

	Pond (A) X 10^{-9} µCi/ml				Pond (C) X 10^{-9} µCi/ml			
	No. Samples		Concentrations		No. Samples		Concentrations	
	Taken	<Det	U+Pu	Pu	Taken	<Det	U+Pu	Pu
Jan	4	0	7 00	0.51	4	0	6.98	0 26
Feb	4	0	8.88	0.42	4	0	10.98	0.72
Mar	4	0	7.09	0.31	4	0	5 66	0 25
Apr	5	0	6.62	1 12	5	0	6 44	1 13
May	4	0	6.23	0.85	4	0	6 73	0 31
Jun	5	0	4.63	1.21	5	0	4 52	0 94
Jul	4	0	3 93	0.97	4	0	4 19	0 47
Aug	4	0	7.27	0.66	4	0	8.63	0 50
Sep	5	0	6.13	0.58	5	0	6 90	0.52
Oct	4	0	6.85	0.32	4	0	4.32	0.48
Nov	4	0	9.04	0.40	4	0	3.80	0 79
Dec	5	0	13.75	0.79	5	0	4.47	0.41

1971 Summary

	U + Pu X 10^{-9} µCi/ml						Plutonium X 10^{-9} µCi/ml					
	No Samples		Concentrations			Percent of	No. Samples		Concentrations			Percent of
	Taken	<Det	Min.	Max.	Avg.	Standard[1]	Taken	<Det	Min	Max.	Avg	Standard[2]
Pond A	26	0	1.33	17.62	7.28	0 11	26	0	0.04	2 76	0 68	0 04
Pond C	26	0	1.06	23.64	6.14	0.09	26	0	0 06	2.40	0.57	0 03

[1] Gross alpha standard is $\frac{C_U}{MPC_U} + \frac{CPu}{MPC_{Pu}} \leq 1$ Where. $MPC_U = 10{,}000 \times 10^{-9}$ µCi/ml; $MPC_{Pu} = 1667 \times 10^{-9}$ µCi/ml

[2] The plutonium standard is 1667 X 10^{-9} µCi/ml.

(A) Radioactivity in Holding Ponds and Effluent Waste Waters

4 Walnut Creek at Indiana Water Samples (Rocky Flats Effluent Water Course)

Concentrations (X 10^{-9} µCi/ml)

	U + Pu				Pu				Am			
Sample	Number	Concentrations			Number	Concentrations			Number	Concentrations		
Period	Samples	Min	Max.	Avg.	Samples	Min	Max.	Avg.	Samples	Min	Max.	Avg.
January	3	2 85	19.71	11.93	3	1.10	2 68	1 69	1	0 73	0 73	0.73
February	4	13 69	30.06	19.30	4	0 86	8 47	4 36	3	0 68	1 40	1 25
March	5	4.76	11 53	8.74	5	1.36	3.33	2 52	5	0 18	4.39	1 91
April	4	6.32	13.68	11.18	4	1 14	3 10	2.09	4	0.01	2.68	0 93
May	4	7.15	12.43	9.91	4	0 67	6.59	2 68	2	0.40	0.47	0 44
June	4	6.40	11.43	9.12	4	1.28	2.37	2.04	2	0.30	1 25	0 57
July	4	3 87	29.54	11.67	4	1 54	3 61	2.56	2	0 41	0 80	0 60
August	5	3 73	36.58	13.16	5	1.03	3.14	1.65	5	0.30	0 68	0.49
September	4	2.18	22.10	9.07	4	0 08	7 99	2.41	4	0.01	0 29	0 14
October	4	3.12	49.34	16.87	4	0.41	2.84	1 96	3	0 21	0.77	0 49
November	5	3.97	6 87	5.85	5	0.67	3.80	1.64	0	–	–	–
December	3	5 77	12.81	8.96	3	0.83	1.33	1 03	0	–	–	–

Yearly Summary

	U + Pu				Pu				Am			
Sample	Number	Concentrations			Number	Concentrations			Number	Concentrations		
Period	Samples	Min	Max.	Avg.	Samples	Min.	Max.	Avg.	Samples	Min.	Max.	Avg.
Jan-Jun	24	2 85	30.06	12 23	24	0.67	8 47	2.56	19	0 01	4 39	1 11
Jul-Dec	25	2.18	49.34	10.90	25	0 41	7.99	0.96	14	0 01	0 80	0 42
Summary	49 (0)	2.18	49.34	11.55	49 (0)	0.41	8.47	2.56	33 (2)	0 01	4 39	0 80

( ) Denotes less than detection limits.

Table VIII. Water Surveys (continued).

(A) Radioactivity in Holding Ponds and Effluent Waste Waters (continued)

4. Walnut Creek at Indiana Water Samples (Rocky Flats Effluent Water Course) (continued)

Yearly Summation

Concentrations (X 10^{-9} μCi/ml)

U + Pu			Pu				Am			
Concentrations		% of	Concentrations			% of	Concentrations			% of
Max.	Avg.	Standard[1]	Min.	Max.	Avg.	Standard[2]	Min.	Max.	Avg.	Standard[3]
49.34	11.55	0.24	0.41	8.47	2.56	0.15	0.01	4.39	0 80	0.06

[1] $\frac{C_U}{MPC_U} + \frac{C_{Pu}}{MPC_{Pu}} \leq 1$ where $MPC_U = 10{,}000 \times 10^{-9}$ μCi/ml and $MPC_{Pu} = 1{,}667 \times 10^{-9}$ μCi/ml

[2] Based on the soluble ^{239}Pu in water standard of 1667×10^{-9} μCi/ml.

[3] Based on the soluble ^{241}Am in water standard of 1333×10^{-9} μCi/ml.

(B) Radioactivity in Reservoirs and Tap Water Samples

1. Reservoir Water Samples

Concentrations (X 10^{-9} μCi/ml)

January – June 1971

	U + Pu			Pu			Am		
Location	Number Samples Taken	Concentrations Max	Avg.	Number Samples Taken	Concentrations Max.	Avg.	Number Samples Taken	Concentrations Max.	Avg
Baseline Reservoir	12	6.06	3 25	11	1.68	0.33	–	–	–
Great Western Reservoir	12	6.29	3.12	10	0.64	0.14	4	1.13	0 60
Ralston Reservoir	12	28.79	20.50	10	0.04	UD*	–	–	–
Standley Reservoir	12	17.44	5.22	9	0.95	0 30	1	0.10	0.10

July – December 1971

	U + Pu			Pu				Am		
Location	Number Samples Taken	Max	Avg.	Number Samples Taken	<Det.	Max	Avg	Number Samples Taken	Max.	Avg
Baseline Reservoir	7	6.92	3.63	7	2	0.46	0 11	–	–	–
Great Western Reservoir	9	16.06	2.97	10	1	0.82	0.27	5	0 46	0.13
Ralston Reservoir	11	22.04	10 29	8	5	0 24	0.03	–	–	–
Standley Reservoir	10	5.16	3.22	10	4	0.24	0.05	3	0.12	0.16

Summation: 1971

Concentrations (X 10^{-9} μCi/ml)

	U + Pu					Pu					Am			
	No. Samples				% of	No. Samples				% of	Number			% of
Reservoir	Taken	<Det.	Max.	Avg.	Std.[1]	Taken	<Det.	Max.	Avg.	Std.[2]	Samples	Max.	Avg.	Std.[3]
Baseline	19	0	6.92	3.39	0.05	18	2	1.68	0.25	0 02	–	–	–	–
Great Western	21	0	16.06	3.05	0.04	20	3	0.82	0.24	0 01	9	1.13	0.32	0.02
Ralston	23	0	28.79	15.62	0.15	18	15	0.24	0.04	0.002	–	–	–	–
Standley	22	0	17.44	3.44	0.04	19	4	0.95	0.16	0.01	4	0.12	0.06	0.01
Summary	85	0	28.79	6.38	0.06	65	24	1.68	0.11	0.01	13	1.13		

Table VIII. Water Surveys (continued).

2. Community Tap Water Samples

January – June 1971

Concentrations (X 10^{-9} μCi/ml)

	U + Pu				Pu			
	Number Samples		Concentrations		Number Samples		Concentrations	
	Taken	<Det.	Max.	Avg.	Taken	<Det.	Max.	Avg.
Arvada	12	0	16.20	7.64	2	0	0.77	0.45
Boulder	12	0	6.93	2.34	10	2	0.97	0.23
Broomfield	12	0	18.58	2.54	6	0	(5.03)	0.98
Denver	12	0	17.19	5.73	11	2	2.79	0.36
Golden	12	0	8.79	3.40	11	4	0.45	0.09
Lafayette	12	0	3.23	1.40	6	1	0.77	0.22
Louisville	12	0	2.45	1.24	3	1	0.52	0.21
Thornton	12	0	17.48	9.29	3	0	0.30	0.18
Westminster	12	0	6.49	2.26	9	0	0.60	0.27

(B) Radioactivity in Reservoirs and Tap Water Samples (continued)

July – December 1971

	U + Pu				Pu			
	Number Samples		Concentrations		Number Samples		Concentrations	
	Taken	<Det.	Max.	Avg.	Taken	<Det.	Max.	Avg.
Arvada	11	0	7.02	4.04	7	3	0.49	0.37
Boulder	11	0	8.62	1.67	10	5	0.65	0.18
Broomfield	11	0	9.00	1.97	7	3	0.59	0.18
Denver	11	0	5.77	2.85	9	5	0.46	0.13
Golden	11	0	9.76	2.91	7	2	0.47	0.26
Lafayette	9	0	4.19	1.35	7	3	0.82	0.43
Louisville	10	0	4.82	1.64	6	1	0.39	0.15
Thornton	10	0	8.31	5.12	7	3	0.46	0.17
Westminster	10	0	4.95	1.74	6	1	0.53	0.27

1971 Summary

	U + Pu					Pu				
	No. Samples		Concentrations		% of	No. Samples		Concentrations		% of
	Taken	<Det.	Max.	Avg.	Standard[1]	Taken	<Det.	Max.	Avg.	Standard[2]
Arvada	23	0	16.20	5.92	0.07	9	3	0.77	0.13	0.01
Boulder	23	0	8.62	2.02	0.03	20	7	0.97	0.15	0.01
Broomfield	23	0	18.58	2.27	0.04	13	3	(5.03)	0.42	0.03
Denver	23	0	17.19	4.35	0.05	20	7	2.79	0.18	0.01
Golden	23	0	9.76	3.17	0.04	18	6	0.46	0.12	0.01
Lafayette	21	0	4.19	1.38	0.03	13	4	0.82	0.25	0.02
Louisville	22	0	4.82	1.42	0.02	9	2	0.52	0.16	0.01
Thornton	22	0	17.48	7.39	0.08	10	3	0.46	0.12	0.01
Westminster	22	0	6.49	2.02	0.03	15	1	0.60	0.25	0.02
Summary	202	0	18.58	3.33	0.04	127	36	(5.03)	0.19	0.01

( ) Denotes suspect data.

[1] The standard for a mixture of soluble U + Pu in water is $\frac{C_U}{MPC_U} + \frac{C_{Pu}}{MPC_{Pu}} = <1$ where $MPC_U = 10{,}000 \times 10^{-9}$ μCi/ml and $MPC_{Pu} = 1{,}667 \times 10^{-9}$ μCi/ml

[2] The standard for soluble ^{239}Pu in water is 1667×10^{-9} μCi/ml.

[3] Based on soluble ^{241}Am (in water) standard of 1333×10^{-9} μCi/ml.

Table VIII. Water Surveys (continued).

(C) Semiannual Water Collection (Summary, 1971)

Concentrations X 10^{-9} μCi/ml

Location	No. Samples	U + Pu Concentrations Min.	Max.	Avg.	% of Standard[1]	No. Samples	Pu Concentrations Min.	Max.	Avg.	% of Standard[2]
<5 Miles	14	0.55	16.34	3.32	0.06	13	0.05	2.76	0.41	0.02
>5 Miles	16	1.09	34.40	5.85	0.07	16	0.08	0.92	0.25	0.01
Summary	30	0.55	34.40	4.70	0.06	29	0.05	2.76	0.32	0.02

[1] The standard for a soluble mixture of U + Pu in water is $\frac{C_U}{MPC_U} + \frac{C_{Pu}}{MPC_{Pu}} \leq 1$ Where: MPC_U is 10,000 X 10^{-9} μCi/ml and MPC_{Pu} is 1,667 X 10^{-9} μCi/ml

[2] The standard for soluble ^{239}Pu in water is 1,677 X 10^{-9} μCi/ml.

(D) Chemical Concentrations in Holding Ponds and Effluent Waste Waters

1. Pond B-4

Sample Period	Number Samples	Range of pH	Average Concentration (mg/l) NO_3^-	PO_4^{-3}	F^-	BOD_5	DO***	Total Solids	Cr^{+6}
January	20	7.3-8.0	16.7	10.9	0.5	5.4	26.3	400	<0.005
February	20	7.4-7.6	6.2	9.2	0.4	9.9	10.8	(681)	<0.005
March	22	7.2-7.9	9.4	6.3	0.4	4.5	10.8	406	<0.005
April	19	7.2-7.8	8.4	4.3	0.4	6.4	11.0	392	<0.005
May	19	7.6-8.4	5.5	12.5	0.4	5.8	9.9	456	<0.005
June	22	7.7-8.5	3.8	13.3	0.5	7.3	10.3	368	<0.005
Summary	122	7.2-8.4	8.3	9.4	0.4	6.6	13.2	450	<0.005
July	21	7.2-8.2	3.4	8.9	0.4	NA	4 4	NA	<0.005
August	22	7.1-9.6	4.1	7.9	0 4	8.2	4.4	NA	<0.005
September	21	7.2-7.9	3.6	15.4	0.4	7.9	5.3	260	<0 005
October	21	7.1-8.1	7.2	20.7	0.4	6.7	6.2	309	<0.005
November	20	7.2-7.7	7.1	22.6	0.7	4.2	8.8	393	<0.005
December	21	7.2-7.8	4.9	17.2	0.4	6.0	9.2	332	<0.005
Summary	126	7.1-9.6	5.1	15.4	0.4	6.6	6.4	324	<0.005

***Dissolved oxygen.

1971 Summary

			Average Concentration (mg/l)						
Jan-Jun	122	7.2-8.4	8.3	9.4	0.4	6.6	13.2	450	<0.005
Jul-Dec	126	7.1-9.6	5.1	15.4	0.4	6.6	6.4	324	<0.005
Summary	248	7.1-9.6	6.7	12.4	0.4	6.6	9.8	392	<0.005
Applicable Std.	–	6.5-8.5	<45.0	–	<1.2	<30.0	>6	<500	<0.050
% of Std.	–	–	14.9	–	28.6	22.0	38.8	78.4	<10

2. Elemental Analyses (Pond B-4)

Concentrations mg/l

	Number Samples	As	Ba	Be	Cd	Cu	Pb	Mn
Yearly Summary	10	0.02	0.005	0.0004	0.005	0.03	0.002	0.006
Applicable Std.****	(2)	0.05	1.00	–	0.01	1.00**	0.05	0.05**
% Std.	–	40	0.05	–	50	3.0	4.0	12

*Run in compliance with State guidelines instead of Sodium Adsorption Ratio.

**These are not standards relating to the safety of the water but are suggested maximums relating to consumer acceptance thereof.

NOTE: Cyanide and selenium are not currently run by Rocky Flats Health Physics Department. Historically, we have depended on the guidance of the Colorado Department of Health, Water Pollution Control Commission for these analyses. Since basic facilities exist for these analyses, however, they will be performed in the future as a means of further protection and compliance with both the spirit and the letter of the law.

****The 1962 Drinking Water Standards of the U.S. Public Health Service call for semiannual analysis of these parameters.

Table VIII. Water Surveys (continued).

(E) Chemical Concentrations in Holding Ponds and Effluent Waste Waters

1. *Pond Grab Water Samples*

Monthly Averages (mg/l)

	Pond A						Pond C					
	pH	NO_3^-	PO_4^{-3}	F^-	Total Solids	Cr^{+6}	pH	NO_3^-	PO_4^{-3}	F^-	Total Solids	Cr^{+6}
January	7.8	11.1	0.6	0.4	173	<0.005	7.8	0.5	0.6	0.4	243	<0.005
February	7.6	13.7	1.1	0.4	101	<0.005	7.7	0.9	1.3	0.4	212	<0.005
March	7.5	19.6	0.6	0.4	164	<0.005	7.5	0.4	0.6	0.4	205	<0.005
April	7.8	29.7	0.7	0.4	183	<0.005	7.5	0.4	0.6	0.4	249	<0.005
May	7.9	85.0	0.6	0.4	393	<0.005	8.0	0.3	0.6	0.4	272	<0.005
June	8.0	20.1	0.6	0.4	233	<0.005	7.8	0.3	0.6	0.4	188	<0.005
Summary	7.8	29.9	07	0.4	208	<0.005	7.7	0.5	0.7	0.4	228	<0.005
July	7.8	23.0	0.6	0.3	*NA	<0.005	7.8	0.3	0.6	0.3	NA	<0.005
August	9.2	23.4	0.6	0.4	NA	<0.005	8.4	0.6	0.6	0.4	NA	<0.005
September	8.5	36.3	0.6	0.4	300	<0.005	8.5	1.2	0.6	0.3	175	<0 005
October	7.6	52.9	0.4	0.4	384	<0.005	8.2	1 3	0.6	0.4	227	<0.005
November	7.8	58.9	0.6	0.5	429	<0.005	8.1	1.5	0.6	0.8	185	<0.005
December	7.7	78.6	0.6	0.4	488	<0.005	7.7	0.9	0.6	0.4	194	<0.005
Summary	8.1	45.5	0.6	0.4	267	<0.005	8.1	1.0	0.6	0.4	195	<0.005

*NA is no analysis.

2. *Yearly Summary – Pond A*

Elemental Analyses	Number Samples	As	Ba	Be	Cd	Cu	Pb	Mn	NA*
(Yearly Summary)	10	0.01	0.01	0.0005	0.005	0.01	0.001	0.01	21.3
Applicable Std.	(2)	0.05	1.00	–	0.01	1.00**	0.05	0.05**	–
% of Standard	–	20%	1%	–	50%	1.0%	2%	20%	–

3. Yearly Summary – Pond C

(Yearly Summary)	10	0.01	0.01	0.0002	0.006	0.01	0.01	0.002	17.6
Applicable Std.	(2)	0.05	1.00	–	0.01	1.00**	0.05	0.05**	–
% of Standard	–	20%	1%	–	60%	1.0%	20%	4.0%	–

*Run in compliance with State quidelines instead of Sodium Adsorption Ratio.

**These are not standards relating to the safety of the water but are suggested maximums relating to consumer acceptance thereof.

NOTE: Cyanide and selenium are not currently run by Rocky Flats Health Physics Department. Historically, we have depended on the guidance of the Colorado Department of Health, Water Pollution Control Commission for these analyses. Since basic facilities exist for these analyses, however, they will be performed in the future as a means of further protection and compliance with both the spirit and the letter of the law.

Table IX. Sediment Samples, Yearly Summary.

Concentrations ($\times 10^{-6}$ μCi/gram)*

	Location	No. Samples	Maximum	Average
A	Pond A	4	26.06	17.53
	Pond B-1	3	641.67	246.32
	Pond B-2	3	385.53	199.00
	Bond B-3	3	174.85	67.99
	Pond B-4	3	181.34	65.68
	Pond C	3	8.47	3.36
		Averages	0.385 μCi/gram	0.030 μCi/gram
B	Baseline Reservoir	2	7.03	3.68
	Great Western Reservoir	2	1.87	1.08
	Ralston Reservoir	2	0.65	0.43
	Standley Reservoir	2	0.42	0.57
		Averages	0.007 μCi/gram	0.0007 μCi/gram

*Samples Dry, depth 4 centimeters.

A = Controlled Area; B = Outside Controlled Area.

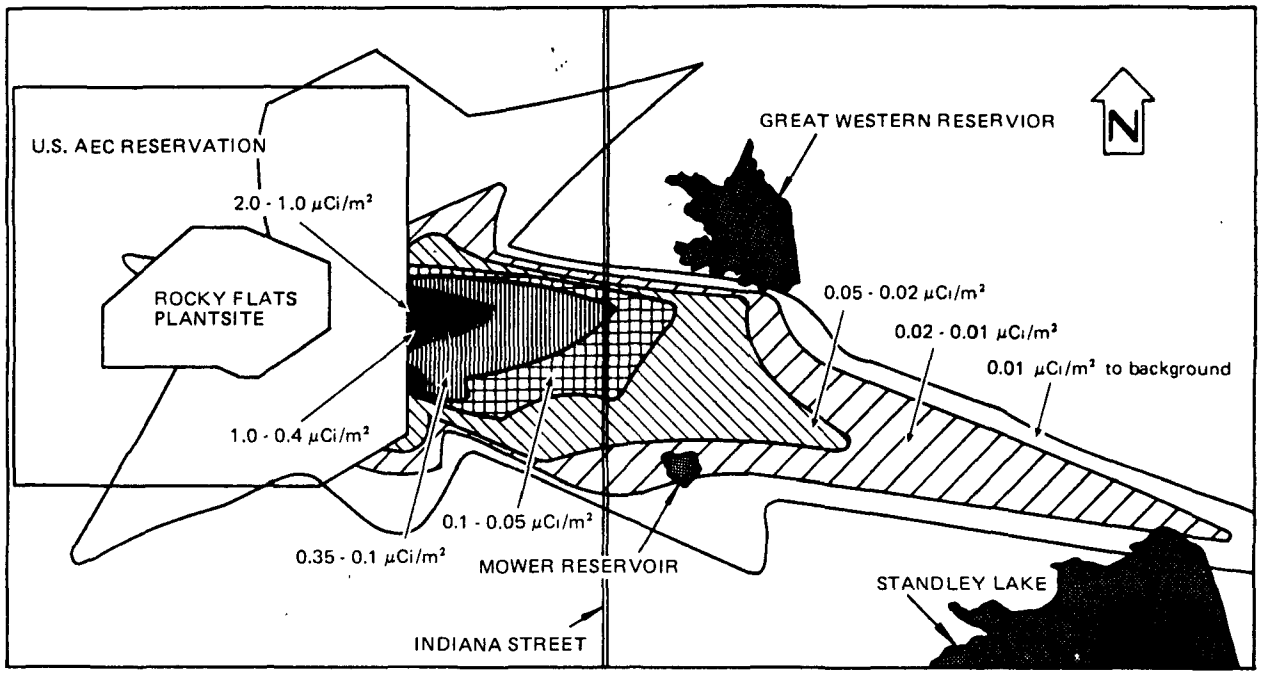


Table X. Surface Soil Analysis: off-site contours.

NOTE: These contours were empirically derived by means of a computer curve-fitting program using the method of least squares. This results in a mathematical expression for grid sectors, giving the activity of the plutonium in the soil as a function of radial distance from the on-site barrel-storage area. Three hundred forty-two soil samples were used in generating these contours. Eighteen samples were taken by the Colorado Committee on Environmental Information, 18 by U.S. AEC Health and Safety Laboratory, 306 by the Rocky Flats Health Physics Department. The values assume a soil density of 1 g/cm^3 at a depth of one centimeter.

Table XI. Vegetation Samples 1971.

Concentrations (X 10^{-3} μCi/gram-Dry)

	June 1971				*September 1971*			
	No. Samples		Concentrations		No Samples		Concentrations	
	Taken	<Det	Max.	Avg.	Taken	<Det	Max.	Avg.
<1 Mile	12	5	0.00130	0.00009	14	4	0.00016	0.00003
1-5 Miles	42	3	0.00254	0.00018	44	11	0.00039	0.00004
>5 Miles	23	5	0.00025	0.00004	24	10	0.00017	0.00004
Summary:	77	13	0.00254	0.00005	82	25	0.00039	0.00002

VI. Summary and Conclusions

Environmental Protection Must Be At Source.

The principal protection for our environment must be provided at the very source of potential degradation and/or potential pollution. No program can replace adequate controls at the source: any environmental program is after the fact.

Rocky Flats Working Toward Total Containment of Radioactive Material

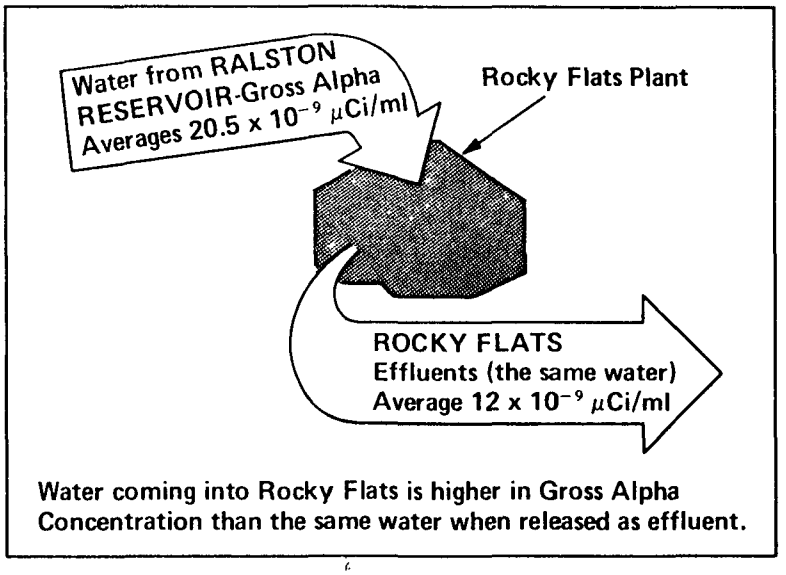
This is especially true for radioactive isotopes. Rocky Flats is working toward total containment of radioactive materials. The data contained in this report are the result of the controls employed at this plant site and do not in any way describe those complex controls in themselves. That these controls are effective can be seen by comparing releases with those established standards over the applicable time periods.

Frame of Reference for Data.

Data are not meaningful without a frame of reference. It is appropriate to provide some background information to better understand this report.

Water From Wells Near Boulder Has 10,000 Times Natural Radioactivity as Water From Potomac Near Washington D.C.

The State of Colorado and the immediate environs of Rocky Flats are most interesting from a radiological point of view. For example, water taken from wells in Maine has about 3000 times the natural radioactivity as that taken from the Potomac River near Washington, D.C. But even that level is low when compared with water taken from wells near Boulder (or, for that matter, Joachimsthal, Czechoslovokia) where natural radioactivity concentrations are 10,000 times that amount.[16] Rocky Flats receives its water from Ralston Reservoir near Golden. Background radiation surveys indicate that this water is higher in gross alpha content when it enters the plant than when it is released as effluent after being used to process radioactive materials.



Water coming into Rocky Flats is higher in Gross Alpha Concentration than the same water when released as effluent.

1971 EPA Survey Shows Colorado Has Highest Natural Radiation Level in U.S.

Residents of Colorado receive an annual cosmic ray dose of about 120 millirem, about three times that received by the average resident of California (40 mrem) and about twice the annual gamma ray dosage from naturally occurring terrestrial radioactivity.[4] In fact, a 1971 survey released by the EPA showed that Colorado has the highest natural radiation levels in the U.S.

Man-Made Radiation Contribution To Total Population Dose is Even Less Than Natural Fluctuations in Natural Background Level.

It is well known that the contribution of man-made radiation (other than medical) to the total population dose has been only a small fraction of the contribution from background radiation; in fact, it is even smaller than the natural fluctuations in that background.[6] Even this background level of about 130 mrem per person per year (about twice that high in Colorado) has not shown any adverse effects on man.

Radiation Levels at Least 10 Times Higher Than General Population Standards Has Not Been Harmful: Exposure to Ten Times General Population Standards Showed Lower Leukemia Rate, Malignant Death Rate, and Total Death Rate Than General Population.

Studies to date indicate that radiation at or below occupational levels (at least ten times higher than standards for the general populace) has not been shown to be harmful. Comparisons between about 35,000 workers who received approximately 50,000,000 mrem over 25 years and the general population show that the radiation workers had a 25% lower leukemia rate; a 42% lower malignant death rate; and a 46% lower death rate from all causes in each male and female age group. The conclusion to this study was, "All one can deduce from these various studies is that there is no indication of any health hazards to any employed."[17]

Present Data Indicate Rocky Flats Death Rate Due to Cancer Less Than One-Half That For General Population.

More specifically, the average annual death rate due to cancer in the U.S. is 130 deaths per 100,000 people.[18] The average annual death rate for the employees at Rocky Flats is 52 deaths due to cancer per 100,000 population, or less than half that of the general population.

It should be noted that this represents a small statistical sample and the only conclusion that can be drawn is that there is no *evidence* of any adverse effects to the Rocky Flats employees. A continuing effort exists to gather more data on all workers in this field. Rocky Flats is actively cooperating with the U.S. Transuranium Registry in this study.

Contamination vs Pollution.

There is one important distinction to be made at this point. The terms pollution and contamination are often, although incorrectly, used interchangeably. Pollution must be defined as concentrations of foreign material in excess of normal values. This concentration, in air, water, soil, etc., must have an adverse effect on man to be a true pollutant. A contaminant is that material, not normally found, but where present can be attributed to man's activities. Environmental contamination, while definitely not desirable, is still not necessarily pollution unless that contaminant can and does have an adverse effect on man or some other life form.

No Measurable Radioactive Contamination Released in 1969 Fire.

Following a fire at Rocky Flats in May 1969, intensified soil and monitoring surveys disclosed some soil contamination in the vicinity of the plant site, primarily to the east of the perimeter fence. Subsequent investigations indicated that no measurable radioactive contamination had escaped from the buildings involved in that fire, and that the primary source of contamination had come from waste drums of contaminated oil stored near the east fence. Since it is felt that some resuspension of this material is inevitable, even though the most affected area is now covered with a thick asphalt pad, steps have been taken to reduce this possibility to an absolute minimum.

Soil Contamination

The affected areas are under constant surveillance. The contours in Table X have been empirically derived using the best data available from all sources, i.e., the U.S. AEC Health and Safety Laboratory and the Colorado Committee for Environmental Information, as well as the surveillance activities of the Rocky Flats Health Physics Department.

Rocky Flats is committed to a soil sampling program. This program requires that samples be taken at a minimum of 6 months. At the present time, however, soil samples are being taken more frequently. Constant evaluation of the data thus generated shows no significant change in the contours.

Dustfall samples taken from the surrounding area may well represent some of this contaminated material that has been resuspended. Wind in the vicinity of Rocky Flats could deposit very small quantities of this material in the Boulder, Golden, Marshall, and Coal Creek areas. Dustfall sampling in these areas indicate that this may very well be the case. There are, however, other factors that might be creating anomalies as great as or even greater than any contribution from Rocky Flats. Wind currents, sweeping down through Boulder and Coal Creek Canyons, and along the Front Range, could be depositing greater than to be expected concentrations of materials associated with world wide fallout* in these areas. *It Must Be Emphasized that these Concentrations, Even Including Any Contributions from Rocky Flats, Are Still on the Same Order of Magnitude as that to Be Expected from World Wide Fallout,*[14] *and, as such, Provide no Known Health and/or Safety Hazard to the Public.* There is probably a very real contribution from Rocky Flats. This contribution is so low as to provide no significant exposure risk to the population in the area. Ways of reducing this contribution are, however, under intensive study.

Dustfall Samples, Even Including Rocky Flats Contribution (If Any) Still Same Order of Magnitude As World Wide Fallout – No Known Health and/or Safety Hazard to the Public.

The Water Quality Office of the Environmental Protection Agency conducted their own independent study of the environment and especially the water courses and effluents from and around Rocky Flats. The conclusion stated in that report[20] was as follows:

WQO of EPA Studied Rocky Flats and made Conclusion:

> "Monitoring data do not indicate any public health hazard associated with the routine discharge of radioactive wastes to Walnut Creek. There has been no measurable degradation of (Rocky Flats) plant origin in the radiological water quality of Great Western Reservoir, the source of public supply for the City of Broomfield. This reflects the general adequacy of the liquid waste management program carried on at the Rocky Flats Plant. In this respect, additional abatement requirements are not indicated at this time."

In that report, the EPA did, however, make some recommendations. Those recommendations and the response to them are included as Appendix A to this report.

Total plutonium releases during 1971 by both stack effluent discharge and effluent water release were a total of 0.975 millicuries (0.016 grams).

Total Plutonium Releases During 1971 were 0.975 mCi (0.016 grams)

Total uranium releases, which include relatively high concentrations of naturally occurring isotopes, were about 5 millicuries. Total beryllium released during the entire year was about 17 grams.

Total Uranium Releases (Including Naturally Occurring Isotope) About 5mCi. Total Beryllium About 17 grams.

*Fallout is actually the radioactive debris from nuclear weapons tests conducted in the atmosphere. It essentially consists of fission products, unexpended fissile material such as plutonium and uranium, and activation products. These radioactive products, vaporized and blown into the atmosphere by the tremendous force of the explosion, condense to form particulate matter that, when it finally falls to the earth, is called fallout. Fission products from nuclear explosions have been in the atmosphere for more than 25 years. The lifetimes of the various radioactive materials in fallout can range from fractions of a second to many years and thus make actual empirical measurement quite complex.[19]

Beryllium and Uranium Releases Have Exceeded Guidelines on Single-Sample, but not Applicable Average Basis.

Plutonium stack effluent releases from Rocky Flats have, on a single sample or single-month-maximum basis, exceeded both recommended guidelines, and especially internal plant goals for limiting effluent concentrations. The same is true, although less frequently, for beryllium and uranium releases. Although insignificant in terms of the yearly average concentrations, methods to limit and control these releases are being studied.

Studies Under Way on Filter Changes to Better Limit Extraordinary Releases.

The primary reason for these higher-than-ordinary releases has been the system employed in changing filters in the exhaust plenums of process buildings. The time interval and the physical implementation of better techniques for these filter changes is under intensive study.

Material Contained in This Report Released monthly to Colorado Department of Health and Regional EPA Office.

The material contained in this report has been released on a monthly basis to the Colorado Department of Health, and the regional office of the EPA. In addition, the state agency maintains its own survey and monitoring procedures.

Over 50,000 Environmental Samples Analyzed: Rocky Flats Effluents Below Standards.

Analyses of over 50,000 samples have shown the ambient levels of radioactivity in effluents from Rocky Flats to be below even the most restrictive standards available. Rocky Flats personnel are continually striving to reduce these levels even further by providing valuable technological and innovative advances in the field of nuclear materials control and safeguards. The Health Physics Department has recently been administratively joined with the research function to create a totally new group concept, that of Health Physics, Research and Ecology. We hope this will lead to even better communications of advances and pertinent information to the public at large as well as to the scientific community. The goal of this and every other group at Rocky Flats as well as the nuclear industry as a whole, must be to reduce radiation releases even lower than the current insignificant levels. As technology in the field has increased, emissions have gone down and this trend will continue.

Health Physics Joined with Research New Group; Health Physics, Research and Ecology.

Rocky Flats is Pioneer in Nuclear Materials.

As a pioneer in the field of nuclear materials, Rocky Flats will have a valuable part to play in this essential transition by providing experience and information. And, as more and more knowledge is gained in the field, Rocky Flats will be able to take advantage of a wider range of technology to better protect its own environs.

Increased Technology will Help Rocky Flats Reduce Emissions Even Further.

Rocky Flats Impact.

Rocky Flats has an essential part to play in the defense of this country and of our way of life. It has an equally important part to play as an integral part of the business and industrial community of Colorado, and as a good neighbor to the people in the area.

Rocky Flats Goal To Do Even Better.

In summation, then, while Rocky Flats has met and mostly surpassed its goals for maintaining radioactive effluent emissions below the most restrictive standards available, to do even better is the implicit goal of the entire operation.

VII. Bibliography

1. Daneth, F. A., Radioactive Standards and Units, *Nature,* 166; 931 (1950).

2. Oldenberg, O., *Introduction to Atomic Physics,* McGraw-Hill, 189, (1954).

3. Latt, R. E., and Andrews, H. L., *Nuclear Radiation Physics,* Prentice Hall, 303, (1963).

4. *Basic Radiation Protection Criteria,* NCRP Report No. 39, National Council on Radiation Protection and Measurements, (1971).

5. Taylor, Lauriston S., *Radiation Protection Standards,* CRC Critical Reviews in Environmental Control, April 1971.

6. Liberman, Joseph A., "Ionizing-radiation Standards for Population," *Physics Today,* November 1971.

7. AEC Manual of Standard Procedures, Chapters 0510, 0524, United States Atomic Energy Commission, Document No. NYO-4700 (1967).

8. Title 10 – Atomic Energy, Part-20 *Standards for Protection Against Radiation,* Code of Federal Regulations, Chapter I, (1960).

9. *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure,* National Bureau of Standards Handbook 69, U.S. Department of Commerce.

10. Cholak, J., Miller, L. H., Princi, F., *Quarterly Progress Report on Toxicity of Beryllium,* AMC-TR-7-665, (1960).

11. *Federal Register,* December 7, 1971.

12. *Water Quality Standards and Stream Classification,* Water Pollution Control Commission, Colorado Department of Health (1971).

13. *The Public Health Service Drinking Water Standards – 1962,* U.S. Department of Health, Education and Welfare, Public Health Service, (1969).

14. Hardy, E. P., and Krey, P. W., (Health and Safety Laboratory, U.S. Atomic Energy Commission), *Determining the Accumulated Deposit of Radionuclides by Soil Sampling and Analysis,* Environmental Plutonium Symposium, August 1971, Los Alamos Scientific Laboratory.

15. Langham, W. H., *Plutonium Distribution Factors as a Problem in Environmental Science,* LA-DC-12856, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, (1972).

16. Kastner, J., *The Natural Radiation Environment,* U.S.AEC, Division of Technical Information, (1968).

17. Hanford Environmental Health Foundation, *Environmental Effects of Producing Electrical Power,* Hearing before the Joint Committee on Atomic Energy, Congress of the United States, Part 1 (October and November, 1969).

18. Rates obtained by telephone conversation with Mr. Edwin Silverberg, Project Statistician, Research Department, American Cancer Society, Inc., New York, N.Y.

19. Peirson, D. H., Worldwide Deposition of Long-Lived Fission Products from Nuclear Explosions, *Nature,* 234 (November 12, 1971).

20. Water Quality Office, Environmental Protection Agency, Division of Technical Support, Radiological Activities Section, *Radioactivity Levels in the Environs of the Rocky Flats Plutonium Plant, Golden, Colorado 1970,* (April 1972)..

VIII. Appendix A

Recommendations of the Environmental Protection Agency, Water Quality Office Report on Rocky Flats, April 1, 1971, and response to those recommendations.

Recommendation 1:

Routine analysis of suspended vs dissolved radioactive materials in the water samples from effluent to Walnut Creek and Great Western Reservoir.

Response:

We are in the process of studying the nature of the plutonium found in our effluent and the nature of the plutonium found in the ponds. Our initial studies (in conjunction with CSU) indicate that much of the plutonium becomes incorporated with the algae. At this point we have not been able to determine if it is a physical incorporation or a biochemical mechanism. Algae vary in size over a wide range. It is difficult to ascertain how much is truly in solution *versus very small undissolved suspended particles of plutonium dioxide* incorporated into small suspended algae. By using different size filters, one would obtain different answers. The total amount of plutonium found is very small. As we learn more about the nature of the plutonium carried in the effluent water we will be in a much better position to understand any potential value which could be derived from separate routine analysis of suspended and dissolved plutonium differentiated from routine analysis of the total plutonium found in the water sample. We will continue to study this and keep the Water Quality Office of the EPA informed of our progress and findings.

Recommendation 2:

In addition to gross alpha activity determinations, specific analyses should be conducted for plutonium-239 and uranium.

Response:

Specific analyses for plutonium-239 and uranium are being completed. This change was effective January 1970.

Recommendation 3:

At least annually, preferably semi-annually, levels of plutonium in the various trophic levels of the aquatic populations inhabiting Great Western Reservoir and Standley Lake should be determined.

Response:

This recommendation requires an extensive full-scale research project. The first phase of this project has been initiated in conjunction with Colorado State University. Phase One relates to the settling ponds on the plant site. After the results of the first phase are interpreted, we will proceed with studies on the various trophic levels of the aquatic populations inhabiting Great Western Reservoir and Standley Lake. We intend to continue our program with Colorado State University and also conduct more "in-house" studies on the aquatic systems of interest. Perhaps, after the research programs are finished, we can develop some type of routine (annual or semi-annual) measurement on the various trophic levels in the aquatic system. We will keep the Water Quality Office of the EPA informed of our progress on these research programs.

Recommendation 4:

Semi-annual monitoring reports should be expanded to include data on effluent flow and radioactivity concentrations in the effluent to the south fork of Walnut Creek. Sufficient data should be presented to permit the calculation of at least the monthly amounts (curies) of plutonium and uranium (suspended and dissolved) discharged to the creek.

Response:

With the exception of separating suspended from dissolved activity (being studied), these types of data are being incorporated into monthly reports furnished the Colorado Department of Health. They are being included in semi-annual reports, copies of which are being forwarded to the EPA.

PREVIOUSLY PUBLICLY RELEASED

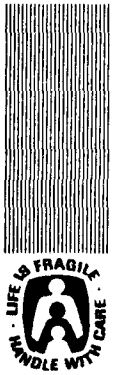
105
RFP-ENV-72

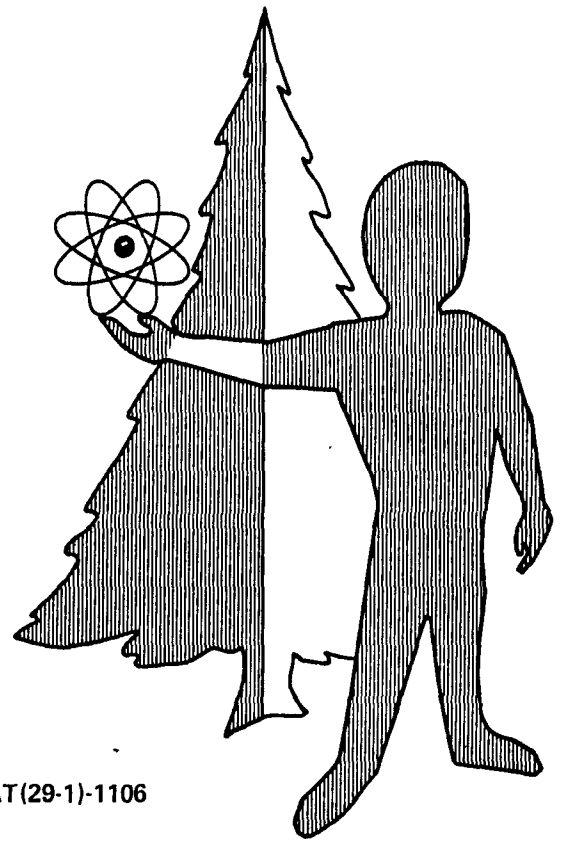
April 13, 1973

ANNUAL ENVIRONMENTAL MONITORING REPORT

Rocky Flats Plant

JANUARY – DECEMBER 1972





DOW CHEMICAL U.S.A.

Rocky Flats Division

U.S. ATOMIC ENERGY COMMISSION CONTRACT AT(29-1)-1106

Health Physics Research & Ecology

Printed
April 13, 1973

107
RFP-ENV-72

ANNUAL ENVIRONMENTAL MONITORING REPORT
ROCKY FLATS PLANT

January through December 1972

Including Estimates of Releases to the Environment
from Plant Operations

Merlyn R. Boss, Farrel D. Hobbs, Robert W. Loser,
and Donald E. Michels

DOW CHEMICAL U.S.A.
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401

Prepared under Contract AT(29-1)-1106
for the
Albuquerque Operations Office
U. S. Atomic Energy Commission

CONTENTS

Introduction 1
Summary 1
Monitoring Data Collection, Analysis, and Evaluation 2
Applicable Standards 2
Airborne Effluent Monitoring 2
Ambient Air Surveillance Monitoring Programs 2
High Volume Air Sample Network 3
Waterborne Effluent Monitoring 4
Regional Water Monitoring Program 4
Vegetation Sampling Program 5
Soil Sampling Program 5
References 5
Tables 1 through 16 7
Figures 1 through 6 27

ANNUAL ENVIRONMENTAL MONITORING REPORT
ROCKY FLATS PLANT

January through December 1972

Merlyn R. Boss, Farrel D. Hobbs, Robert W. Loser, and Donald E. Michels

INTRODUCTION

The Rocky Flats Plant is owned by the U.S. Government and operated by Dow Chemical U.S.A. under contract with the U.S. Atomic Energy Commission. The plant is located in Jefferson County, Colorado, about 16 miles northwest of Denver (Figure 1).

The site consists of about 2,520 acres of fenced property. At the approximate center of the site is the controlled area consisting of 384 acres, in which the production and manufacturing buildings are located.

The Rocky Flats Plant is primarily a radioactive metal fabrication and chemical processing plant, consisting of foundries, fabrication shops, chemical recovery and purification operations, together with associated support functions.

Annual precipitation recorded at the site during 1972 was 14.78 inches, with a record of 24.67 inches during 1969. The extreme temperatures recorded during 1972 were $-12°$ to 96°F, with an annual mean temperature of 69°F. The mean wind velocity was 7.7 miles per hour, with a peak gust of 105 miles per hour on January 11, 1972. The predominant wind direction during 1972 was from the northwest, and occurred during 21 percent of the hourly observations. Peak gust wind velocities in excess of 50 miles per hour occurred monthly, except during late summer and early fall.

The area is nearly devoid of trees. Assorted low-growing prairie grasses, prickly pear, yucca or spanish bayonet cactus, constitute the main ground cover.

Surface water runoff from the Rocky Flats Plant is from west to east. Runoff is carried from the property by two major drainage basins; the North and South forks of Walnut Creek on the north, and Woman Creek lying to the south. South Walnut Creek is considered to be the main effluent water course. The confluence of North and South Walnut Creeks lies just east of the government property (see Figure 2). East of the confluence is Great Western Reservoir. Woman Creek flows east from the government property and into Mower Reservoir, then into Standley Lake. North Walnut Creek, South Walnut Creek, and Woman Creek are considered to be effluent-release routes and have been designated A, B, and C, respectively.

The environmental monitoring program at the Rocky Flats Plant is the responsibility of the Environmental Control group of the Research and Ecology Division. The information and data contained in this report were released monthly to the Rocky Flats Area Office of the U S. Atomic Energy Commission, the Division of Occupational and Radiological Health of the Colorado Department of Health, and the Regional Office of the Environmental Protection Agency. The Colorado Department of Health also maintains air-, soil-, and water-sampling programs around the Rocky Flats site as a portion of their statewide surveillance.

SUMMARY

Results of the environmental monitoring program in the vicinity of the Rocky Flats Plant during 1972 indicate that yearly average environmental concentrations of plutonium in air and water was less than 2 percent of applicable Federal Standards. Total long-lived alpha emitter concentrations in air, including natural background, was less than 30% of the soluble plutonium-239 standard. No apparent changes were noted in the distribution of plutonium in soil from previous years. Changes in the distribution isopleths compared with 1971 are a result of additional sample results in the computer modeling program and do not reflect physical movement of plutonium in soils.

MONITORING DATA COLLECTION, ANALYSIS, AND EVALUATION

Applicable Standards

The numerical guides governing the release of radioactive effluent materials and the concentration standards for radioactivity in environmental samples are those found in AECMC-0524.[1] Although the standards for radioactivity relate to concentrations above background, all measurements reported herein include background radioactivity.

All radioactive isotopes in plant effluents and environmental samples are assumed to be soluble for purposes of comparison with the appropriate concentration standards. The assumption concerning solubility is an additional safeguard since the Maximum Permissible Concentration (MPC) guidelines for soluble radioisotopes are more restrictive than those for insoluble radioactive materials. Concentrations of total long-lived alpha activity in airborne effluents from the plutonium areas are maintained below 0.06×10^{-12} μCi/ml, the soluble plutonium-239 concentration standard set for an individual in an uncontrolled area. Airborne effluents from the uranium areas are maintained below 0.3×10^{-12} μCi/ml. The concentration of uranium plus plutonium in effluent water is maintained below 1667×10^{-9} μCi/ml, the soluble plutonium-239 concentration standard set for a suitable sample of an exposed population. The comparable standard for americium-241 is 1333×10^{-9} μCi/ml. The standards given in AECMC-0524 indicate that soluble plutonium-239 concentrations to a maximum of 5000×10^{-9} μCi/ml are permissible in water at the boundary of the controlled area.

The Environmental Protection Agency's proposed standard for beryllium as defined in Subpart C of 40CFR Part 61 requires that total emissions be less than 10 grams in a 24-hour period.[2]

Effluent waters containing chemical contaminants from plant operations are controlled so that they will meet the receiving water standards of the Colorado Department of Health[3] combined water-use classifications $AB_1 - CD_1$ for a potable drinking water supply, cold water fishery, water for industrial uses, and water for irrigation.

Airborne Effluent Monitoring

Primary control of airborne radioactive and non-radioactive effluents is exercised at the discharge stacks. All effluent exhaust systems are isokinetically sampled on a continuous basis. Each release point is provided with at least two effluent sampling stations in all plutonium facilities. Effluent air samples from the plutonium and uranium buildings are analyzed by direct counting for total alpha activity. Effluent beryllium concentrations from the appropriate buildings are determined using the atomic absorption method.[4] Minimum Detectable Concentration (MDC) for effluent samples from the plutonium areas is $<0.002 \times 10^{-12}$ μCi/ml. The effluent MDC from the uranium areas is $<0.001 \times 10^{-12}$ μCi/ml, while the MDC for a typical beryllium effluent sample is <0.0002 $\mu g/m^3$.

Table 1 shows the quanitites of total long-lived alpha emitters and beryllium released from the plutonium, uranium, and beryllium production areas. The total releases shown in Table 1 also include long-lived alpha activity due to natural background.

Ambient Air Surveillance Monitoring Programs

Ambient air monitoring of filterable airborne particulates containing long-lived alpha and beta emitters is conducted continuously at the plant. The sampling network within the controlled area presently consists of 12 air samplers, five of which are located at the perimeter fence (see Figure 3). The samples are collected daily on Whatman 41 filter media.

The sampling pumps (Gast, Model 0465–V4A–025) operate at an average sampling rate of 2 cfm. All samples are analyzed daily by direct radiometric counting and then allowed to decay for seven days prior to determining the long-lived alpha activity.

Although Rocky Flats Plant operations release only trace amounts of beta-emitting radionuclides, the samples which are collected on Friday of each week are also analyzed for long-lived beta emitters

following a seven-day decay. These data comprise part of the U.S. Atomic Energy Commission fallout monitoring network as well as providing radiological background information.

Air samplers operating at 2 cfm are operated for 10 minutes out of each hour in the surrounding communities of Boulder, Broomfield, Denver, Golden, Lafayette, Marshall, and Westminster (see Figure 4). Other 2-cfm samplers are operated continuously at the mouth of Coal Creek Canyon (S-11, three miles west-southwest of the site) and Wagner (S-18, 2.5 miles southeast of the site). The air samples are collected on Whatman 41 filter paper and are analyzed weekly. Then they are allowed to decay for seven days before determining the long-lived alpha and beta concentrations.

The MDC for long-lived alpha activity in community samples collected ten minutes of each hour is typically $<0.0045 \times 10^{-12}$ μCi/ml. The continuously operating community sample MDC is $<0.0008 \times 10^{-12}$ μCi/ml. Sample MDC's for long-lived alpha activity from the controlled area range between $<0.0055 \times 10^{-12}$ μCi/ml for a daily sample to $<0.0018 \times 10^{-12}$ μCi/ml for a sample collected over the weekend. Typical MDC's for a long-lived beta activity in samples taken within the controlled area of the Rocky Flats Plant are $<0.0629 \times 10^{-12}$ μCi/ml, whereas the community sample MDC's are about $<0.0513 \times 10^{-12}$ μCi/ml. The monthly average concentrations of long-lived alpha emitters from the various communities are shown in Table 2 together with the corresponding concentrations from the sampling network located within the controlled area of the Rocky Flats Plant. The yearly summary in Table 2 shows the average concentration, in all samples collected from the communities surrounding the Rocky Flats Plant, to be $<0.0048 \pm 13\% \times 10^{-12}$ μCi/ml.*

*Throughout the data presented, samples whose concentrations were below the MDC are assumed to be the MDC for averaging purposes. The minimum and maximum concentrations at each location are shown, together with the uncertainties in the analysis due to counting error at the 95 percent (2σ) confidence level. The error term associated with the average concentration at each location represents the deviation (at the 95 percent confidence level) of the mean of the sample concentrations observed.

i.e., $C_{avg} \pm 2\sigma = \bar{c} \pm t_{0.975}\sqrt{\frac{\Sigma Ci^2 - \bar{c}\,\Sigma Ci^2}{n(n-1)}}$

$\bar{c}$ is volume weighted whenever the volume is measured.
n is the number of samples.

Table 3 shows the average monthly long-lived beta concentrations for the surrounding communities and the Rocky Flats site. The average beta concentration in air samples from the surrounding communities (including natural background) is $<0.1078 \pm 21\% \times 10^{-12}$ μCi/ml.

High Volume Air Sample Network

In February 1971, a network of 12 continuously operating high volume air samplers were installed at approximately two to four miles radially from the Government property (locations S-26 through S-37, shown in Figure 4). The samples are collected daily on Whatman 41 filter paper at an average flow rate of 20-25 cfm. The daily filters are composited into weekly samples, whose total volumes vary between 3,000 – 6,000 m^3, depending upon the condition of the sampling pump. These sample filters are radiochemically analyzed specifically for plutonium following isolation on an ion-exchange column.[5] The chemical plutonium recovery for individually composited samples is determined (internally yielded) by adding a known quantity of plutonium-236 tracer and quantified by means of alpha pulse height analysis. One-half of the daily sample filters are retained in order to provide a check on anomalous air concentrations. Typical MDC's for plutonium range down to $<0.01 \times 10^{-15}$ μCi/ml for a 5,000 m^3 sample.

Weekly results for individual stations have been reported on a monthly basis to the U.S. Atomic Energy Commission, the United States Environmental Protection Agency, and the Colorado Department of Health. The stations comprise a statistically homogeneous group,* as indicated in Table 4. Furthermore, the data for individual stations also comprised homogeneous sub-groups in all cases but one.** Since all stations are statistically homogeneous, their data can be combined. For each week of sampling, the analyses

*Log-normal statistics are used in the numerical analysis of data from these stations.[6]

**Station S-34 yielded four samples that were anomalously large compared to the remaining samples. However, the truncated group of 46 samples yields the lowest geometric standard deviation (GSD) observed (Table 4), suggesting that the four high samples should be regarded as part of the background distribution.

were averaged. Values are shown in Figure 5 and listed in Table 5. The year-long geometric average plutonium concentration is 0.000044 μCi/ml X 10^{-12} multiplied or divided by 1.33.* For purposes of comparison with earlier results, the volume-weighted monthly arithmetic station averages for the high-volume air sampler network are shown in Table 5-A.

Waterborne Effluent Monitoring

Daily effluent water samples are collected from the outfalls of Ponds A, B-4, and C (Figure 2). The daily samples are analyzed for pH, nitrates, phosphates, fluorides, and hexavalent chromium. BOD_5 and dissolved oxygen are determined in Pond B-4 three days each week.[5]

These daily samples are composited into weekly samples for analysis of combined uranium and plutonium (gross alpha) and specifically for plutonium. The weekly samples from Pond B-4 also are analyzed specifically for americium. The combined alpha activity from uranium and plutonium are isolated from other long-lived alpha emitters using an ion-exchange technique.[5] All effluent water samples are internally yielded for plutonium using a plutonium-236 tracer. Samples analyzed for americium are internally yielded using a curium-244 tracer. The uranium, plutonium, and americium alpha activities are determined from pulse-height analysis of the samples. The minimum detectable sample concentration for uranium, plutonium, and americium in water is <0.01 X 10^{-9} μCi/ml.

The weekly composite samples are further composited into monthly samples in which the concentrations of 42 different elements are determined. These analyses are performed using emission and atomic absorption spectrometry. Monthly composite samples are combined quarterly and analyzed by standard methods[7] for the various nonradioactive constituents shown in Table 6.

*Uncertainty in mean value is commonly expressed as a plus or minus value. Denotation of uncertainty takes a different form when log-normal statistics are used. The term 0.000044 multiplied or divided by 1.33 means that the limits of uncertainty on the mean value 0.000044 are given by 0.000044 x 1.33 and 0.000044 ÷ 1.33. In this case, and in all other tables and graphs in this section, the factors for uncertainty pertain to 95 percent confidence levels.

Radioactive concentrations in the holding ponds from which samples were collected are shown in Tables 7, 8, 9, and 10. The annual average concentrations of plutonium-239 in Ponds A, B-4, and C were <1.68 X 10^{-9} μCi/ml, 14.86 X 10^{-9} μCi/ml, and <1.33 X 10^{-9} μCi/ml, respectively. The americium-241 concentration in Pond B-4 averaged <2.15 X 10^{-9} μCi/ml. The estimated total releases of the radionuclides processed at the Rocky Flats Plant and released in effluents from Pond B-4 are also shown in Tables 8 and 10. The yearly average concentration in samples collected from Pond B-4 have been volume weighted, since the flow rate is measured at the outfall from this pond. Flow rate measurements from Pond B-4 were supplied, since June, by the Denver Office of the U.S. Geological Survey when construction at this location forced the closure of the sampling and volume measurement station. Flow rates through Ponds A and C are not presently measured.

Daily water samples also are collected from Walnut Creek at Indiana Street, upstream from Great Western Reservoir, for weekly compositing. Radioactive analysis on these samples is identical to those of Pond B-4. The results of these samples are shown in Table 11. The annual average plutonium-239 and americium-241 concentrations at this location were 8.82 X 10^{-9} μCi/ml and <1.01 X 10^{-9} μCi/ml respectively.

Regional Water Monitoring Program

Semimonthly water samples are collected from four reservoirs and nine tap water locations around the Rocky Flats and greater Denver areas. The reservoirs include: (1) Baseline, whose primary use is a source of irrigation water, (2) Ralston Reservoir, the water supply for portions of Denver, Arvada, Wheatridge, and the Rocky Flats Plant, (3) Great Western Reservoir, which is the Broomfield water supply, and (4) Standley Lake, which serves Westminster and portions of the Thornton-Northglenn area (see Figure 4). Tap or treated water is collected from the surrounding communities of Arvada, Boulder, Broomfield, Denver, Golden, Lafayette, Louisville, Thornton, and Westminster. These data are summarized in Table 12 and include background radioactivity. The annual average plutonium-239 concentration in all reservoirs was

$<0.48 \times 10^{-9}$ μCi/ml and $<0.31 \times 10^{-9}$ μCi/ml in all treated water samples. Analysis for americium is routinely performed on water samples from Great Western and Standley Reservoirs. These data are presented in Table 13. The annual average americium-241 concentration in all reservoirs was $<0.29 \times 10^{-9}$ μCi/ml.

Twice each year – normally in June and September – water samples are collected from additional surrounding reservoirs, lakes, and streams. Samples are collected out to a distance of about 20 miles from the plant and are analyzed for gross alpha (combined uranium and plutonium) and specifically for plutonium. These data are presented in Table 14 and include background radioactivity. The annual average plutonium-239 concentration in all reservoirs was $<0.32 \times 10^{-9}$ μCi/ml. Samples from locations greater than five miles are felt to be uninfluenced by the plant, and are therefore used as indicators of environmental background levels in water. The MDC for both gross alpha and plutonium in these samples is $<0.01 \times 10^{-9}$ μCi/ml.

Vegetation Sampling Program

Vegetation samples are collected twice yearly from about 40 locations onsite and more than 50 locations outside of the government property. These collections are normally made in June and September each year and are taken over an area of approximately 315 square miles around the plant.

The samples are collected from alongside public rights-of-way and consist primarily of native grasses and volunteer feed grain crops. The root systems of these plants are not collected. The resultant samples are radiochemically analyzed, unwashed, for total plutonium content. All vegetation samples are internally yielded using plutonium-236 and the plutonium content is determined by alpha pulse-height analysis.[5] The MDC for plutonium-239 in these samples is $<0.01 \times 10^{-9}$ μCi/g (dry weight). A summary of these data is shown in Table 15. The annual average concentration of plutonium-239 in vegetation samples was $<0.33 \times 10^{-6}$ μCi/gram (dry).

Soil Sampling Program

Soil samples from uncontrolled property covering a 75 square mile area are collected twice yearly. Samples are routinely collected in June and September from 60 locations lying on the circumferences of three circles having radii of 1, 2, and 5 miles, centered at the plant site. Soil from the top five centimeters is normally collected for plutonium analysis.

The samples are oven dried at 120°C and weighed, homogenized, and sieved to remove the coarser rubble. Ten grams of pulverized soil are prepared for analysis using the method reported by Talvitie.[8] All samples are internally yielded using a plutonium-236 tracer, and the plutonium content is determined by alpha pulse-height analysis. The minimum detectable concentration for plutonium-239 in these samples is $<0.03 \times 10^{-6}$ μCi/g (dry weight).

The results of the soil sampling program are shown in Table 16. Isopleths of plutonium concentrations have been derived by computer analysis of over 300 individual sample results, and are presented in Figure 6. No apparent changes in analytical results were noted from previous years soil analysis.[9] Contour changes appearing in Figure 6 are a result of additional sample results in the computer modeling program and do not reflect movement of plutonium in soil.

REFERENCES

1. *Standards for Radiation Protection*, U.S. Atomic Energy Commission, AEC Manual, Chapter 0524, 1968.

2. *National Emission Standards for Hazardous Air Pollutants*, 40CFR Part 61, Subpart C (Proposed), U.S. Environmental Protection Agency, 1971.

3. *Water Quality Standards and Stream Classification*, Water Pollution Control Commission, Colorado Department of Public Health, 1971.

4. D. L. Bokowski, Rapid Determination of Beryllium by a Direct-Reading Atomic Absorption Spectrometer, *Am. Ind. Hyg. Assoc., 29*, p. 474-481 (1968).

5. *Standard Laboratory Procedures for the Determination of Radioactivity and Chemical Concentrations in Environmental and Bioassay Samples,* D. L. Bokowski, (ed), RFP-2039, to be published.

6. R. I. Larsen, A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards: USEPA, Air Programs Pub. AP-89, Supt. of Doc., Washington, 1971.

7. *Standard Methods for the Examination of Water and Wastewater,* 13th Edition, American Public Health Association, New York, 1971.

8 N A. Talvitie, *Anal Chem., Vol. 43,* No. 13, p 1827-1830 (1971)

9. L. M. Steward and M. R. Boss, *Annual Report: Environmental Safeguard '71,* RFP-ENV-71B, March 10, 1972.

TABLES

The values presented herein are composites of many thousands of individual analytical results. Where appropriate, concentration averages which are weighted by volume or weighted by the number of samples are so indicated.

Small discrepancies may result between calculations attempted by the reader and the published results because of these weighting or rounding techniques.

Table 1. Airborne Effluents Released to Atmosphere During 1972.

	Measured as Total Long-Lived Alpha Emitters			
Sample Period	Plutonium Areas (μCi)*	Enriched Uranium Areas (μCi)*	Depleted Uranium Areas (μCi)*	Beryllium Areas (grams)***
Jan	< 1.4	< .39	< 1.9	< .16
Feb	< 4.3	< .63	< 2.5	< .18
Mar	< 2.0	< .92	< 1.9	< .22
Apr	< 2.4	<1.4	< 8.2	<1.2
May	< 3.0	< .79	< 2.8	< .15
Jun	< 2.9	< .95	< 5.0	< .38
Total**	<16	<5.1	<22	<2.3
Jul	< 1.8	< .50	< 3.4	< .24
Aug	<16	< .46	< 2.4	< .37
Sept	< 3.3	< .55	< 4.2	< .41
Oct	< 4.4	< .42	< 5.2	< .25
Nov	< 4.1	< .89	<18	< .37
Dec	<12	< .75	< 9.3	< .32
Total**	<42	<3.6	<42	<2.0

*Reporting of combined average concentrations from a multiplicity of exhaust stacks in a single value is not a correct procedure. Only total release values are reported.

**Volume weighted total.

***The EPA Standard for Beryllium Release is <3650 grams/year.

Airborne Effluent Summary – 1972

		Concentration*		
Area	Effluent Type	C_{min}	C_{max}	Total Release
Plutonium	Total Long-Lived Alpha	<0.002	1.5	<58. μCi
Enriched Uranium	Total Long-Lived Alpha	<0.001	0.027	< 8.7 μCi
Depleted Uranium	Total Long-Lived Alpha	<0.001	0.53	<64. μCi
Beryllium	Beryllium	<0.0002	0.054	< 4.3 g

*The total long-lived alpha effluent concentrations are expressed in $\times 10^{-12}$ μCi/ml, the beryllium concentrations are $\mu g/m^3$.

Table 2. Total Long-Lived Alpha Concentrations $\pm 2\sigma$ ($\times 10^{-12}$ μCi/ml) In Air.

Volume Weighted Averages

Community	Jan	Feb	Mar	Apr	May	Jun
Boulder	<0 0066 ± 47%	<0.0106 ±109%	<0.0024 ±1230%	<0.0060 ±1013%	<0.0064 ±73%	<0 0038 ±50%
Broomfield	<0.0068 ±612%	<0.0160 ± 77%	<0.0098 ± 98%	<0.0064 ± 83%	<0.0045 ±13%	<0 0053 ±72%
Coal Creek	<0 0039 ± 56%	<0 0054 ± 64%	<0 0056 ± 18%	<0.0060 ± 63%	<0 0051 ±45%	<0.0049 ±35%
Denver	<0 0047 ± 51%	<0 0070 ± 79%	<0.0054 ± 43%	<0.0081 ± 72%	<0.0071 ±68%	<0.0053 ±77%
Golden	<0.0043 ± 37%	<0.0061 ±118%	<0.0051 ± 29%	<0.0051 ± 4%	<0 0049 ±22%	<0 0074 ±97%
Lafayette	<0.0036 ± 58%	<0 0063 ± 61%	<0.0066 ± 77%	<0.0086 ± 65%	<0 0060 ±47%	<0 0049 ±20%
Marshall	<0.0047 ± 81%	<0.0079 ±138%	<0.0062 ± 82%	<0.0054 ± 9%	<0.0077 ±65%	<0.0047 ±53%
Wagner	<0.0051 ±131%	<0 0036 ± 0%	<0.0043 ± 37%	<0 0045 ± 36%	<0.0039 ±21%	<0 0049 ±49%
Westminster	<0.0049 ± 55%	<0 0070 ± 53%	<0.0054 ± 39%	<0.0075 ± 195%	<0.0047 ±26%	<0 0051 ±43%
Community Average	<0.0048 ± 58%	<0.0070 ± 29%	<0 0050 ± 43%	<0.0064 ± 53%	<0.0056 ±13%	<0 0051 ±14%
Rocky Flats Plant Average	<0 0052 ± 15%	<0 0053 ± 9%	<0.0055 ± 26%	<0 0053 ± 11%	<0.0056 ± 9%	<0.0052 ±11%

January–June 1972 – Summary

Community	n	Vol (m^3)	Conc. ($\times 10^{-12}$ μCi/ml) C_{min}	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Boulder	24	2962 4	<0 0014	0.0693 ±35%	<0.0048 ±139%	<24.0
Broomfield	24	2039.1	<0 0030	0.0491 ±23%	<0.0064 ± 72%	<32.0
Coal Creek	25	2473 1	<0.0030	0.0102 ±27%	<0.0051 ± 15%	<25.5
Denver	25	2408.3	<0.0034	0.0142 ±21%	<0.0062 ± 21%	<31.0
Golden	25	2420 6	<0 0031	0.0139 ±21%	<0.0054 ± 20%	<27.0
Lafayette	25	2403 3	<0.0031	0 0155 ±20%	<0.0059 ± 22%	<29 5
Marshall	25	2427 3	<0.0030	0.0159 ±28%	<0 0058 ± 26%	<29.0
Wagner	22	2692 4	<0.0030	0.0072 ±37%	<0.0046 ± 9%	<23.0
Westminster	23	2242 0	<0 0030	0.0183 ±20%	<0 0057 ± 42%	<28 5
Community Summary	218	22068.0	<0.0014	0.0693 ±35%		
Average					<0.0055 ± 17%	<27.5
Rocky Flats Plant Summary	1481	174869.0	<0 0014	0.0638 ±10%		
Average					<0.0054 ± 6%	< 9 0

*The standard for Pu-239 in air is 0.02 $\times 10^{-12}$ μCi/ml for community samples and 0.06 $\times 10^{-12}$ μCi/ml for samples taken within the controlled area of the Rocky Flats plant.

**Volume weighted average.

Volume Weighted Averages

Community	Jul	Aug	Sept	Oct	Nov	Dec
Boulder	<0.0037 ±86%	<0 0054 ± 55%	0.0050 ± 88%	<0.0053 ± 58%	<0 0062 ± 65%	<0 0040 ± 18%
Broomfield	<0.0048 ±44%	<0.0069 ± 88%	0.0021 ± 95%	0.0038 ±606%	<0 0058 ±166%	<0.0055 ± 0%
Coal Creek	<0 0037 ±81%	<0.0044 ± 31%	<0.0068 ±113%	<0.0044 ± 23%	<0.0025 ±128%	<0.0012 ± 67%
Denver	<0 0045 ±69%	0.0073 ±143%	–	0.0097 ±144%	<0.0024 ±433%	<0.0069 ± 87%
Golden	<0.0039 ±72%	<0.0054 ± 8%	<0.0021 ±171%	<0 0068 ± 64%	<0 0049 ±106%	<0 0046 ± 47%
Lafayette	<0.0044 ±47%	<0 0050 ± 5%	<0.0050 ± 68%	<0 0089 ± 82%	<0 0033 ± 94%	<0 0084 ±208%
Marshall	<0.0070 ±53%	<0.0077 ± 61%	<0 0050 ±112%	<0.0053 ± 67%	<0.0055 ± 29%	<0 0056 ± 34%
Wagner	0.0044 ±89%	<0.0063 ±103%	<0.0029 ± 72%	<0.0042 ± 31%	<0 0038 ± 26%	<0.0034 ± 65%
Westminster	<0.0048 ±27%	<0.0059 ± 51%	<0.0049 ±135%	–	<0 0056 ±162%	0.0055 ±823%
Community Average	<0.0045 ±15%	<0.0059 ± 15%	<0.0036 ± 33%	<0.0055 ± 38%	<0.0040 ± 35%	<0.0033 ± 45%
Rocky Flats Average	<0.0059 ± 8%	<0.0054 ± 15%	<0.0080 ± 56%	0 0078 ± 19%	<0 0052 ± 21%	<0.0056 ±127%

Table 2. Total Long-Lived Alpha Concentrations ±2σ (X 10^{-12} μCi/ml) in Air (continued).

July–December 1972 – Summary

Community	n	Vol (m^3)	Conc. (X 10^{-12} μCi/ml) C_{min}	C_{max} ±2σ	C^{**}_{avg} ±2σ	% of Standard*
Boulder	26	3451.7	<0.0023	0.0086 ±26%	<0.0049 ±17%	<25.0
Broomfield	22	5190.4	<0.0010	0.0226 ±23%	<0.0034 ±39%	<17.0
Coal Creek	26	5642.9	<0.0008	0.0125 ±22%	<0.0026 ±55%	<13.0
Denver	14	2040.5	<0.0013	0.0121 ±27%	<0.0047 ±55%	<23.5
Golden	25	3040.2	<0.0011	0.0114 ±27%	<0.0041 ±31%	<20.5
Lafayette	24	2689.9	<0.0019	0.0163 ±20%	<0.0055 ±27%	<28.0
Marshall	26	2559.2	<0.0026	0.0116 ±24%	<0.0060 ±15%	<30.0
Wagner	25	3394.2	<0.0019	0.0113 ±24%	<0.0040 ±24%	<20.0
Westminster	16	1672.0	<0.0018	0.0131 ±20%	<0.0054 ±32%	<27.0
Community Summary	204	29681.0	<0.0008	0.0226 ±23%		
Average					<0.0042 ±14%	<21.0
Rocky Flats Plant Summary	1501	180604.0	<0.0014	0.1699 ± 6%		
Average					<0.0063 ±22%	<10.5

*The standard for Pu-239 in air is 0.02 X 10^{-12} μCi/ml for community samples and 0.06 X 10^{-12} μCi/ml for samples taken within the controlled area of the Rocky Flats plant.

**Volume weighted average.

1972 Summary – Total Long-Lived Alpha Activity in Air

Community	n	Vol (m^3)	Conc. (X 10^{-12} μCi/ml) C_{min}	C_{max} ±2σ	C^{**}_{avg} ±2σ	% of Standard*
Boulder	50	6414.1	<0.0014	0.0693 ±35%	<0.0049 ±65%	<24.5
Broomfield	46	7146.5	<0.0010	0.0491 ±23%	<0.0042 ±71%	<21.0
Coal Creek	51	8116.0	<0.0008	0.0125 ±22%	<0.0034 ±26%	<17.0
Denver	39	4448.8	<0.0013	0.0142 ±21%	<0.0056 ±21%	<28.0
Golden	50	5460.8	<0.0011	0.0139 ±21%	<0.0047 ±17%	<23.5
Lafayette	49	5093.2	<0.0019	0.0163 ±20%	<0.0057 ±18%	<28.5
Marshall	51	4986.5	<0.0026	0.0159 ±28%	<0.0059 ±14%	<29.5
Wagner	47	6086.6	<0.0019	0.0113 ±24%	<0.0042 ±14%	<21.0
Westminster	39	3914.0	<0.0018	0.0183 ±20%	<0.0056 ±29%	<28.0
Community Summary	422	51749.5	<0.0008	0.0693 ±35%		
Average					<0.0048 ±13%	<24.0
Rocky Flats Plant Summary	2982	355473.0	<0.0014	0.1699 ± 6%		
Average					<0.0059 ±12%	< 9.8

*The standard for Pu-239 in air is 0.02 X 10^{-12} μCi/ml for community samples and 0.06 X 10^{-12} μCi/ml for samples taken within the controlled area of the Rocky Flats plant.

**Volume weighted average.

Table 3. Total Long-Lived Beta Activity in Air ($\times 10^{-12}$ μCi/ml).

Volume Weighted Averages

Community	Jan	Feb	Mar	Apr	May	Jun
Boulder	<0.4384 ±266%	<0.1381 ±195%	<0.0468 ±698%	<0.1054 ±586%	<0.2211 ±113%	<0.2412 ± 55%
Broomfield	<0.2000 ±335%	<0.2384 ± 68%	<0.1073 ± 96%	<0.1016 ± 91%	<0.1401 ±128%	<0.1204 ± 41%
Coal Creek	0.3076 ±363%	<0.0611 ± 66%	<0.1033 ± 89%	<0.1075 ± 88%	<0.0705 ± 57%	<0.1538 ± 99%
Denver	<0.2462 ±263%	<0.0889 ± 88%	<0.1154 ± 83%	<0.2581 ± 62%	<0.2259 ±179%	<0.1124 ± 78%
Golden	<0.1713 ±271%	<0.1010 ± 25%	<0.0632 ± 34%	<0.3055 ±110%	<0.2464 ± 46%	<0.1688 ± 30%
Lafayette	0.4155 ±274%	<0.0847 ±151%	<0.0894 ± 80%	<0.1247 ±153%	<0.1739 ±226%	<0.1158 ±117%
Marshall	<0.1834 ±256%	<0.1200 ±155%	<0.0657 ±116%	<0.1081 ± 57%	<0.2151 ±129%	<0.0960 ± 19%
Wagner	<0.0461 ±184%	<0.0439 ± 75%	<0.0406 ± 6%	<0.1776 ±430%	<0.0563 ±209%	<0.1373 ± 60%
Westminster	0.3445 ±373%	<0.0834 ± 75%	<0.1253 ±167%	<0.1280 ±345%	<0.3798 ±346%	<0.1406 ± 73%
Community Average	<0.2613 ± 60%	<0.0938 ± 37%	<0.0766 ± 38%	<0.1581 ± 48%	<0.1841 ± 67%	<0.1462 ± 61%
Rocky Flats Average	<1.0964 ± 42%	<0.0944 ± 18%	<0.0739 ± 16%	<0.4512 ± 36%	<0.2637 ± 23%	<0.2204 ± 18%

January–June 1972 – Summary

Community	n	Vol (m^3)	Conc. ($\times 10^{-12}$ μCi/ml) C_{min}	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Boulder	24	2962.4	<0.0207	1.5317 ±4%	<0.1663 ±109%	<0.50
Broomfield	24	2039.1	<0.0337	0.6623 ±3%	<0.1369 ± 75%	<0.43
Coal Creek	25	2473.1	<0.0472	1.2028 ±4%	<0.1442 ± 72%	<0.44
Denver	25	2408.3	<0.0351	0.8613 ±5%	<0.1803 ± 55%	<0.55
Golden	25	2420 6	<0.0534	0.6630 ±5%	<0.1819 ± 61%	<0.55
Lafayette	25	2403.3	<0.0525	1.4903 ±4%	<0.1797 ± 70%	<0.58
Marshall	25	2427.3	<0.0384	0.6261 ±6%	<0.1336 ± 63%	<0.41
Wagner	22	2692.4	<0.0370	0.6701 ±4%	<0.0937 ± 83%	<0.28
Westminster	23	2242.0	<0.0535	0.9906 ±4%	<0.1948 ± 74%	<0.58
Community Summary	218	22068.5	<0.0207	1.5317 ±4%		
Average					<0.1562 ± 24%	<0.48
Rocky Flats Plant Summary	272	21842.0	<0.0629	7.1393 ±1%		
Average					<0.3411 ± 32%	<0.34

*The standard for total long-lived beta activity in air is 33 X 10^{-12} μCi/ml for community samples and 100 X 10^{-12} μCi/ml for samples taken within the controlled area of the Rocky Flats plant.

**Volume weighted average.

Volume Weighted Averages

Community	Jul	Aug	Sept.	Oct	Nov	Dec
Boulder	<0.1451 ± 52%	<0.1354 ± 59%	<0.0888 ±102%	<0.0550 ± 87%	<0 0614 ± 72%	<0.0610 ± 54%
Broomfield	<0.1187 ±108%	<0.1855 ± 96%	<0.0266 ± 41%	<0 0395 ±350%	<0.0930 ±215%	<0.0627 ± --
Coal Creek	<0.1064 ± 20%	<0.0708 ± 96%	<0.1016 ± 18%	<0.0646 ± 66%	<0.0308 ±110%	<0.0214 ± 66%
Denver	<0.1239 ± 34%	<0.1209 ± 32%	–	<0.0934 ±506%	<0.0191 ±368%	<0 1238 ±548%
Golden	<0.0567 ± 47%	<0.1393 ±198%	<0.0600 ±365%	<0.0994 ± 53%	<0.0965 ±135%	<0.0896 ± 73%
Lafayette	<0.0519 ± 83%	<0.1131 ±145%	<0.0867 ± 30%	<0.1282 ± 73%	<0.0624 ±182%	0.0931 ±227%
Marshall	<0 0673 ± 28%	<0.0983 ± 35%	<0.1193 ± 8%	<0.1112 ± 67%	<0.1142 ±112%	<0.1065 ± 72%
Wagner	<0.0849 ±148%	<0.0742 ± 90%	<0.1125 ±100%	<0.0674 ±145%	<0.0565 ±102%	<0.0430 ± 18%
Westminster	<0.1246 ±484%	<0.1156 ± 69%	<0.0844 ±129%	–	<0.1003 ±225%	<0 0368 ±2019%
Community Average	<0.0974 ± 65%	<0.1163 ± 22%	<0.0637 ± 96%	<0.0727 ± 81%	<0.0600 ±120%	<0.0486 ±111%
Rocky Flats Plant Average	<0.1156 ± 21%	<0.0900 ± 13%	<0.1275 ± 13%	<0.0906 ± 16%	<0.0725 ± 7%	<0.1633 ± 40%

Table 3. Total Long-Lived Beta Activity in Air (X 10^{-12} μCi/ml) (continued).

July–December 1972 – Summary

Community	n	Vol (m^3)	Conc. (X 10^{-12} μCi/ml) C_{min}	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Boulder	26	3451.7	<0.0356	0.1815 ± 9%	<0.0912 ± 74%	<0.25
Broomfield	22	5190.4	<0.0203	0.3365 ±11%	<0.0569 ±172%	<0.17
Coal Creek	26	5642.9	<0.0090	0.1312 ±11%	<0.0437 ±112%	<0.14
Denver	14	2040.5	<0.0090	0.1763 ±12%	<0.0658 ±109%	<0.23
Golden	25	3040.2	<0.0130	0.2650 ± 8%	<0.0830 ± 92%	<0.25
Lafayette	24	2689.9	<0.0213	0.2746 ± 8%	<0.0846 ± 78%	<0.26
Marshall	26	2559.2	<0.0532	0.2827 ± 9%	<0.1022 ± 76%	<0.31
Wagner	25	3394.2	<0.0319	0.1943 ± 8%	<0.0731 ± 79%	<0.21
Westminster	16	1672.0	<0.0207	0.3722 ±11%	<0.0917 ±133%	<0.28
Community Summary	204	29681.0	<0.0090	0.3722 ±11%		
Community Average					<0.0719 ± 32%	<0.22
Rocky Flats Plant Summary	300	24450.0	<0.0629	2.0485 ± 3%		
Rocky Flats Plant Average					<0.1118 ± 12%	<0.11

*The standard is 33 X 10^{-12} μCi/ml for total long-lived beta activity in air for community samples and 100 X 10^{-12} μCi/ml for samples taken within the controlled area of the Rocky Flats plant.

**Volume weighted average.

1972 Summary – Total Long-Lived Beta Activity in Air

Community	n	Vol (m^3)	Conc. (X 10^{-12} μCi/ml) C_{min}	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Boulder	50	6414.1	<0.0207	1.5317 ±4%	<0.1259 ±75%	<0.37
Broomfield	46	7146.5	<0.0203	0.6623 ±3%	<0 0794 ±90%	<0.24
Coal Creek	51	8116.0	<0.0090	1.2028 ±4%	<0.0739 ±75%	<0.24
Denver	39	4448.8	<0.0090	0.8613 ±5%	<0.1278 ±51%	<0.42
Golden	50	5460.8	<0.0130	0.6630 ±5%	<0.1268 ±52%	<0.39
Lafayette	49	5093.2	<0.0213	1.4903 ±4%	<0 1295 ±54%	<0.42
Marshall	51	4986.5	<0.0384	0.6261 ±6%	<0.1174 ±48%	<0.36
Wagner	47	6086.6	<0.0319	0 6701 ±4%	<0.0885 ±57%	<0.24
Westminster	39	3873.5	<0.0207	0.9906 ±4%	<0.1503 ±64%	<0.45
Community Summary	422	51749.5	<0.0090	1.5317 ±4%		
Community Average					<0.1078 ±21%	<0.33
Rocky Flats Plant Summary	572	46292.0	<0.0626	7.1393 ±1%		
Rocky Flats Plant Average					<0.2200 ±27%	<0.22

*The standard for total long-lived beta activity in air is 33 X 10^{-12} μCi/ml for community samples and 100 X 10^{-12} μCi/ml for samples taken within the controlled area of the Rocky Flats plant.

**Volume weighted average.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 4. Plutonium Concentrations in Offsite Air Samples, 1972 Averages.

Sampler	$\bar{x}_g$**	σ_g	No. of Samples	Max.	Min.
S-26	.066 X ÷ 1.3	2.9	51	.84	<Det
S-27	.052 X ÷ 1.4	3.6	49	.82	
S-28	.040 X ÷ 1.5	3.7	46	1.50	
S-29	.043 X ÷ 1.6	6.2	52	3.37	
S-30	.033 X ÷ 1.4	3.6	47	.59	
S-31	.049 X ÷ 1.6	5.8	48	3.37	
S-32	.064 X ÷ 1.6	5.4	50	1.43	
S-33	.065 X ÷ 1.4	3.6	50	1.08	
S-34	.060 X ÷ 1.2	1.8	46*	5.74	
S-35	.049 X ÷ 1.5	4.4	50	1.01	
S-36	.031 X ÷ 1.5	3.6	38	.47	
S-37	.039 X ÷ 1.4	3.7	47	.65	

Units on $\bar{x}_g$ and max are X 10^{-15} μCi/ml, uncertainties are at 95 percent confidence level.

σ_g is a factor describing the variability of concentrations observed at one station. For S-26 there is a one sigma probability (17 percent chance) that a random value will be larger than (.066)X(2.9) or smaller than $(.066)\left(\frac{1}{2.9}\right)$.

Differences in σ_g are not significant at .95 although S-34 is significant at .90.

*Station S-34 yielded four samples that were anomalously large compared to the remaining samples. However, the truncated group of 46 samples yields the lowest geometric standard deviation observed, suggesting that the four high samples should be regarded as part of the background distribution. The five highest of 50 values were 5.74, 2.75, 2.20, 1.72, and .44.

**Uncertainty in mean value is commonly expressed as a plus or minus value. Denotation of uncertainty takes a different form when log-normal statistics are used. The term 0.000044 multiplied or divided by 1.33 means that the limits of uncertainty on the mean value 0.000044 are given by 0.000044 X 1.33 and 0.000044 ÷ 1.33. In this case, and in all other tables and graphs in this section, the factors for uncertainty pertain to 95 percent confidence levels.

Table 5. Weekly Average Plutonium Concentrations* Offsite (X 10^{-15} μCi/ml).

Date	$\bar{x}_g$	Date	$\bar{x}_g$	Date	$\bar{x}_g$	Date	$\bar{x}_g$
1-3		4-7		7-14		10-20	
	.34		.023		.035		.023
1-7		4-14		7-21		10-27	
	.27		.017		.060		.035
1-14		4-21		7-28		11-13	
	.32		.13		.093		.031
1-21		4-28		8-4		11-10	
	.083		.034		.027		.041
1-28		5-5		8-11		11-17	
	.29		.042		.026		.017
2-4		5-12		8-18		11-22	
	.086		.14		.010		.038
2-11		5-19		8-25		12-1	
	.12		.028		.062		.028
2-18		5-26		9-1		12-8	
	.23		.022		.033		.042
2-25		6-2		9-8		12-15	
	.067		.043		.064		.024
3-3		6-9		9-15		12-20	
	.12		.042		.038		.027
3-10		6-16		9-22		12-29	
	.13		.067		.17		
3-17		6-23		9-29			
	.19		.058		.042		
3-25		6-30		10-6			
	.042		.040		.022		
3-30		7-7		10-13			
	.086		.029		.023		
4-7		7-14		10-20			

Year Avg. .044 X 10^{-15} μCi/ml. The standard for 239-Pu in air is 20 X 10^{-15} μCi/ml.

Year-long geometric average was obtained after truncating the distribution below .04 X 10^{-15} μCi/ml.

*Geometric average concentrations for 12 stations. All stations yield week-long composite samples. Values less than .04 are biased high because they are dominated by analyses that were below the detection limit.

Table 5-A. Offsite Plutonium Concentration in Air ±2σ (X 10^{-15} μCi/ml).

Volume Weighted Averages

Location	Jan	Feb	Mar	Apr	May	Jun
S-26	0.34 ± 141%	0.36 ± 94%	<0.22 ±105%	<0.06 ±133%	<0.04 ±200%	0.06 ±100%
S-27	<0.09 ±1270%	<0.19 ±105%	<0.11 ±100%	<0.11 ±218%	<0.09 ± 89%	<0.05 ±100%
S-28	–	<0.13 ±123%	<0.21 ± 95%	<0.05 ± 80%	<0.06 ±117%	<0.42 ±240%
S-29	0.39 ± 113%	<0.97 ±267%	<0.19 ±179%	<0.14 ±136%	<0.06 ±133%	<0.03 ± 33%
S-30	–	<0.07 ±200%	<0.21 ±143%	<0.10 ±100%	<0.07 ±143%	<0.03 ± 33%
S-31	<0.18 ± 106%	0.73 ±130%	<0.23 ±126%	<0.04 ±100%	<0.12 ±158%	0.34 ±259%
S-32	0.31 ± 129%	<0.47 ±202%	<0.20 ±135%	<0.08 ±100%	0.20 ±140%	<0.04 ±200%
S-33	0.25 ± 28%	0.40 ±100%	<0.11 ±227%	<0.04 ±125%	<0.10 ± 80%	<0.06 ± 66%
S-34	<1.77 ± 239%	<0.08 ±112%	0.22 ±100%	<0.06 ±117%	<0.07 ±171%	<0.06 ± 17%
S-35	<0.36 ± 192%	0.30 ±120%	0.16 ± 62%	<0.10 ±150%	<0 03 ± 67%	<0.25 ±148%
S-36	<0.03 ± –	0.20 ±160%	<0.11 ±173%	<0.05 ±140%	<0.04 ±125%	<0.02 ±850%
S-37	–	0.18 ± 78%	<0.44 ± 70%	<0.04 ±100%	<0.07 ±100%	<0.05 ± 80%
Average	0.49 ± 78%	<0.34 ± 53%	<0.20 ± 15%	<0.07 ± 14%	<0 07 ± 14%	<0.14 ± 21%

January–June 1972 – Summary

Location	n	Vol (m^3)	Conc. (X 10^{-15} μCi/ml) C_{min}	C_{max} ±2σ	C_{avg} ±2σ	% of Standard*
S-26	26	133743	<0.01	0.84 ±8%	<0 17 ± 51%	<0.8
S-27	24	73605	<0.02	0.38 ±9%	<0.11 ± 41%	<0.6
S-28	22	132444	<0.01	1.50 ±4%	<0.16 ± 86%	<0.8
S-29	26	101743	<0.02	3.37 ±3%	<0.33 ± 79%	<1.6
S-30	22	80734	<0.02	0.59 ±6%	<0.11 ± 52%	<0.6
S-31	25	98288	<0.02	1.30 ±4%	<0.29 ± 54%	<1.4
S-32	25	103343	<0.02	1.34 ±4%	<0.24 ± 49%	<1.2
S-33	25	93564	<0.02	0.81 ±8%	<0.17 ± 46%	<0 8
S-34	25	96673	<0.01	5.74 ±4%	<0.42 ±121%	<2.1
S-35	26	85359	<0.02	0.99 ±5%	<0 19 ± 50%	<1.0
S-36	22	117374	<0.01	0.47 ±8%	<0.08 ± 69%	<0.4
S-37	21	95031	<0.02	0.65 ±4%	<0.12 ± 52%	<0.6
Summary Average	289	1211901	<0.01	5.74 ±4%	<0.20 ± 27%	<1.0

*The soluble plutonium standard is 20 X 10^{-15} μCi/ml to a population group.

Volume Weighted Averages

Location	Jul	Aug	Sept	Oct	Nov	Dec
S-26	<0.01 ± 0%	<0.09 ± 56%	<0.07 ±273%	<0.02 ± 0%	<0.06 ± 77%	<0.02 ± 46%
S-27	<0.04 ±375%	<0.08 ±688%	<0.12 ±391%	<0.03 ± 37%	<0.09 ± 79%	<0.21 ±154%
S-28	<0.01 ± 0%	<0.05 ±100%	<0.10 ±130%	<0.01 ± 0%	<0.01 ±124%	<0.01 ± 0%
S-29	<0.05 ± 80%	<0.07 ±126%	<0.07 ±239%	<0.03 ±223%	<0.10 ±208%	<0.12 ±311%
S-30	<0.03 ± 67%	<0.08 ± 76%	<0.03 ±300%	<0.02 ± 20%	<0.07 ±262%	<0.07 ±645%
S-31	<0.05 ± 80%	<0.09 ±351%	<0.05 ± 69%	<0.08 ±163%	<0.05 ±140%	<0.03 ±309%
S-32	<0.06 ±183%	<0.11 ±135%	<0.18 ±223%	<0.29 ±271%	<0 04 ± 82%	<0.50 ±208%
S-33	<0.08 ±325%	<0.05 ±290%	<0.15 ±131%	<0.24 ±314%	<0.05 ±168%	<0.01 ± 0%
S-34	<0.07 ±114%	<0.08 ± 93%	<0.06 ±250%	<0.03 ± 0%	<0.53 ±221%	<0.29 ±494%
S-35	<0.09 ± 89%	<0.06 ± 83%	<0.34 ±216%	<0.02 ± 0%	<0.03 ± 0%	<0.02 ±196%
S-36	–	–	<0 10 ±270%	<0.02 ± 0%	<0.02 ±176%	<0 01 ± 0%
S-37	<0.06 ± 83%	<0.04 ± 50%	<0.11 ±221%	<0 03 ± 53%	<0.05 ±144%	<0 13 ±154%
Average	<0.04 ± 25%	<0.07 ± 51%	<0.11 ± 53%	<0.06 ± 97%	<0.07 ±149%	<0.08 ±126%

Table 5-A. Offsite Plutonium Concentration in Air ±2σ (X 10^{-15} μCi/ml) (continued).

July–December 1972 – Summary

Location	n	Vol (m^3)	Conc. (X 10^{-15} μCi/ml) C_{min}	C_{max} ±2σ	C_{avg} ±2σ	% of Standard*
S-26	26	105248	<0.01	0.24 ±12%	<0.05 ± 44%	<0.3
S-27	26	72102	<0.01	0.82 ±17%	<0.10 ± 85%	<0.5
S-28	26	149944	<0.01	0.21 ± 7%	<0.03 ± 64%	<0.2
S-29	26	58218	<0.02	0.48 ± 9%	<0.03 ±182%	<0.2
S-30	25	92901	<0.01	0.53 ± 7%	<0.05 ±102%	<0.2
S-31	23	81548	<0.01	0.24 ±17%	<0.05 ± 61%	<0.2
S-32	25	48551	<0 02	1.43 ± 5%	<0.19 ± 69%	<1.0
S-33	25	88385	<0.01	1.08 ± 4%	<0.10 ± 95%	<0.5
S-34	25	63543	<0.02	2.20 ± 5%	<0.18 ±165%	<0 9
S-35	24	64835	<0.01	1.01 ± 4%	<0.09 ± 96%	<0.4
S-36	16	92204	<0.01	0.22 ± 6%	<0.02 ±150%	<0.1
S-37	26	77090	<0.01	0.32 ± 7%	<0.07 ± 46%	<0.4
Summary Average	293	994569	<0.01	2.20 ± 5%	<0.07 ± 37%	<0.4

*The soluble plutonium standard is 20 X 10^{-15} μCi/ml to a population group.

1972 Summary – Offsite Plutonium Concentrations in Air

Volume Weighted Averages

Location	n	Vol (m^3)	Conc. (X 10^{-15} μCi/ml) C_{min}	C_{max} ±2σ	C_{avg} ±2σ	% of Standard*
S-26	52	238991	<0.01	0.84 ± 8%	<0.12 ±39%	<0.6
S-27	50	145707	<0.01	0.82 ±17%	<0.11 ±43%	<0.6
S-28	48	282388	<0.01	1.50 ± 4%	<0.09 ±73%	<0.4
S-29	52	159961	<0.02	3.37 ± 3%	<0.22 ±61%	<1.1
S-30	47	173635	<0.01	0.59 ± 6%	<0.08 ±47%	<0.4
S-31	48	179836	<0.01	1.30 ± 4%	<0.18 ±49%	<0.9
S-32	50	151894	<0.02	1.43 ± 5%	<0.22 ±39%	<1.1
S-33	50	181949	<0.01	1.08 ± 4%	<0.14 ±43%	<0.7
S-34	50	160216	<0.01	5.74 ± 4%	<0.32 ±84%	<1.6
S-35	50	150194	<0.01	1.01 ± 4%	<0.15 ±42%	<0.8
S-36	38	209578	<0.01	0.47 ± 8%	<0.05 ±70%	<0.2
S-37	47	172121	<0.01	0.65 ± 4%	<0.10 ±31%	<0.5
Summary Average	582	2206470	<0.01	5.74 ± 4%	<0.14 ±21%	<0.7

*The soluble plutonium standard is 20 X 10^{-15} μCi/ml to a population group.

Table 6. Nonradioactive Materials Released in Effluent Water, Annual Averages.

Parameter	Sampling Point A	Sampling Point B-4	Sampling Point C	Standard	Agency
A. Physical and Biological					
Color (Pt-Co units)	15	25	13	15 Units	USPHS
Turbidity – JT U	0.7	0.8	0.6	5 Units	USPHS
Total Dissolved Solids – mg/l	319.[1]	387.[1]	193.[1]	500.	CDH
BOD_5 – mg/l	NA	< 8.7	NA	30.*	CDH
B. Chemical					
Sulfate (as SO_4) – mg/l	33.5	76.5	37.0	250.	USPHS
Chloride – mg/l	28.	57.	12.	250.	USPHS
Chromium (Cr^{+6} as Na_2CrO_4) µg/l	< 5.	< 5.	< 5.	50.	USPHS
Cyanide – mg/l	< 0.01	< 0.01	< 0.01	0.01†	USPHS
Fluoride – mg/l	0.87	0.71	0.59	1.0†	USPHS
Arsenic (total) µg/l	< 5.5	< 6.5	< 6.0	10.0	USPHS
Barium (total) µg/l	<100.	<100.	<100.	1000.	USPHS
Beryllium (total) µg/l	< 1.5	< 1.3	< 1.8	–	
Cadmium (total) µg/l	< 1.0	< 1.0	< 1.0	10.†	USPHS
Copper (total) µg/l	18.	27.	15.	1000.	USPHS
Iron (total) µg/l	25.	30.	23.	300.	USPHS
Lead (total) µg/l	9.3	9.5	9.3	50.†	USPHS
Manganese (total) µg/l	9.2	5.5	6.4	50.†	USPHS
Selenium (total) µg/l	< 7.3	< 8.0	< 6.7	10.	USPHS
Silver (total) µg/l	< 1.0	< 1.0	< 1.0	50.	USPHS
Zinc (total) µg/l	34.	49.	53.	5000.†	USPHS
Phenols µg/l	< 3.5	< 5.0	< 3.5	1.†	USPHS
Surfactants mg/l	< 0.02	0.5	< 0.03	0.5†	USPHS
Nitrate (as NO_3^-) mg/l	35.2	3.5	0.5	45.†	USPHS

[1] Total solids.

*The Colorado Water Pollution Control Commission also requires an 80% BOD_5 reduction for facilities having secondary treatment and disinfection.

†Units are for drinking water. They do not apply to discharge water.

Table 7. Radioactivity in Pond (A) Water Samples.

		U + Pu			Pu		
		Conc. ($\times 10^{-9}$ μCi/ml)			Conc. ($\times 10^{-9}$ μCi/ml)		
	n	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$
Jan	3	4.92 ± 9%	8.85 ± 6%	7.15 ± 70%	0.13 ±55%	0.71 ±20%	0.35 ±219%
Feb	4	9.01 ± 6%	12.84 ± 5%	10.30 ± 28%	0.29 ±35%	3.15 ±10%	1.17 ±181%
Mar	5	3.90 ± 9%	16 35 ± 5%	10.29 ± 54%	0.17 ±47%	9.92 ± 6%	2.66 ±192%
Apr	4	5.06 ± 8%	7.94 ± 6%	6.74 ± 33%	0.13 ±53%	0.41 ±30%	0.32 ± 64%
May	5	0.94 ±20%	3.29 ±10%	2.23 ± 47%	0.10 ±65%	0.43 ±35%	0.24 ± 85%
June	4	3.60 ±11%	4.36 ± 9%	4.07 ± 14%	0.47 ±30%	0.92 ±20%	0.73 ± 45%
Summary	25	0.94 ±20%	16.35 ± 5%		0.10 ±65%	9.92 ± 6%	
Average				6.74 ± 23%			0.98 ± 83%
July	4	4.68 ± 9%	6.84 ± 7%	6.02 ± 27%	0.37 ±30%	2.02 ±13%	1.07 ±107%
Aug	5	2.74 ±11%	13.53 ± 5%	7.40 ± 75%	0.42 ±30%	6.17 ± 8%	3.03 ±104%
Sept	4	3.43 ± 6%	19.92 ± 3%	8.89 ±136%	0.34 ±20%	17.61 ± 3%	4.82 ±281%
Oct	3	5.64 ± 5%	19.50 ± 3%	10.75 ±176%	0.73 ±14%	8.80 ± 3%	4.00 ±264%
Nov	3	7.68 ± 4%	24.16 ± 3%	13.29 ±176%	<0.01 ± –	1.81 ± 8%	<0.61 ±422%
Dec	4	5.96 ± 4%	28.62 ± 2%	14.69 ±112%	<0.01 ± –	2.21 ± 8%	<0.93 ±189%
Summary	23	2.74 ±11%	28.62 ± 2%		<0.01 ± –	17.61 ± 3%	
Average				9.89 ± 31%			<2.45 ± 70%
1972 Summary	48	0.94 ±20%	28.62 ± 2%		<0.01 ± –	17.61 ± 3%	
1972 Average				8.17 ± 19%			<1.68 ± 54%
% of Standard*				<0.16%			<0.10%

*The U + Pu soluble standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667×10^{-9} μCi/ml

**Sample weighted average.

Table 8. Radioactivity in Pond (B-4) Effluent Water Samples.

			U + Pu				Pu			
		Vol	Conc. (X 10^{-9} μCi/ml)			Release	Conc. (X 10^{-9} μCi/ml)			Release
	n	(10^6 liters)	C_{min} ±2σ	C_{max} ±2σ	C_{avg}** ±2σ	(mCi)	C_{min} ±2σ	C_{max} ±2σ	C_{avg}** ±2σ	(mCi)
Jan	4	17.722	8.75 ± 6%	33.54 ±3%	17.33 ±104%	0.307	1.06 ±20%	5.18 ± 2%	3.18 ±114%	0.056
Feb	4	48.831	17.63 ± 5%	38.27 ±3%	26.84 ± 51%	1.311	1.79 ±19%	8.14 ± 7%	5.10 ± 86%	0.249
Mar	5	50.412	11.59 ± 5%	31.12 ±3%	21.28 ± 54%	1.073	2.48 ±14%	3.44 ±11%	2.99 ± 18%	0.151
Apr	4	55.530	9.00 ± 6%	25.33 ±4%	14.88 ± 79%	0.826	1.42 ±17%	16.11 ± 6%	5.71 ±195%	0.317
May	5	46.035	4.50 ± 9%	20.41 ±4%	10.74 ± 71%	0.494	0.85 ±22%	8.97 ± 6%	2.90 ±147%	0.134
Jun	4	65.350	3.06 ± 9%	10.34 ±4%	6.46 ± 75%	0.422	0.66 ±25%	4.56 ±10%	2.22 ±127%	0.145
Summary	26	283.880	3.06 ± 9%	38.27 ±3%		4.433	0.66 ±25%	16.11 ± 6%		1.052
Average					16.24 ± 24%				3.54 ± 38%	
Jul	4	29.232	4.64 ±10%	10.73 ±4%	7.73 ± 66%	0.226	1.13 ± 6%	5 29 ± 9%	2.78 ±113%	0.081
Aug	5	24.121	2.44 ±12%	8.47 ±6%	5.54 ± 70%	0.134	0.48 ±30%	6 94 ± 8%	3.09 ±120%	0.075
Sept	4	31 463	2.80 ± 8%	20.52 ±2%	9.64 ±126%	0.303	0.68 ±14%	15.37 ± 3%	5.05 ±218%	0.159
Oct	1	18 839	(1)	(1)	28.85	0.543	(1)	(1)	18.33	0.345
Nov	4	29.356	57.27 ± 2%	74.52 ±1%	67.20 ± 17%	1.973	34.83 ± 1%	64.78 ± 1%	53.39 ± 28%	1.567
Dec	4	20 968	45.24 ± 2%	134.83 ±1%	88.66 ± 66%	1.859	29.67 ± 2%	123.62 ± 1%	77.44 ± 79%	1.624
Summary	22	153.979	2.44 ±12%	134.83 ±1%		5.038	0.48 ±30%	123 62 ± 1%		3.851
Average					36.54 ± 81%				25.99 ±103%	
1972 Summary	48	437.859	2.44 ±12%	134.83 ±1%		9.471	0.48 ±30%	123.62 ± 1%		4.903
1972 Average					25.29 ± 31%				14.86 ± 79%	
% of Standard*					1.00%				0.89%	

[1] No flow through Pond for three of four weeks.

*The U + Pu soluble standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667×10^{-9} μCi/ml.

**Volume weighted average.

Table 9. Radioactivity in Pond (C) Water Samples.

		U + Pu			Pu		
		Conc. ($\times 10^{-9}$ μCi/ml)			Conc. ($\times 10^{-9}$ μCi/ml)		
	n	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$
Jan	3	4.37 ±10%	7.77 ± 7%	6.28 ± 69%	0.15 ±50%	0.47 ± 9%	0 27 ±160%
Feb	3	10.52 ± 6%	14.41 ± 5%	12.66 ± 39%	0.49 ±30%	1.79 ±15%	1.07 ±153%
Mar	5	5.69 ± 8%	14.93 ± 5%	9 93 ± 42%	0.07 ±85%	1.57 ±15%	0.77 ±105%
Apr	4	3.85 ±10%	8.83 ± 5%	6.11 ± 56%	0.26 ±40%	1.00 ±20%	0.62 ± 78%
May	5	1.57 ±15%	7.87 ± 7%	4.36 ± 67%	0.23 ±43%	2.08 ±15%	0.77 ±121%
Jun	4	2.01 ±16%	2.97 ±11%	2.46 ± 31%	0.26 ±41%	0.94 ±20%	0 67 ± 90%
Summary	24	1.57 ±15%	14.93 ± 5%		0.07 ±85%	2.08 ±15%	
Average				6.77 ± 25%			0.68 ± 32%
Jul	4	2.71 ±12%	5.14 ± 9%	4.09 ± 48%	0.92 ±19%	2.09 ±15%	1.52 ± 68%
Aug	5	3 01 ±10%	14.61 ± 6%	6.02 ±100%	1.36 ±16%	5.21 ± 9%	2.50 ± 78%
Sept	4	2.10 ± 8%	15.24 ± 3%	5.65 ±180%	0.47 ±16%	12.35 ± 3%	3.48 ±270%
Oct	3	5.66 ± 5%	8.57 ± 4%	7.03 ± 51%	3.02 ± 6%	3.30 ± 7%	3.15 ± 11%
Nov	3	2.06 ± 7%	26.20 ± 2%	11.14 ±293%	<0.01 ± -	2.29 ± 7%	<1 24 ±230%
Dec	4	2.98 ± 6%	15.59 ± 3%	8.12 ±118%	<0.01 ± -	0.88 ±11%	<0.38 ±186%
Summary	23	2.06 ± 7%	26.20 ± 2%		<0.01 ± -	12.35 ± 3%	
Average				6.78 ± 38%			<2.05 ± 54%
1972 Summary	47	1.57 ±15%	26.20 ± 2%		<0.01 ± -	12.35 ± 3%	
1972 Average				6.78 ± 22%			<1.33 ± 42%
% of Standard*				0.13%			0.08%

*The soluble U + Pu standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667×10^{-9} μCi/ml.

**Sample Weighted Average.

Table 10. Americium Released in Effluent Water from Pond B-4.

		Conc. ($\times 10^{-9}$ μCi/ml)			Total Release
	n	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C_{avg} \pm 2\sigma$	(mCi)
Jan	4	0.13	0.81	0.53 ± 90%	0.009
Feb	4	<0.01	1.62	<0.79 ±132%	<0.039
Mar	5	0.22	1.32	0.55 ±100%	0.028
Apr	6	0.56	2.80	1.28 ± 73%	0.071
May	5	0.11	1.86	0.62 ±142%	0.029
Jun	5	0.34	2.51	0.88 ±131%	0.057
Summary	29	<0.01	2.80		<0.227
Average				<0.80 ± 34%	
Jul	4	<0.01	2.69	<0.88 ±223%	<0.026
Aug	4	<0.01	1.69	<0.79 ±151%	<0.019
Sept	4	0.16	1.23	0.74 ±101%	0.023
Oct	1	<0.01	<0.01	<0.01 ± -	<0.0002
Nov	3	3.82	12.94	8.31 ±136%	0.244
Dec	4	15.20	15.38	11.90 ± 61%	0 249
Summary	20	<0.01	15.38		<0.632
Average				<4.11 ± 62%	
1972 Summary	49	<0.01	15.38		<0.941
1972 Average				<2.15 ± 51%	
% of Standard*				<0.07% of Std.	

*The soluble americium concentration standard is 1333×10^{-9} μCi/ml.

**Volume weighted average (volumes from Table 8).

THIS PAGE INTENTIONALLY LEFT BLANK

Table 11. Radioactivity in Walnut Creek Water Samples.

		U + Pu Conc. ($\times 10^{-9}$ μCi/ml)			Pu Conc. ($\times 10^{-9}$ μCi/ml)			Am Conc. ($\times 10^{-9}$ μCi/ml)		
	n	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	$C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$
Jan	3	9.51 ± 6%	11.69 ±6%	10.54 ± 26%	0.53 ±30%	1.18 ±18%	0.82 ±100%	<0.01 ± -	0.21 ±45%	<0.11 ±1155%
Feb	5	14.28 ± 5%	26.83 ±4%	19.49 ± 30%	2.17 ±14%	4.38 ±10%	2.85 ± 39%	<0.01 ± -	0.61 ±25%	<0.33 ± 284%
Mar	7	5.11 ± 9%	29.45 ±4%	19.62 ± 39%	0.64 ±24%	7.45 ± 9%	3.36 ± 63%	<0.01 ± -	4.37 ±10%	<0.29 ± 166%
Apr	4	11.53 ± 9%	34.70 ±3%	17.65 ±102%	0.91 ±21%	3.37 ±11%	2.05 ± 79%	0.39 ±32%	0.72 ±25%	0.56 ± 356%
May	6	2.99 ±11%	22.68 ±3%	9.11 ± 80%	0.34 ±30%	3.46 ±11%	1.62 ± 68%	NS	NS	–
Jun	4	3.64 ±11%	7.02 ±8%	5.14 ± 50%	0.82 ±17%	1.56 ±20%	1.06 ± 52%	NS	NS	–
Summary	29	2.99 ±11%	34.70 ±3%		0.34 ±30%	7.45 ± 9%		<0.01 ± -	4.37 ± 8%	
Average				14.22 ± 23%			2.15 ± 28%			<0.30 ± 110%
Jul	3	3.12 ±10%	7.93 ±7%	5.59 ±107%	0.28 ±30%	3.71 ±10%	1.58 ±163%	<0.01 ± -	1.13 ± 9%	<0.57 ±1249%
Aug	5	3.56 ±10%	5.45 ±9%	4.19 ± 22%	1.17 ±19%	2.93 ±11%	1.86 ± 49%	<0.01 ± -	1.16 ± 9%	<0.67 ± 119%
Sept	4	2.63 ± 8%	24.30 ±2%	10.08 ±154%	1.00 ±11%	20.40 ± 3%	6.70 ±219%	0.33 ±36%	0.62 ±20%	0.46 ± 76%
Oct	3	11.33 ± 3%	72.33 ±1%[1]	41.74 ±181%	3.61 ± 6%	23.30 ± 2%[1]	13.20 ±185%	–	–	4.83 ± - [2]
Nov	3	15.15 ± 3%	113.09 ±1%	48.59 ±285%	7.67 ± 4%	108.77 ±12%	42.69 ±129%	1.90 ±14%	3.89 ±12%	2.90 ± 147%
Dec	4	28.30 ± 3%	65.15 ±1%	42.51 ± 64%	19.61 ± 3%	48.40 ± 2%	29.64 ± 74%	1.69 ±15%	7.52 ± 7%	4.09 ± 66%
Summary	22	2.63 ± 8%	113.09 ±1%		0.28 ±30%	108.77 ±12%		<0.01 ± -	7.52 ± 7%	
Average				23.59 ± 54%			16.56 ± 63%			<2.13 ± 53%
1972 Summary	51	2.63 ± 8%	113.09 ±1%		0.28 ±30%	108.77 ±12%		<0.01 ± -	7.52 ± 7%	
1972 Average				18.26 ± 31%			8.82 ± 57%			<1.01 ± 51%
% of Standard*				0.62%			0.53%			<0.08%

[1] No flow in Walnut Creek.

[2] Only one sample taken for Am analysis.

*The soluble U + Pu standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667×10^{-9} μCi/ml.

The soluble americium standard is 1333×10^{-9} μCi/ml.

**Sample weighted average.

NS – No Sample Taken.

Table 12. Summary of Radioactivity in Reservoir and Tap Water Sources.

January–June 1972 – Summary

Reservoir	n	U + Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*	Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Baseline	3	0.58 ±5%	1.45 ±3%	0.95 ±118%	0.01	<0.01 ± -	0.13 ±11%	<0.07 ±213%	<0.01
Great Western	12	2.59 ±2%	8.81 ±1%	4.32 ± 29%	0.06	0.08 ±13%	1.16 ± 4%	0.28 ± 71%	0.02
Ralston	12	3.64 ±1%	25.77 ±1%	10.22 ± 43%	0.13	0.03 ±18%	1.86 ± 2%	0.52 ±118%	0.03
Standley	12	2.93 ±1%	7.23 ±1%	5.22 ± 54%	0.07	0.04 ±17%	0.73 ± 5%	0.28 ± 50%	0.02
Summary	39	0.58 ±5%	25.77 ±1%			<0.01 ± -	1.86 ± 2%		
Average				6.15 ± 28%	0.08			<0.34 ± 50%	<0.02
Tap Water Source									
Arvada	12	0.70 ±5%	6.33 ±1%	2.39 ± 50%	0.04	<0.01 ± -	1.61 ± 3%	<0.35 ± 87%	<0.02
Boulder	12	0.53 ±5%	2.78 ±3%	1.56 ± 43%	<0.03	<0.01 ± -	1.25 ± 4%	<0.28 ± 77%	<0.02
Broomfield	12	1.36 ±2%	5.03 ±1%	3.02 ± 28%	0.05	0.08 ±11%	0.81 ± 3%	0.32 ± 50%	<0.02
Denver	12	0.38 ±6%	13.68 ±1%	5.22 ± 52%	0.08	0.04 ± 4%	4.29 ± 2%	0.63 ±125%	0.04
Golden	12	0.57 ±6%	(30.30 ±1%)[1]	5.67 ± 96%	<0.09	<0.01 ± -	3.07 ± 2%	<0.59 ± 94%	<0.04
Lafayette	12	0.53 ±5%	8.02 ±1%	1.87 ± 73%	<0.04	<0.01 ± -	2.10 ± 3%	<0.37 ± 97%	<0.02
Louisville	12	0.73 ±4%	5.24 ±1%	1.94 ± 52%	0.04	0.10 ±31%	1.91 ± 3%	0.38 ± 80%	0.02
Thornton	11	3.95 ±2%	39.87 ±1%	14.52 ± 58%	<0.17	<0.01 ± -	2.10 ± 4%	<0.42 ± 92%	<0.03
Westminster	11	0.66 ±4%	5.11 ±1%	2.11 ± 41%	0.03	<0.01 ± -	0.58 ± 4%	<0.27 ± 39%	<0.02
Summary	106	0.38 ±6%	39.87 ±1%			<0.01 ± -	4.29 ± 2%		
Average				4.18 ± 28%	<0.06			<0.40 ± 28%	<0.02

[1] Suspect Data. Significantly high value compared to average and previous year values.

*The soluble U+ Pu standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667×10^{-9} μCi/ml.

**Sample weighted average.

July–December 1972 – Summary

Reservoir	n	U + Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*	Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Baseline	11	<0.01 ± -	18.69 ±1%	<4.62 ±102%	<0.07	<0.01 ± -	2.22 ±3%	<0.55 ± 87%	<0.03
Great Western	11	1.11 ±3%	9.25 ±1%	4.26 ± 44%	<0.10	<0.01 ± -	6.42 ±1%	1.09 ±115%	<0.07
Ralston	11	0.94 ±3%	12.15 ±1%	4.37 ± 58%	0.06	<0.01 ± -	1.77 ±3%	<0.36 ±100%	<0.02
Standley	9	2.52 ±1%	7.47 ±1%	4.14 ± 36%	0.06	<0.01 ± -	0.95 ±4%	<0.40 ± 71%	<0.02
Summary	42	<0.01 ± -	18.69 ±1%			<0.01 ± -	6.42 ±1%		
Average				<4.36 ± 31%	<0.07			<0.61 ± 55%	<0.04
Tap Water Source									
Arvada	11	<0.01 ± -	3.31 ±3%	<1.18 ± 53%	<0.03	<0.01 ± -	1.28 ±3%	<0.40 ± 81%	<0.02
Boulder	11	<0.01 ± -	2.60 ±2%	<1.23 ± 46%	<0.04	<0 01 ± -	1.23 ±3%	<0.47 ± 67%	<0.03
Broomfield	11	<0.01 ± -	7.13 ±2%	<2.27 ± 67%	<0.05	<0.01 ± -	2.85 ±3%	<0.61 ± 91%	<0.04
Denver	10	0.77 ±3%	4.26 ±1%	2.37 ± 41%	0.05	<0.01 ± -	2.36 ±1%	<0.61 ± 73%	<0.04
Golden	11	0.24 ±5%	5.50 ±2%	2.26 ± 44%	0.04	<0.01 ± -	1.60 ±3%	<0.36 ± 88%	<0.02
Lafayette	10	0.26 ±5%	2.22 ±3%	0.91 ± 65%	<0.04	<0.01 ± -	2.73 ±3%	<0.59 ± 93%	<0.04
Louisville	11	0.53 ±6%	6.44 ±1%	2.01 ± 62%	<0.04	<0.01 ± -	1.67 ±2%	<0.34 ±103%	<0.02
Thornton	9	1.05 ±3%	11.65 ±1%	5.03 ± 56%	<0.10	<0.01 ± -	3.04 ±1%	<0.95 ± 85%	<0.06
Westminster	11	0.70 ±5%	7.43 ±1%	2.17 ± 67%	0.05	<0.01 ± -	2.09 ±3%	<0.62 ± 77%	<0.04
Summary	95	<0.01 ± -	11.65 ±1%			<0.01 ± -	3.04 ±1%		
Average				<2.11 ± 20%	<0.05			<0.54 ± 27%	<0.03

*The soluble U + Pu standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667×10^{-9} μCi/ml.

**Sample weighted average.

Table 12. Summary of Radioactivity in Reservoir and Tap Water Sources (continued).

1972 Summary

Reservoir	n	U + Pu Conc. ($\times 10^{-9}$ µCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*	Pu Conc. ($\times 10^{-9}$ µCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Baseline	14	<0.01 ± -	18.69 ±1%	<3.83 ±96%	<0.06	<0.01 ± -	2.22 ±3%	<0.44 ±87%	<0.03
Great Western	23	1.11 ±2%	9.25 ±1%	4.29 ±23%	<0.08	<0.01 ± -	6.42 ±1%	<0.67 ±88%	<0.04
Ralston	23	0.94 ±2%	25.77 ±1%	7.43 ±36%	<0.10	<0.01 ± -	1.86 ±2%	<0.44 ±71%	<0.03
Standley	21	2.52 ±1%	7.47 ±1%	4.76 ±33%	0.06	<0.01 ± -	0.95 ±4%	<0.34 ±40%	<0.02
Summary	81	*0.01 ± -*	*25.77 ±1%*			*<0.01 ± -*	*6.42 ±1%*		
Average				<5.22 ±21%	<0.08			<0.48 ±39%	<0.03
Tap Water Source									
Arvada	23	<0.01 ± -	6.33 ±1%	<1.81 ±37%	<0.04	<0.01 ± -	1.61 ±3%	<0.38 ±52%	<0.02
Boulder	23	<0.01 ± -	2.78 ±3%	<1.40 ±29%	<0.03	<0.01 ± -	1.25 ±4%	<0.37 ±47%	<0.02
Broomfield	23	<0.01 ± -	7.13 ±2%	<2.67 ±29%	<0.05	<0.01 ± -	2.85 ±3%	<0.46 ±61%	<0.03
Denver	22	0.38 ±6%	13.68 ±1%	3.92 ±39%	0.07	<0.01 ± -	4.29 ±2%	<0.62 ±67%	<0.04
Golden	23	0.24 ±5%	(30.30 ±1%)[1]	4.04 ±66%	0.06	<0.01 ± -	3.07 ±2%	<0.48 ±61%	<0.03
Lafayette	22	0.26 ±5%	8.02 ±1%	1.43 ±50%	<0.04	<0.01 ± -	2.73 ±3%	<0.48 ±62%	<0.03
Louisville	23	0.53 ±6%	6.44 ±1%	1.97 ±37%	<0.04	<0.01 ± -	1 91 ±3%	<0.36 ±59%	<0.02
Thornton	20	1.05 ±3%	39.87 ±1%	10.25 ±48%	<0.14	<0.01 ± -	3.04 ±1%	<0.66 ±60%	<0.04
Westminster	22	0.66 ±4%	7.43 ±1%	2.14 ±36%	0.04	<0.01 ± -	2.09 ±3%	<0.45 ±52%	<0.03
Summary	201	<0.01 ± -	39.87 ±1%			<0.01 ± -	4.29 ±2%		
Average				<3.20 ±21%	<0.05			<0.31 ±21%	<0.02

[1] Suspect data. Significantly high value compared to average and previous year values.

*The soluble U + Pu standard is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ µCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ µCi/ml

The soluble plutonium standard is 1667×10^{-9} µCi/ml.

**Sample weighted average.

Table 13. Americium Concentrations in Reservoir Water Samples.

Reservoir	n	January to June 1972 Conc. ($\times 10^{-9}$ μCi/ml) C_{min}	C_{max}	$C^{**}_{avg} \pm 2\sigma$	n	July to December 1972 Conc. ($\times 10^{-9}$ μCi/ml) C_{min}	C_{max}	$C^{**}_{avg} \pm 2\sigma$
Great Western	9	<0.03	1.23	0.36 ± 95%	9	<0.01	1.43	<0.40 ± 94%
Standley	7	<0.01	0.42	<0.12 ±112%	5	<0.01	0.78	<0.218 ±191%
Summary	16	<0.01	1.23		14	<0.01	1.43	
Average				<0.255 ± 74%				<0.334 ± 75%

Americium Concentrations in Reservoirs – 1972

Reservoir	n	Conc. ($\times 10^{-9}$ μCi/ml) C_{min}	C_{max}	$C^{**}_{avg} \pm 2\sigma$	% of Standard*
Great Western	18	<0.01	1.43	<0.38 ±59%	<0.028
Standley	12	<0.01	0.78	<0.16 ±92%	<0.012
Summary	30	<0.01	1.43		
Average				<0.29 ±50%	<0.022

*The soluble americium standard is 1333 X 10^{-9} μCi/ml.
**Sample weighted average.

Table 14. Radioactivity in Surrounding Lakes, Reservoirs, and Streams.

June 1972

Location	n	U + Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$
<5 Miles	11	1.18 ±3%	6.90 ±1%	3.34 ± 42%	<0.01 ± -	1.17 ±4%	<0.24 ±91%
>5 Miles	14	0.60 ±5%	99.84 ±1%	14.62 ±108%	<0.01 ± -	0.27 ±5%	<0.08 ±64%
Summary	25	0.60 ±5%	99.84 ±1%		<0.01 ± -	1.17 ±4%	
Average				9.66 ± 89%			<0.15 ±64%

September 1972

Location	n	U + Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$
<5 Miles	15	0.32 ±7%	11.65 ±1%	2.25 ±72%	<0.01 ± -	6.33 ±2%	<0.54 ±165%
>5 Miles	16	0.16 ±9%	79.22 ±1%	15.20 ±82%	<0.01 ± -	1.25 ±3%	<0 37 ± 52%
Summary	31	0.16 ±9%	79.22 ±1%		<0.01 ± -	6.33 ±2%	
Average				8.93 ±74%			<0.45 ± 91%

Summary 1972

Location	n	U + Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard	Pu Conc. ($\times 10^{-9}$ μCi/ml) $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{**}_{avg} \pm 2\sigma$	% of Standard
<5 Miles	26	0.32 ±7%	11.65 ±1%	2.71 ±40%	<0.05	<0.01 ± -	6.33 ±2%	<0.41 ±120%	<0.03
>5 Miles	30	0.16 ±9%	99.84 ±1%	14.93 ±62%	<0.16	<0.01 ± -	1.25 ±3%	<0.24 ± 48%	<0.01
Summary	56	0.16 ±9%	99.84 ±1%			<0.01 ± -	6.33 ±2%		
Average				9.26 ±55%	<0.11			<0.32 ± 72%	<0.02

*The soluble standard for a mixture of U + Pu is $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ Where: $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml, $RCG_{Pu} = 1667 \times 10^{-9}$ μCi/ml

The soluble plutonium standard is 1667 X 10^{-9} μCi/ml.

**Sample weighted average.

Table 15. Plutonium in Vegetation Samples.

Location	June 1972 n	Pu Conc. [X 10^{-6} μ Ci/g(dry)] $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{*}_{avg} \pm 2\sigma$	September 1972 n	Pu Conc. [X 10^{-6} μCi/g(dry)] $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{*}_{avg} \pm 2\sigma$
<1 Mile	40	<0.01 ± -	3.11 ±3%	<0.39 ±55%	58	0.05 ±14%	4.14 ±8%	0.48 ±34%
1-5 Miles	29	<0.01 ± -	1.23 ±4%	<0.12 ±92%	47	0.03 ±12%	2.71 ±3%	0.31 ±44%
>5 Miles	20	<0.01 ± -	1.05 ±4%	<0.22 ±66%	21	0.02 ±13%	1.04 ±9%	0.20 ±50%
Summary	89	<0.01 ± -	3.11 ±4%		126	0.02 ±12%	4.14 ±8%	
Average				<0.26 ±41%				0.37 ±26%

Location	1972 Summary n	Pu Conc. [X 10^{-6} μCi/g(dry)] $C_{min} \pm 2\sigma$	$C_{max} \pm 2\sigma$	$C^{*}_{avg} \pm 2\sigma$
<1 Mile	98	<0.01 ± -	4.14 ±8%	<0.44 ±30%
1-5 Miles	76	<0.01 ± -	2.71 ±3%	<0.24 ±42%
>5 Miles	41	<0.01 ± -	1.05 ±4%	<0.21 ±41%
Summary	215	<0.01 ± -	4.14 ±8%	
Average				<0.33 ±22%

*Sample weighted average.

Table 16. Plutonium Concentrations in Soil Samples from Around the Rocky Flats Plant [d/m/g (dry weight)].

1 Mile Location	n	$C_{avg} \pm 2\sigma$	2 Mile Location	n	$C_{avg} \pm 2\sigma$	5 Mile Location	n	$C_{avg} \pm 2\sigma$
1-000	6	0.58 ± 97%	2-000	6	0.53 ±160%	5-000	6	0.35 ± 92%
1-018	6	0.34 ± 46%	2-018	6	2.04 ±195%	5-018	6	0.44 ±115%
1-036	7	0.40 ± 87%	2-036	5	1.03 ±129%	5-036	–	–
1-054	7	1.16 ±133%	2-054	6	0.62 ± 67%	5-054	6	0.46 ± 82%
1-072	6	1.12 ±112%	2-072	6	0.85 ± 98%	5-072	6	0.39 ± 95%
1-090	6	21.62 ± 96%	2-090	6	11.66 ± 94%	5-090	6	0.46 ± 46%
1-108	6	48.09 ± 67%	2-108	6	1.89 ± 82%	5-108	3	0.93 ±140%
1-126	6	20.04 ±126%	2-126	6	6.05 ±205%	5-126	7	0.31 ± 69%
1-144	6	2.52 ±104%	2-144	6	0.69 ±103%	5-144	4	0.43 ± 94%
1-162	5	2.00 ±193%	2-162	7	0.39 ± 59%	5-162	5	0.90 ±188%
1-180	5	0.19 ±112%	2-180	7	0.41 ± 66%	5-180	4	2.16 ±157%
1-198	5	0.56 ± 36%	2-198	7	0.88 ± 98%	5-198	–	–
1-216	5	0.36 ± 51%	2-216	6	0.77 ±124%	5-216	5	0.65 ± 66%
1-234	6	1.36 ±117%	2-234	5	1.65 ±214%	5-234	7	0.54 ± 67%
1-252	6	0.94 ± 82%	2-252	6	1.25 ±128%	5-252	7	0.46 ± 78%
1-270	5	0.45 ±151%	2-270	5	0.73 ± 93%	5-270	7	0.97 ± 60%
1-288	6	0.61 ±144%	2-288	4	0.41 ±160%	5-288	–	–
1-306	1	0.68 ± -	2-306	6	0.48 ± 51%	5-306	5	0.69 ±136%
1-324	5	0.71 ±114%	2-324	6	0.43 ± 67%	5-324	3	0.38 ±270%
1-342	6	3.70 ±229%	2-342	5	0.32 ±135%	5-342	7	0.71 ± 90%

THIS PAGE INTENTIONALLY LEFT BLANK

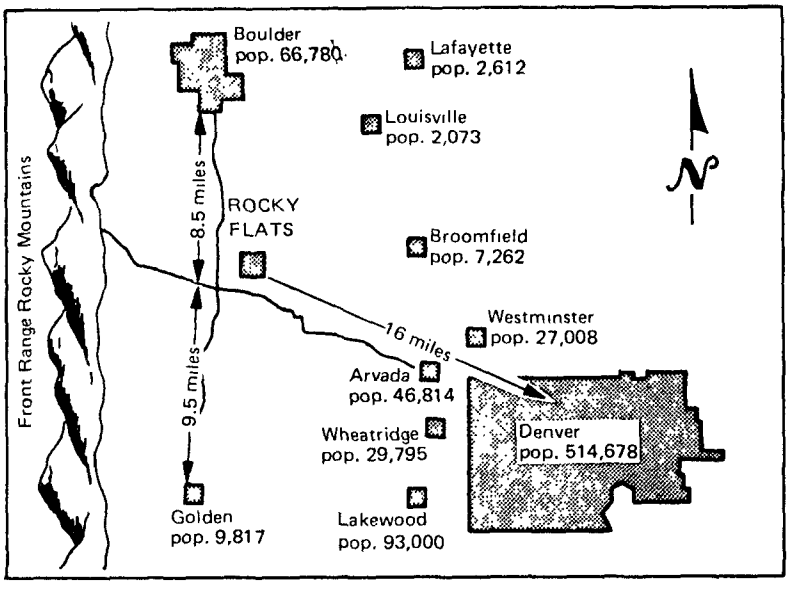
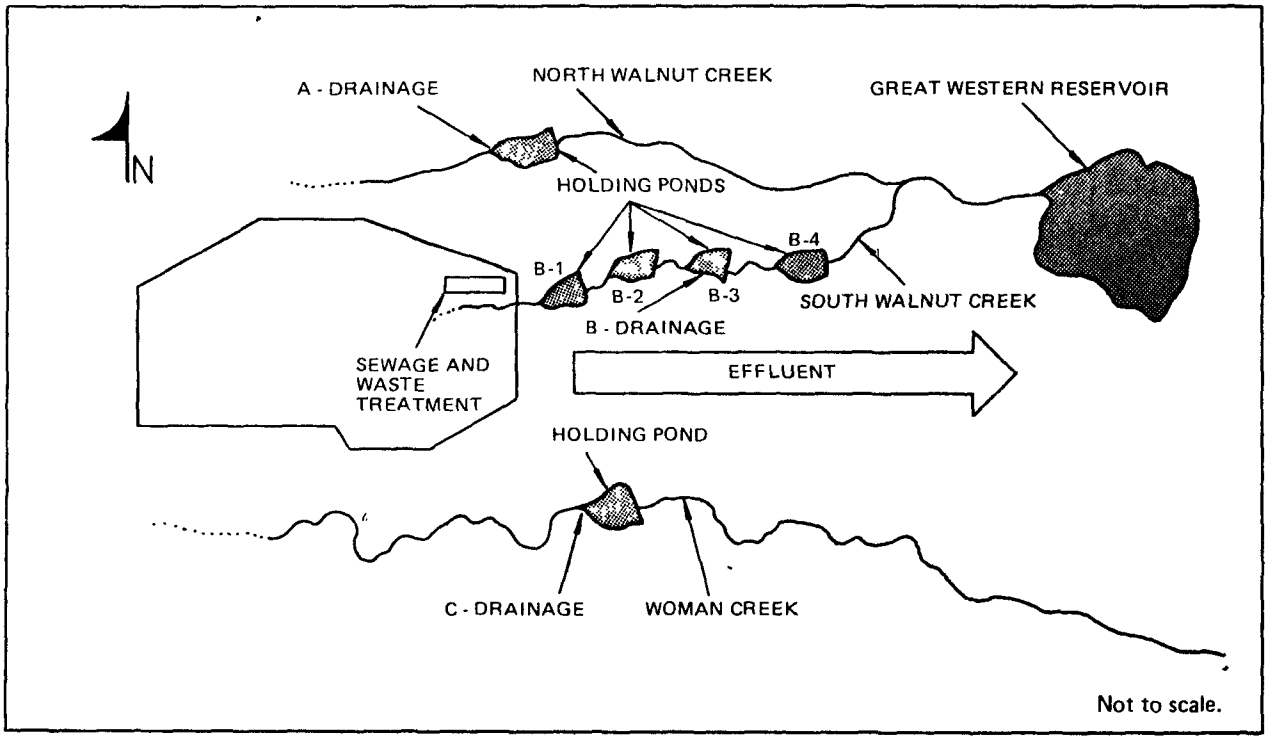


Figure 1. Rocky Flats Area.

Figure 2. Liquid Effluent Water Courses.



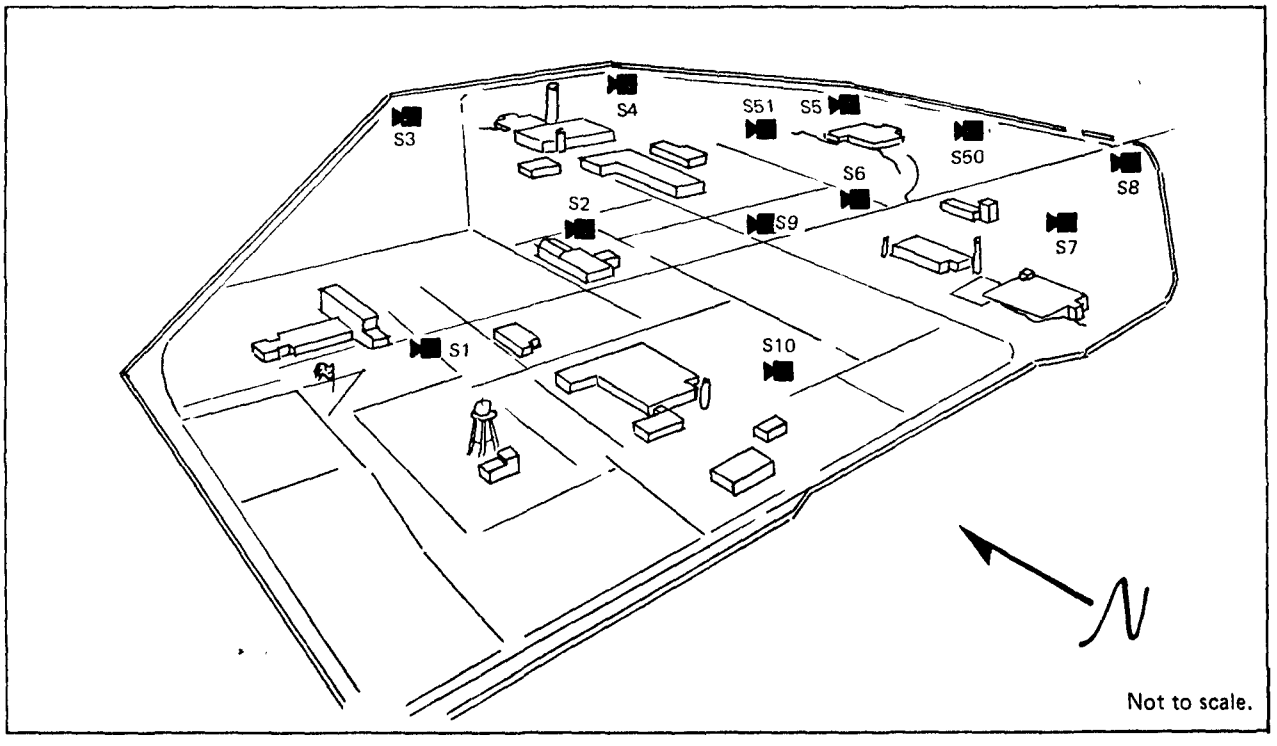


Figure 3. Rocky Flats Onsite Air Samplers.

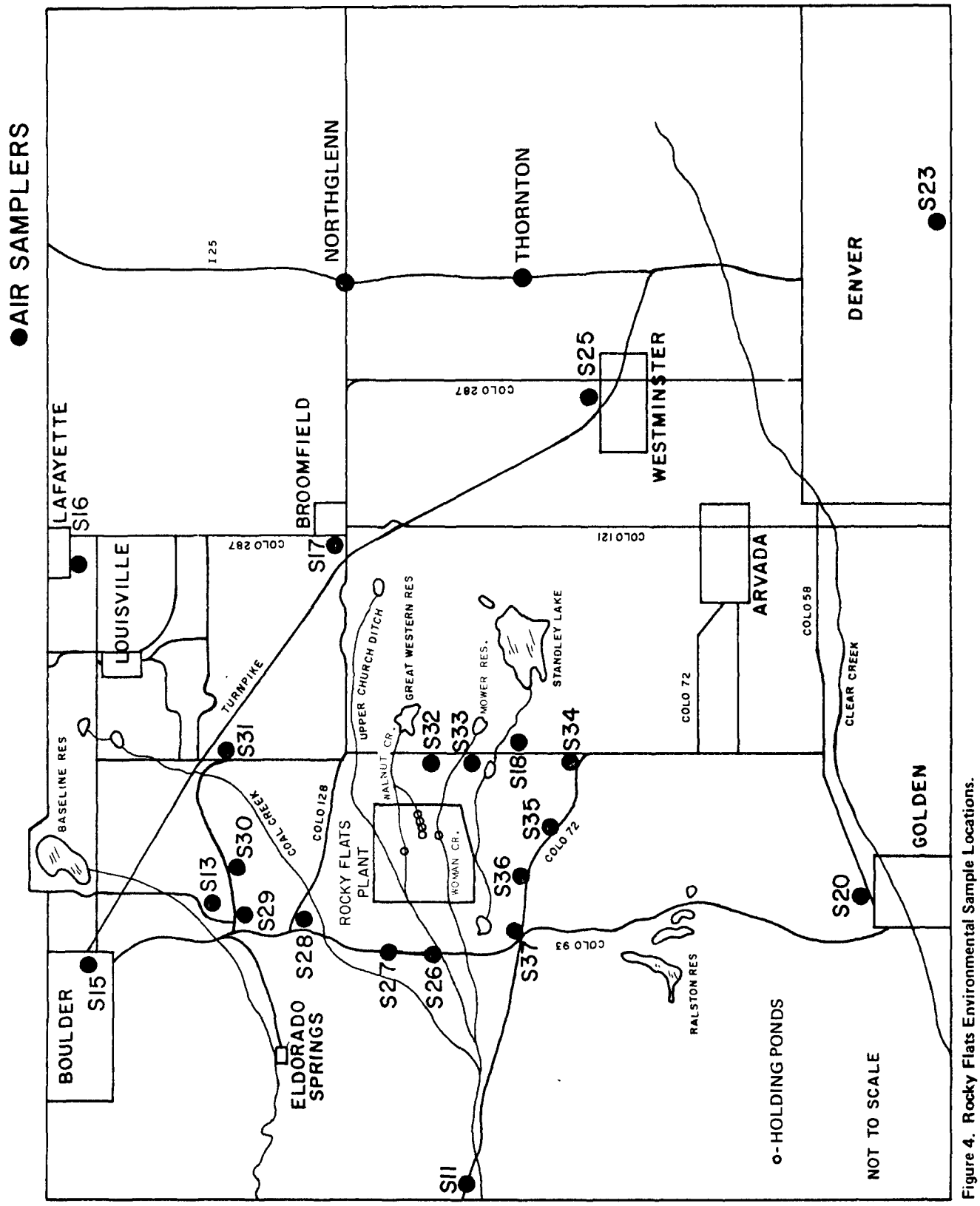


Figure 4. Rocky Flats Environmental Sample Locations.

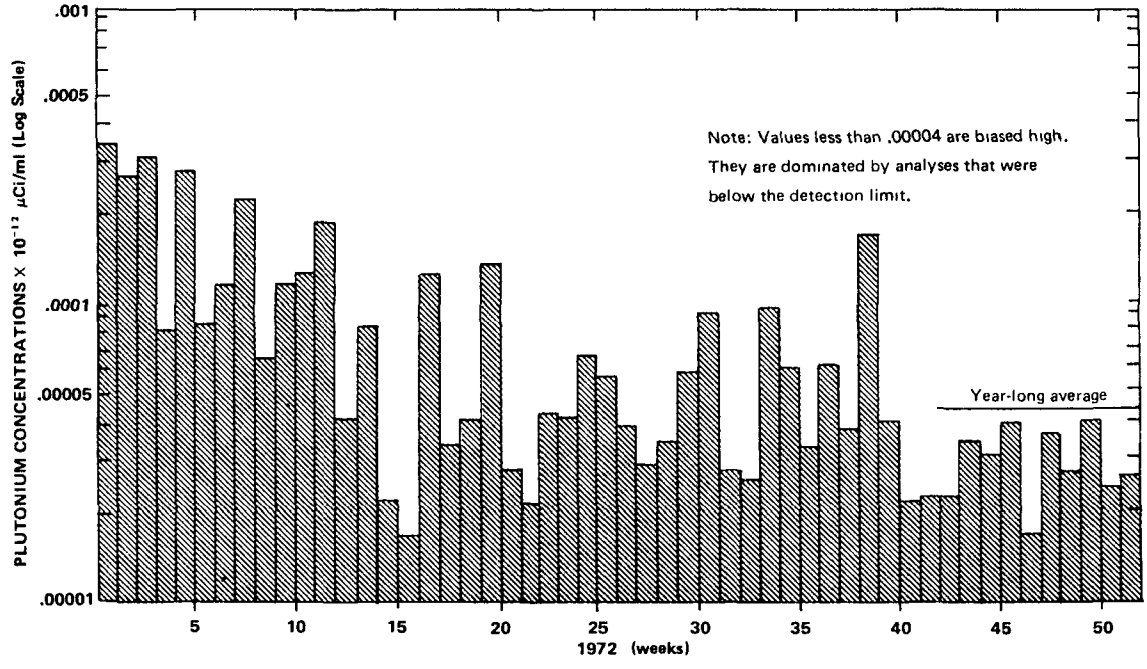


Figure 5. Weekly Average Plutonium Concentrations in Air, Offsite Geometric Average Concentrations for 12 Stations. (S-26 through S-37)

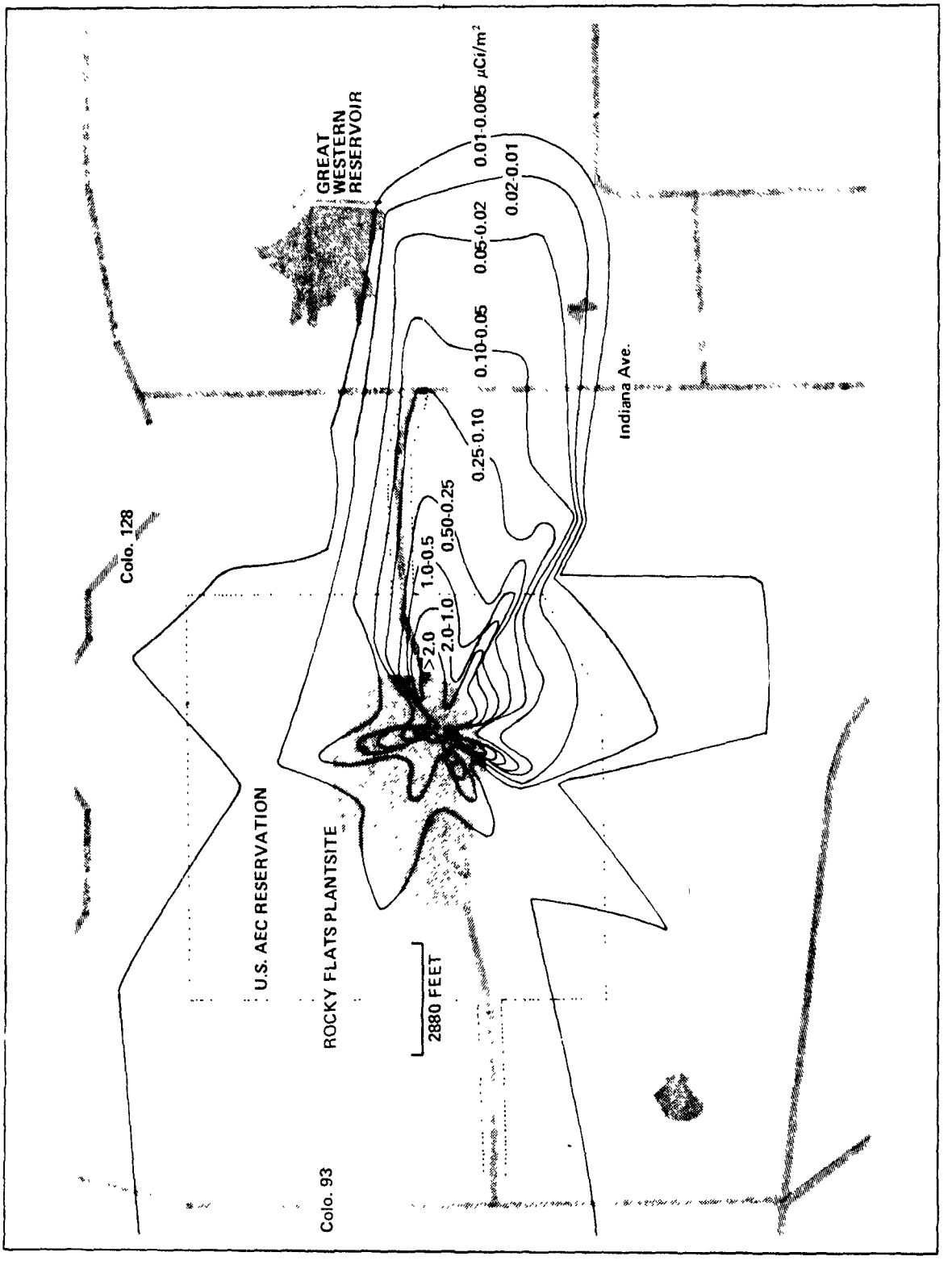


Figure 6. Isopleths of Plutonium Concentrations in Soil (μCi/m^2).

EVALUATION OF DOSE TO THE PUBLIC NEAR ROCKY FLATS

Addendum to the Rocky Flats 1972 Environmental Monitoring Report
RFP-ENV-72
April 13, 1973

I. Introduction:

Rocky Flats releases uranium and plutonium radionuclides through effluent air and water. The effluents are carefully monitored at the point of release and at the plant boundary. In addition, measurements are made of air and drinking water at points of consumption by the general public.

II. Summary

The concentrations of uranium and plutonium in public areas as a result of air and water effluent releases from the Rocky Flats Plant are all below one percent of the relevant AECM 0524 Radioactivity Concentration Guides (RCG).

III. Monitoring Data and Analysis

a. Water

Bimonthly water samples are collected from nine tap water locations around the Rocky Flats areas. These locations include Arvada, Boulder, Broomfield, Denver, Golden, Lafayette, Louisville, Thornton and Westminster. Following is the annual average plutonium and plutonium-plus-uranium concentrations for these locations and a comparison with the applicable standard. The standard for uranium is $10{,}000 \times 10^{-9}$ μCi/ml and for plutonium-239 is 1667×10^{-9} μCi/ml. The standard for soluble uranium plus plutonium is

$$\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$$

Tap Water Samples.

	U + Pu		Pu	
Location	Avg. Conc. ($\times 10^{-9}$ μCi/ml)	% of RCG	Avg. Conc. ($\times 10^{-9}$ μCi/ml)	% of RCG
Arvada	<1.81 ±37%	<0.04	<0.38 ±52%	<0.02
Boulder	<1.40 ±29%	<0.03	<0.37 ±47%	<0.02
Broomfield	<2.67 ±29%	<0.05	<0.46 ±61%	<0.03
Denver	3.92 ±39%	0.07	<0.62 ±67%	<0.04
Golden	4.04 ±66%	0.06	<0.48 ±61%	<0.03
Lafayette	1.43 ±50%	<0.04	<0.48 ±62%	<0.03
Louisville	1.97 ±37%	<0.04	<0.36 ±59%	<0.02
Thornton	10.25 ±48%	<0.14	<0.66 ±60%	<0.04
Westminster	2.14 ±36%	0.04	<0.45 ±52%	<0.03
Average	<3.20 ±21%	<0.05	<0.31 ±21%	<0.02

b. Air is sampled continuously at twelve locations around the plant at distances between two and four miles. The samples are collected daily on Whatman 41 filter paper at an average flow rate of 20-25 cfm. The daily filters are composited into weekly samples, whose volumes vary between 3000 and 6000 m^3, and are radiochemically analyzed specifically for plutonium. These stations sample the air to which the general public in the vicinity of the plant might be exposed. The major population centers are at a greater distance (10 to 20 miles) and therefore are exposed to a lower plutonium concentration in air from any Rocky Flats contribution because of greater dilution. Log-normal statistics are used in the numerical analysis of the data from these stations. Following is a summary of the annual average plutonium concentrations at these locations and a comparison with the Radioactivity Concentration Guide.

The RCG used is for soluble plutonium-239 in air and is 20×10^{-15} μCi/ml. The use of the soluble plutonium RCG adds additional conservatism to the interpretation since the plutonium is probably in an insoluble form for which the RCG is 330×10^{-15} μCi/ml.

Air Samples.

Sampler	Direction from Center of Plant	Avg. Pu Conc. ($\times 10^{-15}$ μCi/ml)	% of RCG
S-26	W	0.066	0.33
S-27	W	0.052	0.26
S-28	NW	0.040	0.20
S-29	NW	0.043	0.22
S-30	N	0.033	0.17
S-31	NE	0.049	0.25
S-32	E	0.064	0.32
S-33	E	0.065	0.33
S-34	SE	0.060	0.30
S-35	S	0.049	0.25
S-36	S	0.031	0.16
S-37	SW	0.039	0.20
Average		0.044	0.22

PREVIOUSLY PUBLICLY RELEASED

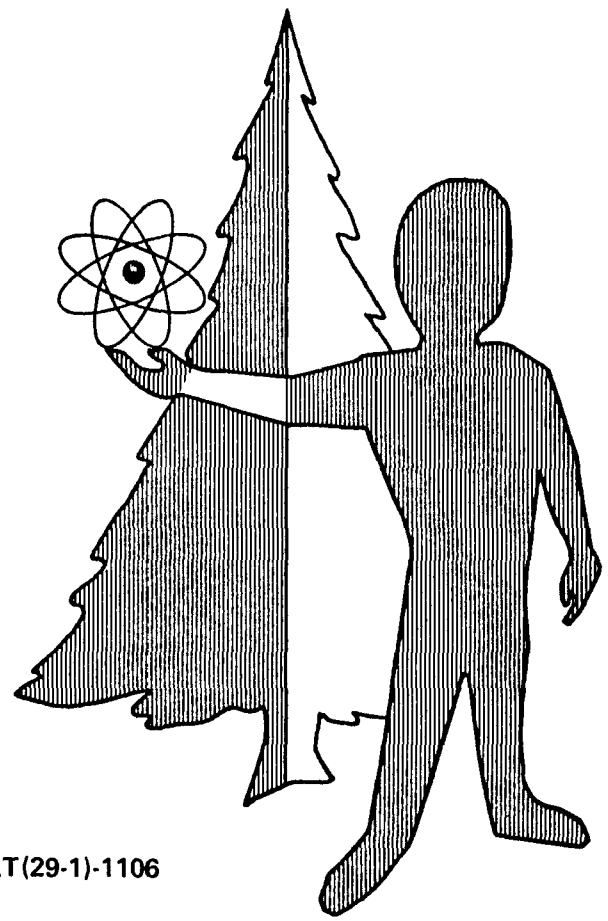
RFP-ENV-73

April 26, 1974

ANNUAL ENVIRONMENTAL MONITORING REPORT

Rocky Flats Plant

JANUARY – DECEMBER 1973



DOW CHEMICAL U.S.A.

Rocky Flats Division

U.S. ATOMIC ENERGY COMMISSION CONTRACT AT(29-1)-1106

Environmental Sciences & Waste Control

Printed
April 26, 1974

RFP-ENV-73

ANNUAL ENVIRONMENTAL MONITORING REPORT

ROCKY FLATS PLANT

A USAEC-Owned Facility

January through December 1973

Environmental Control
George J. Werkema, Group Leader

Environmental Sciences and Waste Control
Milton A. Thompson, Director

CONTRIBUTORS

I. B. Allen
D. C. Coonfield
R. R. Gunning
F. D. Hobbs
C. T. Illsley
J. M. West

DOW CHEMICAL U.S.A.
Rocky Flats Division
P. O. Box 888
Golden, Colorado 80401

Prepared under Contract AT(29-1)-1106
for the
Albuquerque Operations Office
U. S. Atomic Energy Commission

RFP-ENV-73

DISTRIBUTION

INTERNAL

Library
R. W. Bistline
W. C. Bright
H. E. Bowman
R. V. Carroll (50 copies)
C. H. Dompierre
L. C. Farrell, Jr.
J. H. Hanes
R. D. Howerton (2 copies)
C. R. Lagerquist
R. D. Forest
J. B. Owen
M. A. Thompson (50 copies)
G. J. Werkema
J. F. Willging
Environmental Master File (2 copies)

EXTERNAL

USAEC - Washington, D. C.
Major General Edward B. Giller (5 copies)
USAEC--Germantown, Maryland
Gordon C. Facer
Blake P. Brown
Dr. R. L. Watters
USAEC - New York, New York
Dr. John H. Harley
Dr. Herbert Volchok
Philip W. Krey
USAEC--Albuquerque, New Mexico
George Dennis
Harry D. Hawkins
Jack R Roeder (12 copies)
USAEC - Golden, Colorado
B. W. Colston (3 copies)
Savannah River Plant
C. M. Patterson
Sandia Corporation
Dr. W. H. Kingsley
Lawrence Livermore Laboratory
Technical Information Department
Paul Guttikson

EXTERNAL (continued)

Los Alamos Scientific Laboratory
Harry S. Jordan
Dr. L. J. Johnson
Mound Laboratory
Dr. D. G. Carfagno
Oak Ridge National Laboratory
Walter G. Stockdale (2 copies)
Union Carbide Corporation
K. Z. Morgan
Battelle Pacific N. W. Laboratories
R. C. Thompson
J. P. Corley
C. E. Elderkin
U. S. Public Health Service

Colorado Public Health Department
Dr. E. G. Dreyfus
A. J. Hazle
Robert D. Siek
B. S. Evans
Jefferson County (Colorado) Health Department
Don MacDougall (2 copies)
Boulder City-County Health Department
Dr. Charles H. Dowding, Jr.
City of Broomfield
G. D. DiCiero
V. C. Chaney
Environmental Protection Agency
James W. Shaw
Paul W. Smith (6 copies)
University of Colorado
Jerry Martin
Colorado State University
Dr. J. E. Johnson
Dr. F. Ward Whicker
U. S. Army Environmental Hygiene Agency
Commanding Officer
The Dow Chemical Company (Michigan)
C. E. Otis (5 copies)

CONTENTS

Introduction 1
Summary 2
Monitoring Data Collection, Analysis, and Evaluation 2
Applicable Standards 2
Airborne Effluent Monitoring 2
Data Reduction 3
Ambient Air Monitoring 3
Waterborne Effluent Monitoring 5
Regional Water Monitoring 6
Soil Sampling 6
Tritium 7
Sanitary Landfill 7
Assessment of the Rocky Flats Plant's Contribution to Public Radiation Dose ... 7
References 9
Tables 1 through 17 11
Figures 1 through 9 27

THIS PAGE INTENTIONALLY LEFT BLANK

ANNUAL ENVIRONMENTAL MONITORING REPORT
ROCKY FLATS PLANT
A USAEC-Owned Facility

January through December 1973

George J. Werkema and Milton A. Thompson

INTRODUCTION

The Rocky Flats Plant is owned by the U. S. Government and operated by Dow Chemical U.S.A. under contract with the U. S. Atomic Energy Commission. The plant is located in Jefferson County, Colorado, about 16 air miles northwest of Denver (Figure 1).

The site consists of about 2,520 acres of fenced property. At the approximate center of the site is a 384-acre, controlled area that contains all of the Plant's major structures.

The Rocky Flats Plant is primarily a radioactive metal fabrication and chemical processing plant. Its mission involves foundry, fabrication, plutonium recovery and purification operations, and associated support functions.

Annual precipitation recorded at the site during 1973 was 21.55 inches. For the 21-year period, 1952 through 1973, the average annual rainfall was 15.84 inches. The extreme temperatures recorded during 1973 were −7 to 97 °F, with an annual mean temperature of 47 °F. The mean wind velocity was 8.6 miles per hour, with a peak gust of 92 miles per hour on January 12, 1973. Peak gusts in excess of 50 miles per hour occurred monthly, except during late summer and early fall. Hourly observations showed the predominant wind direction during 1973 was from the west. This direction accounted for 22% of wind-direction data.

Assorted low-growing prairie grasses, prickly pear, and spanish bayonet cactus constitute the main ground cover. Cottonwood trees grow adjacent to the watercourses.

Surface water runoff from the Rocky Flats Plant is from west to east. Runoff is carried from Plant property by two major drainage basins, the North and South forks of Walnut Creek on the north, and Woman Creek to the south. South Walnut Creek is the main effluent watercourse. The confluence of North and South Walnut Creek is one-half mile east of the Plant's eastern boundary (Figure 2). One mile east of the confluence is Great Western Reservoir, the water supply for the city of Broomfield. Woman Creek flows east from Rocky Flats into Standley Lake or it can be diverted into Mower Reservoir, a source of irrigation water. Standley Lake is the water supply for the city of Westminster and portions of the Thornton-Northglenn area. North Walnut Creek, South Walnut Creek, and Woman Creek are effluent release routes and have been designated A, B, and C, respectively.

The environmental monitoring program at the Rocky Flats Plant is the responsibility of the Environmental Sciences and Waste Control Department's Environmental Control group. Most of the information and data contained in this report were released monthly to the Rocky Flats Area Office of the U. S. Atomic Energy Commission, the Division of Occupational and Radiological Health of the Colorado Department of Health, and the Regional Office of the Environmental Protection Agency. Concentrations of plutonium in Rocky Flats and community ambient air and airborne plutonium releases are presented for the first time in this report.

The Colorado Department of Health also maintains air, soil, and water sampling programs around the Rocky Flats site as a portion of its statewide surveillance. The Jefferson County Health Department performs monthly sewage plant effluent sampling and analysis and has a continuous particulate air sampler on the plant site that is operated by the Colorado Department of Health. The Health and Safety Laboratory of the U. S. Atomic Energy Commission maintains three particulate air sampling stations in the vicinity of the Rocky Flats Plant and periodically performs soil sampling and analysis. Additional monitoring is performed by the U. S. Environmental Protection Agency through its studies of accumulations of plant effluent materials in various environmental media.

SUMMARY

Results of the environmental monitoring program in the Rocky Flats vicinity indicate the average environmental concentrations of plutonium-239 in air and water during 1973 were less than two percent of applicable U. S. Atomic Energy Commission Radioactivity Concentration Guides. Average concentrations of americium-241 and hydrogen-3 (tritium) in water samples were less than one percent of applicable U. S. Atomic Energy Commission Radioactivity Concentration Guides. The annual average concentrations of residual chlorine, settleable solids, and turbidity in Rocky Flats sewage plant effluent did not meet the new wastewater discharge standards promulgated by the Colorado Department of Health in 1973.

MONITORING DATA COLLECTION, ANALYSIS, AND EVALUATION

Applicable Standards

The U. S. Atomic Energy Commission has published radioactivity concentration guides (RCG's)[1] governing concentrations of radionuclides in air (RCG_a) and water (RCG_w) accessible for intake by occupationally exposed individuals, incidentally exposed individuals, and the population at large.

Although the standards for radioactivity relate to concentrations above background, all measurements reported herein include background radioactivity. Numerical values of the standards are cited as appropriate in the tables presented elsewhere in this report.

All radionuclides in plant effluents and environmental samples are assumed to be soluble for purposes of comparison with appropriate concentration standards. This assumption is an additional safeguard since the radioactivity concentration guides for soluble radionuclides are more restrictive than those for insoluble radioactive materials.

During 1973, concentrations of total long-lived alpha activity in airborne effluents from plutonium areas were maintained below 60×10^{-15} microcuries per milliliter (μCi/ml), the soluble plutonium concentration guide value for an individual in an uncontrolled area. All references to plutonium standards in this report pertain to plutonium-239 unless otherwise noted.

Airborne effluents from uranium areas were maintained below 3×10^{-12} μCi/ml during 1973. The concentration of uranium plus plutonium in effluent water at the plant boundary was maintained below 1600×10^{-9} μCi/ml, the soluble plutonium concentration guide value for a suitable sample of an exposed population. The comparable standard for americium-241 is 1300×10^{-9} μCi/ml. The Environmental Protection Agency's discharge limitation for beryllium is 10 grams in a 24-hour period.[2]

Chemical and bacteriological parameters of effluent water from plant operations are compared with waste water discharge standards promulgated by the Colorado Department of Health,[3] or by the U. S. Environmental Protection Agency,[4] whichever are more restrictive.

Airborne Effluent Monitoring

Exhaust air from Rocky Flats production and research facilities was sampled continuously. In the plutonium facilities, there were at least two sampling points located in each exhaust air duct

downstream from the final stage of filters. The filterable particulate component of the sample stream was collected on Gelman Type E glass fiber filter media. Particulate samples were collected weekly in uranium and beryllium facilities and three times each week in plutonium facilities. Each sample was analyzed for total long-lived alpha-emitting radionuclides and beryllium, as appropriate. Beginning in July 1973, samples from plutonium facilities were composited weekly and analyzed specifically for plutonium. All references to plutonium concentrations in this report pertain to plutonium-238, 239, and 240 unless otherwise noted.

Plutonium was determined in effluent and environmental samples by a radiochemical technique in which plutonium was separated from other radionuclides by ion exchange chromatography,[5] electroplated on a stainless steel disk, and analyzed by alpha pulse height spectrometry. The chemical recovery of that analytical procedure for plutonium was determined by adding a standard aliquot of a plutonium-236 tracer. Effluent beryllium concentrations were determined using the atomic absorption method.[6]

The Minimum Detectable concentration (MDC) for effluent samples from plutonium facilities was 0.002×10^{-12} μCi/ml by direct counting. The effluent MDC from uranium facilities was 0.001×10^{-12} μCi/ml by direct counting, and the MDC for a beryllium effluent sample was 0.0002 $\mu g/m^3$.

Table 1 shows the quantities of radionuclides and beryllium released from plant facilities during 1973. The releases of total long-lived alpha-emitting radionuclides shown in Table 1 include long-lived alpha activity due to natural background.

Data Reduction

Throughout the data presented, samples that had concentrations below the MDC were considered as having the MDC for averaging purposes. When one or more MDC values are included in a set of values, the computed mean value of that set is indicated by a "less than" sign (<). The error term (±%) associated with maximum concentrations (C_{max}) of total long lived alpha represents the counting error at the 95 percent confidence level. The average concentrations (C_{avg}) are represented by pairs of numbers that define the 95% confidence interval for C_{avg}. This interval is centered at $\bar{c}$ and is bounded by the percentage deviations from $\bar{c}$. The probability that C_{avg} lies within the stated interval is 95%, or

$$P\left[\left(\bar{c} - t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_i^2 - n\bar{c}^2}{n(n-1)}}\right) \leq C_{avg} \leq \left(\bar{c} + t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_i^2 - n\bar{c}^2}{n(n-1)}}\right)\right] = 0.95,$$

where

$\bar{c}$ – is the arithmetic mean of observed concentrations and is volume weighted whenever the volume is measured,

$t_{0.975}$ – is taken from a standard t-test table,

n – is the number of samples, and

c_i – is an individual observed concentration.

Ambient Air Monitoring

Ambient air was sampled continuously at 13 locations within and on the perimeter of the Rocky Flats Plant exclusion area (Figure 3). Gast, Model 0465-V4A-025 sampling pumps were used to draw air through Gelman Type E glass fiber filter media at a sampling rate of two cubic foot per minute (cfm). The filters were collected five days each week and analyzed for total long-lived alpha-emitting radionuclides. The sample collected on Thursday of each week was further analyzed for total long-lived beta-emitting radionuclides. Beginning in July 1973, the daily samples were composited monthly and analyzed for plutonium. Sample MDCs for long-lived alpha activity in the Plant's exclusion area ranged between 0.0055×10^{-12} μCi/ml for a daily sample to 0.0018×10^{-12} μCi/ml for a sample collected over the weekend. The MDC for long-lived beta activity in these samples was typically 0.0629×10^{-12} μCi/ml.

Table 2 shows the volume-weighted, monthly, arithmetic, average concentrations of total long-lived alpha-emitting radionuclides in airborne particulates at sample stations within the Plant's exclusion area during the first half of 1973. The average concentration of total long-lived alpha-emitters in ambient air at all exclusion area stations during the first half of 1973 was $<6.0 \pm 17\% \times 10^{-15}$ μCi/ml. This concentration was less than 10% of the RCG_a for soluble plutonium in ambient air accessible to incidentally exposed individuals. Plutonium concentrations in ambient air within the exclusion area during the last half of 1973 were obtained by radiochemical analysis of monthly composite samples. The results are shown in Table 3. The average concentration of plutonium in ambient air at all exclusion area stations during the last half of 1973 was $<1.21 \pm 99\% \times 10^{-15}$ μCi/ml. This concentration was less than 2% of the RCG_a for soluble plutonium in ambient air accessible to incidentally exposed individuals.

The volume-weighted, monthly, arithmetic, average concentrations of long-lived beta-emitting radionuclides in airborne particulates of sample stations within the exclusion area during 1973 are given in Table 4. The annual, average concentration of long-lived beta emitters at all exclusion area stations during 1973 was $<0.119 \times 10^{-12}$ μCi/ml. This concentration was less than 0.12% of the RCG_a for total long-lived beta activity in ambient air accessible to incidentally exposed individuals.

Airborne particulate samples were collected at 12 locations surrounding the Rocky Flats Plant between two and four miles distance from the plant center (Figure 4). Air was drawn continuously through Delbag Microsorban filter media at a 27 cfm sampling rate. Beginning in April 1973, samples were collected three days each week, composited monthly, and radiochemically analyzed specifically for plutonium. The MDC for plutonium in those samples was 0.002×10^{-15} μCi/ml for a 30,000 m^3 sample volume.

Table 5 shows the volume-weighted, monthly, arithmetic, average concentrations of plutonium in filterable airborne particlates at the two- to four-mile sample stations. The annual, average concentration of plutonium in ambient air at those stations during 1973 was $<0.053 \pm 53\% \times 10^{-15}$ μCi/ml. That concentration was less than 0.26% of the RCG_a for soluble plutonium in public areas. The monthly average concentrations of plutonium at those stations are graphed in Figure 5.

Airborne particulate samples were collected at 9 locations in or near population centers in the vicinity of the Rocky Flats Plant. Those locations, shown in Figure 4, included Boulder, Broomfield, Denver, Golden, Lafayette, Marshall, Westminster, northwest Arvada (S-18), and Coal Creek Canyon (S-11). Beginning in March 1973, air was drawn continuously through Gelman Type E glass fiber filter media at a sampling rate of 2 cfm. Prior to March 1973, community ambient air was sampled for 10 minutes each hour. Samples were collected weekly and analyzed for total long-lived alpha- and beta-emitting radionuclides. Beginning in July 1973, weekly samples were composited monthly and analyzed for plutonium. The MDC for long-lived alpha activity in community samples was typically 0.0008×10^{-12} μCi/ml, whereas the total long-lived beta activity MDC's were about 0.0094×10^{-12} μCi/ml. The MDC for plutonium in ambient community samples was 0.015×10^{-15} μCi/ml for a 3,000 m^3 sample.

The monthly, volume-weighted, arithmetic, average concentrations of long-lived alpha-emitting radionuclides in ambient air at community samplers during the first half of 1973 are shown in Table 6. The average concentration of long-lived alpha emitters during that period at all community samplers was $<2.6 \pm 20\% \times 10^{-15}$ μCi/ml. That concentration was less than 13% of the RCG_a for soluble plutonium in public areas.

Monthly concentrations of plutonium at community air sample stations during the last half of 1973 are shown in Table 7. During that period, the average concentration of plutonium in population centers near the Rocky Flats Plant was $<0.264 \pm 163\% \times 10^{-15}$ μCi/ml. That concentration was less than 1.3% of the RCG_a for soluble plutonium in public areas. A single anomalous result from a sample collected at Golden during July 1973 was responsible for elevating the six-month average above typical background concentrations for the area.

The other six-month station averages shown in Table 7 are typical of background from global fallout.

Table 8 presents the monthly average concentrations of long-lived beta-emitting radionuclides in ambient air at community samplers during 1973. The annual, average concentration of long-lived beta emitters at all community samplers was $<0.038 \pm 14\% \times 10^{-12}$ μCi/ml. That concentration was less than 0.1% of the RCG_a for total long-lived beta activity in public areas.

Waterborne Effluent Monitoring

Waste water discharged from the Rocky Flats Plant consisted of treated sanitary and process waste, cooling tower blowdown, steam condensate, and filter backwash from the water treatment plant. Sanitary wastes were treated in an activated sludge, secondary treatment facility, then discharged to the "B" branch (southernmost) of Walnut Creek (Figure 2). Four holding ponds, B-1, B-2, B-3, and B-4 on the "B" branch of Walnut Creek provided additional treatment of water discharged from the sanitary waste treatment facility. Ponds B-1 and B-2 were equipped to impound accidental spills.

The "A" branch of Walnut Creek received cooling water blowdown and steam condensate from process and laboratory facilities on the north side of the plant reservation. Three holding ponds, A-1, A-2, and A-3 were located on the "A" branch of Walnut Creek, with A-1 and A-2 being equipped to impound accidental spills.

Water treatment plant filter backwash and cooling tower blowdown from process facilities on the south side of the plant reservation were discharged to Woman Creek. One holding pond, C-1, was located on Woman Creek and was usable for impounding accidental spills.

Water was sampled continuously and collected daily from the outfalls of Ponds A-3, B-4, and C-1 (Figure 2). The daily samples were composited into weekly samples for analysis of uranium plus plutonium (gross alpha) and specifically for plutonium. Uranium and plutonium were isolated from other long-lived alpha emitters by ion exchange chromatography,[5] and their concentrations determined by alpha pulse height spectrometry. Weekly samples from Pond B-4 were also radiochemically analyzed for americium. The chemical recovery of the analytical procedure for plutonium was determined by adding a plutonium-236 tracer. Americium recovery was determined by a curium-244 tracer. The MDCs for uranium, plutonium, and americium in water samples were identical and equal to 0.01×10^{-9} μCi/ml.

During 1973, sanitary waste was combined with treated and low-level process waste for final treatment at the sewage treatment plant. Annual, average concentrations of chemical and biological parameters of routine sewage plant effluent samples are shown in Table 9 and compared with applicable discharge water quality standards. The annual, average concentrations of residual chlorine, settleable solids, and turbidity in the Rocky Flats sewage plant effluent did not meet the new wastewater discharge standards promulgated by the Colorado Department of Health in 1973. A tertiary treatment facility, which will be completed in 1974, will remove solids and turbidity and permit more efficient operation of the chlorine contact basin.

Concentrations of uranium plus plutonium, and plutonium in water sampled at the outfalls of Ponds A-3, B-4, and C-1 are shown in Tables 10, 11, and 12, respectively. The annual, average concentrations of plutonium in the outfalls of Ponds A-3, B-4, and C-1 during 1973 were $<0.29 \pm 37\% \times 10^{-9}$ μCi/ml ($<0.02\%$ of RCG_W) $7.37 \pm 47\% \times 10^{-9}$ μCi/ml (0.46% of RCG_W), and $<0.18 \pm 42\% \times 10^{-9}$ μCi/ml ($<0.01\%$ of RCG_W), respectively. The monthly, average plutonium concentrations in Pond B-4 are graphed in Figure 6. The annual, average americium-241 concentration in Pond B-4 effluent during 1973 was $<1.79 \pm 122\% \times 10^{-9}$ μCi/ml, as shown in Table 13. That concentration was less than 0.14% of the RCG_W for soluble americium-241 in public areas.

Walnut Creek was sampled continuously during 1973 at Indiana Street, which is downstream from the confluence of the stream's five tributaries and approximately one mile east of the Plant's east boundary. A sample was collected daily; the

samples were composited weekly and analyzed for uranium plus plutonium, plutonium, and americium. Results of the analyses for uranium plus plutonium and plutonium are shown in Table 14. The annual, average concentrations of uranium plus plutonium and plutonium at the Indiana Street location were 11.43 ±60% X 10^{-9} μCi/ml (0.27% of RCG_W) and 3.11 ±43% X 10^{-9} μCi/ml (0.19% of RCG_W), respectively. The annual, average concentration of americium-241 in Walnut Creek at Indiana Street was <1.31 ±81% X 10^{-9} μCi/ml as shown in Table 13. That concentration was less than 0.10% of the RCG_W for soluble americium-241 in public water supplies.

Regional Water Monitoring

Water samples were collected weekly from two reservoirs and nine tap water locations around the Rocky Flats and greater Denver areas. The reservoirs included Great Western Reservoir, which is the Broomfield water supply, and Standley Lake, which served Westminster and portions of the Thornton-Northglenn area (Figure 4). Tap or treated water was collected from the surrounding communities of Arvada, Boulder, Broomfield, Denver, Golden, Lafayette, Louisville, Thornton, and Westminster. The weekly samples were composited monthly and analyzed for uranium plus plutonium and plutonium. These data are summarized in Table 15. The annual, average plutonium concentration was <0.06 ±45% X 10^{-9} μCi/ml in reservoir water samples and <0.07 ±34% X 10^{-9} μCi/ml in community water samples. These concentrations were less than 0.004% of the RCG_W for soluble plutonium in public water supplies. The concentration of americium-241 was also determined in water samples from Great Western Reservoir and Standley Lake. Table 13 presents the results of those analyses. The annual, average americium-241 concentrations in Great Western Reservoir and Standley Lake were <0.16 ±148% X 10^{-9} μCi/ml (0.01% of RCG_W) and <0.20 ±185% X 10^{-9} μCi/ml (<0.02% of RCG_W), respectively.

In September 1973, water samples were collected from additional area reservoirs, lakes, and streams. Samples were collected to a distance of about 20 miles from the Plant and were analyzed for uranium plus plutonium and specifically for plutonium. The MDCs for uranium plus plutonium and plutonium in those samples were identical and equal to 0.01 X 10^{-9} μCi/ml. The data presented in Table 16 show the annual, average plutonium concentration in those samples was <0.31 ±0.76% X 10^{-9} μCi/ml. That concentration was less than 0.02% of the RCG_W for soluble plutonium in public areas.

Soil Sampling

The geometry of all soil samples is carefully controlled by driving a 10-cm by 10-cm cutting tool 5 cm into undisturbed soil and excavating the soil contained within the tool cavity. The samples are oven dried at 120 °C, then weighed, homogenized, and sieved to remove the coarser rubble. Ten grams of pulverized soil are prepared for plutonium analysis using the method reported by Talvitie.[7] The chemical recovery of the analytical procedure for plutonium is determined by adding a plutonium-236 tracer. The MDC for plutonium in these samples is <0.03 X 10^{-6} μCi/g (dry weight). There are no Federal standards for the concentration of plutonium in soil.

Two land areas within the Rocky Flats Plant site were studied extensively during 1973. An aerial radiological survey of the site in 1973 indicated maximum radiation levels about 5 times natural background within a 1-hectare area southeast of a former oil storage area, which is now covered with asphalt. Soil samples collected by Dow Health Physics personnel in 1970 and subsequent years indicated the presence of plutonium in the soil in the same area. The maximum concentration observed in 1970 was 26 μCi/m^2. The 1970 soil analysis data were published in a report by Michels.[8]

Subsequent to the aerial survey, ground surveys of the 1-hectare area, using sensitive field instruments for detecting low-energy radiation (FIDLER), were made by the USAEC Health and Safety Laboratory and by Dow Environmental Control. An isorad map from data provided by the Dow survey is shown in Figure 7. Agreement between results of the Health and Safety Laboratory and Dow surveys was good. Recent radiochemical analyses of a limited number of soil samples from the area have yielded plutonium concentrations up to 99.0 $\mu Ci/m^2$. Those samples were taken from locations indicated by the FIDLER survey and were not intended to correspond to previously sampled locations.

In a second study, 200 soil samples were collected at 50-foot intervals along five north-south traverses between the Plant's security and boundary fences to the east. The range of plutonium concentrations in the soil from that area was 0.003 to 9.72 $\mu Ci/m^2$. The samples were collected to determine the sensitivity and calibration factor for an aerial radiological survey by personnel from EG&G, Incorporated.

Sixty routine soil samples were collected during 1973 in the plant environs. Samples were collected each 18 degrees of arc on circles of 1-, 2-, and 5-mile radius, concentric with the center of the plant, and analyzed for plutonium. Compared to previous years' data, the 1973 values for plutonium in soil appeared significantly lower. This apparent decrease was attributed to improved sensitivity and reliability of the radiochemical method of analysis.

The 1973 data are displayed on an azimuthal map in Figure 8. This map indicates the majority of anomalous values were found in samples collected in the eastern sector between N54°E and E54°S. The distribution of plutonium in this sector is related to the westerly, prevailing winds at Rocky Flats.

Tritium

Tritium was released in plant effluent water during 1973 as the result of processing a shipment of plutonium that, unknown to Rocky Flats Plant personnel, had been contaminated with tritium by another USAEC facility. To prevent a recurrence of such an incident, procedures have been established to detect tritium and other radionuclides in all incoming shipments and in plant effluents. This incident has been investigated by the USAEC[9] and by the USEPA.[10]

Beginning in October 1973, water sampled continuously at the outfalls of Ponds A-3, B-4, C-1, and in Walnut Creek at Indiana Street was analyzed daily for tritium by liquid scintillation spectrometry. The water sample collected weekly at Great Western Reservoir was also analyzed for tritium. The average concentrations of tritium in those samples are summarized in Table 17.

Sanitary Landfill

The Rocky Flats Plant sanitary landfill is located at the west end of an arroyo that collects surface runoff water tributary to Walnut Creek. Except during infrequent periods of high rainfall, the "Landfill" branch of Walnut Creek is dry along most of its length. Two earthen dams were constructed in the "Landfill" branch in September 1973 to retain landfill seepage water in which concentrations of tritium above background were detected. As the ponds filled, the water was transferred to low-level, process-waste storage ponds.

Landfill seepage water has been analyzed daily since October 1973 for tritium and other radionuclides. The decrease in tritium concentration is shown graphically in Figure 9.

ASSESSMENT OF THE ROCKY FLATS PLANT'S CONTRIBUTION TO PUBLIC RADIATION DOSE

Throughout this report, it has been assumed that plutonium discharged in Rocky Flats Plant effluents is in a soluble chemical form. This assumption is conservative because the RCGs for insoluble plutonium in air and water are larger than those for soluble plutonium.[1] Radioactivity Concentration Guides (formerly Maximum Permissible Concentrations) were originally recommended by the International Commission on Radiological Protection (ICRP) [11]

The ICRP selected bone as the critical organ for uptake of soluble plutonium. The assumption was made that the residence time in any intermediate organs, such as lung, the lymphatic system, or the circulatory system, was relatively short for purposes of long-term dose assessment. The ICRP derived RCGs for radionuclides that localize in the bone on the basis of a direct comparison with radium-226, taking into account such individual differences among radionuclides as radioactive decay, daughter products, nonuniform distribution of radionuclides in the bone, essentialness of exposed tissue, and radiosensitivity of exposed tissue.

The Radioactivity Concentration Guides for soluble plutonium are those concentrations in air and water that, after fifty years continuous exposure, will result in a specific accumulation in the bone of an exposed individual. That accumulation is the amount of plutonium biologically equivalent to 0.003 μCi of radium-226 in exposure of the population at large. The amount of plutonium taken to be biologically equivalent to 0.003 μCi of radium-226 in the bone is 0.001 μCi. The 50-year bone accumulations presented in the subsequent discussion were calculated by multiplying 0.001 μCi by the ratio of the observed concentration to the RCG, that is,

$$\text{Accumulation} = 0.001\ \mu\text{Ci} \times \frac{C_{avg}}{RCG}.$$

There is no direct means to compute radiation dose commitments resulting from accumulation of nonuniformly distributed alpha-emitting radionuclides in bone. For purposes of uniformity in reporting, population dose commitments in this report have been estimated by multiplying the appropriate Radiation Protection Standard by the ratio of the observed radionuclide concentration to the RCG, that is,

$$\text{Dose} = \text{Standard} \times \frac{C_{avg}}{RCG}$$

The Radiation Protection Standard for dose to the bone for the population at large is 1 rem per year.

Air samplers are located on those public highways nearest the Rocky Flats Plant boundary. The plutonium concentrations in air samples collected at those locations during 1973 are shown in Table 5. The volume-weighted, annual, average concentration of plutonium in air at those stations during 1973 was less than 0.053×10^{-15} μCi/ml. That concentration was less than 0.26% of the RCG_a for soluble plutonium in air accessible to the population at large, and was indistinguishable from normal fluctuations in plutonium concentration in air from world-wide fallout. After 50 years of continuous exposure to air containing 0.053×10^{-15} μCi/ml plutonium, an exposed individual would have a bone accumulation of 2.6×10^{-6} μCi of plutonium and an annual dose commitment to the bone of less than 2.6×10^{-3} rem.

Air samplers are located in population centers near the Rocky Flats Plant. The plutonium concentration in air samples collected at those locations during July-December 1973 are shown in Table 7. The volume-weighted, six-month average concentration of plutonium in air at those stations, including one suspect result from the sample collected at Golden in July, was less than 0.264×10^{-15} μCi/ml. This concentration was less than 1.3% of the RCG_a for soluble plutonium in air accessible to the population at large. After 50 years of continuous exposure to air containing 0.264×10^{-15} μCi/ml plutonium, an exposed individual would have a bone accumulation of 13×10^{-6} Ci of plutonium and an annual dose commitment to the bone of less than 1.3×10^{-2} rem.

Samples of tap water from population centers near the Rocky Flats Plant are collected weekly, composited monthly, and analyzed for plutonium. Results of analyses are shown in Table 15. The sample-weighted, annual, average concentration of plutonium in community water during 1973 was less than 0.07×10^{-9} μCi/ml. This concentration was less than 0.004% of the RCG_w for soluble

plutonium in water accessible to the public at large. After 50 years of drinking only water containing 0.07×10^{-9} μCi/ml plutonium, an exposed individual would have a bone accumulation of 4×10^{-8} μCi of plutonium, and an annual dose commitment to the bone of less than 4×10^{-5} rem.

The critical organ for tritiated water exposure is taken to be body tissue.[11] Tritium equilibrates rapidly with protium (hydrogen-1) atoms in body tissue and fluids. An evaluation of dose can be made by multiplying the radiation protection standard, 0.17 rem, by the ratio of the observed average concentration in drinking water to the applicable RCG.

Tritiated water was discharged to Great Western Reservoir, the water supply for the city of Broomfield, as the result of an accidental release from the Rocky Flats Plant during May 1973.[9] Beginning in October, water samples were collected weekly from Great Western Reservoir and analyzed for tritium. The average concentration of tritium in Great Western Reservoir water during October-December 1973, shown in Table 17, was 8.221×10^{-6} μCi/ml. This concentration is 0.82% of the RCG_W for tritium in water accessible to the population at large. The dose commitment to an individual drinking only water containing 8.221×10^{-6} μCi/ml tritium for seven months is 8×10^{-4} rem.

For purposes of comparison, the annual natural background dose commitment for a person living in Colorado is about 0.2 rem, including external radiation from radionuclides in soil, cosmic sources, and internal radiation from natural radionuclides such as potassium-40, which are incorporated in biological material.

REFERENCES

1. Standards for Radiation Protection, U. S. Atomic Energy Commission, AEC Manual, Chapter 0524, 1968.

2. National Emission Standards for Hazardous Air Pollutants, 40 CFR Part 61, Subpart C (Proposed), U. S. Environmental Protection Agency, 1971.

3. Standards for the Discharge of Wastes, Water Pollution Control Commission, Colorado Department of Health, 1972.

4. Secondary Treatment Information, 40 CFR, Part 133, U. S. Environmental Protection Agency, August 14, 1973.

5. "Standard Laboratory Procedures for the Determination of Radioactivity and Chemical Concentrations in Environmental and Bioassay Samples," D. L. Bokowski, (Ed), USAEC RFP-2039, Rocky Flats Division, Dow Chemical U.S.A., to be published.

6. D. L. Bokowski, "Rapid Determination of Beryllium by a Direct-Reading Atomic Absorption Spectrometer," *Am. Ind. Hyg. Assoc.*, 29, pp 474-481 (1968).

7. N. A. Talvitie, *Anal. Chem.*, 43, pp 1827-1830 (1971).

8. D. E. Michels, "Diagnosis of Plutonium Re-entrained in Air," USAEC RFP-1927, Rocky Flats Divison, Dow Chemical U.S.A., April 27, 1973.

9. "Investigation of the Tritium Release Occurrence at the Rocky Flats Plant," U. S. Atomic Energy Commission, November 26, 1973.

10. "Investigative Report of the 1973 Tritium Release at the Rocky Flats Plant in Golden, Colorado," U. S. Environmental Protection Agency, Region VIII, to be published, (1974).

11. Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959). *Health Physics* 3, 1960.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES 1 through 17

Table 1. Airborne Radionuclides Released to Atmosphere.

Month	Plutonium Facilities μCi*	Enriched Uranium Facilities μCi**	Depleted Uranium and Research Facilities μCi**	Beryllium Facilities grams ***
January	<11.36	< 0.69	< 3.19	<0.23
February	< 3.49	< 0.31	< 2.14	<0.28
March	< 2.44	< 1.54	< 1.10	<0.13
April	< 3.79	< 5.49	< 1.58	<0.22
May	< 2.88	< 0.54	< 1.96	<0.09
June	< 2.16	< 0.26	< 8.09	<0.14
July	< 2.83	< 0.44	<31.75	<0.33
August	< 1.78	< 0.28	< 4.08	<0.34
September	< 2.14	< 0.42	< 1.04	<0.55
October	< 5.39	< 0.55	< 1.45	<3.32
November	<30.68	< 0.04	< 2.4	<0.75
December	< 8.45	< 0.10	< 4.66	<0.70
Total	<77.39	< 10.66	<63.44	<7.1

*Radiometrically determined as total long-lived alpha activity during January-June. Radiochemically determined as plutonium-239 during July-December.

**Radiometrically determined as total long-lived alpha activity.

***The USEPA discharge limitation for beryllium is 3,650 grams/year.

Table 2. Total Long-Lived Alpha Activity in Rocky Flats Ambient Air.

Volume-Weighted Station Averages Concentrations (X 10^{-15} μCi/ml).

Station	January	February	March	April	May	June
S-1	<4.2 ±34%	<5.0 ±28%	<8.7 ±123%	<4.8 ±29%	< 4.8 ±35%	< 4.9 ± 37%
S-2	<4.6 ±22%	<4.9 ±32%	<6.4 ± 62%	<5.3 ±40%	< 5.1 ±29%	< 4.9 ± 38%
S-3	<4.9 ±51%	<5.0 ±28%	<6.2 ± 40%	<5.0 ±33%	< 5.6 ±36%	< 5.7 ± 41%
S-4	<4.5 ±37%	<4.1 ±30%	<4.5 ± 38%	<5.2 ±28%	< 5.3 ±34%	< 5.4 ± 31%
S-5	<4.1 ±28%	<4.2 ±35%	<4.4 ± 37%	<7.3 ±43%	*	*
S-6	<3.8 ±30%	<4.2 ±34%	<4.8 ± 38%	<5.3 ±28%	< 4.9 ±32%	< 5.2 ± 31%
S-7	<4.5 ±25%	<4.1 ±66%	<5.0 ± 38%	<5.8 ±33%	<17.0 ±42%	< 5.7 ± 35%
S-8	<5.1 ±31%	<6.2 ±24%	<7.9 ± 45%	<6.6 ±34%	< 6.4 ±33%	< 9.0 ± 47%
S-9	<4.4 ±33%	<4.0 ±31%	<8.9 ± 49%	<7.5 ±50%	< 4.7 ±40%	< 5.3 ± 42%
S-10	<4.2 ±33%	<4.5 ±39%	<5.6 ± 60%	<5.8 ±34%	< 5.7 ±54%	< 5.4 ± 31%
S-50	<5.5 ±54%	<5.7 ±28%	<4.6 ± 36%	<6.8 ±50%	<10.0 ±31%	<34.2 ±223%
S-51	<5.1 ±35%	<5.4 ±42%	<5.9 ± 40%	<6.2 ±32%	< 5.8 ±47%	< 6.4 ± 38%
S-52	<4.4 ±34%	<3.9 ±34%	<5.5 ± 41%	<4.9 ±58%	< 7.4 ±92%	< 4.4 ± 34%
Volume-weighted average	<4.5 ±10%	<4.7 ± 9%	<6.1 ± 18%	<6.0 ±11%	< 6.9 ±14%	< 8.2 ± 75%

January-June 1973 Summary

Station	n	Vol (m^3)	Concentration (X 10^{-15} μCi/ml)			% of
			C_{min}	C_{max}	C_{avg}	RCG_a**
S-1	122	14181.0	<1.8	118.9 ±17%	< 5.5 ± 36%	< 9.2
S-2	120	13773.5	<1.8	45.4 ±27%	< 5.2 ± 17%	< 8.7
S-3	115	13284.5	<1.8	26.3 ±36%	< 5.4 ± 16%	< 9.0
S-4	118	13529.0	<1.8	15.8 ±46%	< 4.8 ± 13%	< 8.0
S-5	81	9291.0	<1.8	27.0 ±35%	< 4.9 ± 19%	< 8.2
S-6	122	14181.0	<1.8	18.4 ±43%	< 4.7 ± 13%	< 7.8
S-7	114	13366.0	<1.8	79.9 ±10%	< 7.1 ± 20%	<11.8
S-8	117	13366.0	<1.8	39.4 ±29%	< 6.9 ± 16%	<11.5
S-9	121	14099.5	<1.8	44.0 ±16%	< 5.8 ± 19%	< 9.7
S-10	111	12795.5	<1.8	20.2 ±41%	< 5.1 ± 16%	< 8.5
S-50	121	14099.5	<1.8	727.3 ± 7%	<10.9 ±109%	<18.2
S-51	96	11002.5	<1.8	23.6 ±38%	< 5.7 ± 16%	< 9.5
S-52	103	11736.0	<1.8	47.3 ±27%	< 5.1 ± 22%	< 8.5
Summary	1461	168705.0	<1.8	727.3 ± 7%	–	–
Volume-weighted average	–	–	–	–	< 6.0 ± 17%	<10.0

*Sampler S-5 out of service.

**The RCG_a for soluble plutonium-239 in ambient air accessible to incidentally exposed individuals is 60 X 10^{-15} μCi/ml.

Table 3. Plutonium in Rocky Flats Ambient Air.

Monthly Composite Station Concentrations (X 10^{-15} μCi/ml).

Station	July	August	September	October	November	December
S-1	4.795	0.124	0.105	0.276	0.085	0.032
S-2	0.067	0.312	0.160	0.326	0.164	0.120
S-3	0.229	0.649	0.061	0.195	0.188	0.180
S-4	0.188	0.522	0.148	0.217	0.223	0.239
S-5	0.129	0.097	0.095	0.005	0.072	0.062
S-6	0.177	0.495	0.134	0.219	0.370	0.168
S-7	1.273	0.030	0.604	0.906	0.306	0.462
S-8	1.687	4.109	1.017	2.864	2.478	1.457
S-9	0.120	0.258	0.304	0.519	0.117	0.195
S-10	0.582	0.103	0.233	0.338	0.613	0.403
S-50	0.383	1 934	0.691	1.520	0.456	0.438
S-51	0.094	*	*	*	0.832	45.531
S-52	0.928	0.317	0.182	0.861	0.308	0.486
Volume-weighted average	0.539 ± 156%	0.369 ± 224%	0.211 ± 106%	0.370 ± 161%	0.497 ± 77%	5.375 ± 138%

July-December 1973 Summary

Station	n	Vol (m^3)	Concentration (X 10^{-15} μCi/ml)			% of RCG_a***
			C_{min}	C_{max}	C_{avg}**	
S-1	6	11994.0	0.032	4.795	1.114 ± 174%	1.8
S-2	6	14765.0	0.067	0.326	0.190 ± 58%	0.3
S-3	6	14680.0	0.610	0.649	0.254 ± 83%	0.4
S-4	6	14765.0	0.148	0.522	0.258 ± 54%	0.4
S-5	6	177750.0	0.005	0.129	0.077 ± 57%	0.1
S-6	6	14684.0	0.134	0.495	0.266 ± 53%	0.4
S-7	6	14765.0	<0.030	1.273	<0.588 ± 80%	<1.0
S-8	6	14765.0	1.017	4.109	2.297 ± 50%	3.8
S-9	6	14435.0	0.117	0.519	0.248 ± 66%	0.4
S-10	6	14033.0	0.103	0.613	0.378 ± 55%	0.6
S-50	6	11909.5	0.383	1.934	0.699 ± 122%	1.1
S-51	3	55932 0	0.094	45.531	6.509 ± 1136%	10.8
S-52	6	14680.0	0.182	0.928	0.507 ± 66%	0.8
Summary	75	389157.5	0.005	45.531	–	–
Volume-weighted average	–	–	–	–	<1.214 ± 99%	<2.0

*Sampler out of service

**Volume-weighted average

***RCG_a for soluble plutonium-239 in ambient air accessible to incidentally exposed individuals is 60 X 10^{-15} μCi/ml.

Table 4. Total Long-Lived Beta Activity in Rocky Flats Ambient Air.

Volume-Weighted Station Averages Concentrations (X 10^{-12} μCi/ml).

Station	January	February	March	April	May	June
S-1	<0.102 ± 100%	<0.112 ± 188%	<0.160 ± 51%	<0.105 ± 103%	<0.081 ± 27%	<0.095 ± 66%
S-2	<0.080 ± 60%	0.178 ± 111%	<0.114 ± 81%	<0.161 ± 102%	<0.112 ± 75%	<0.103 ± 72%
S-3	<0.087 ± 32%	<0.073 ± 61%	0.309 ± 79%	<0.187 ± 154%	<0.079 ± 65%	<0.063 ± 0%
S-4	0.196 ± 56%	<0.122 ± 193%	<0.159 ± 82%	<0 204 ± 85%	<0.082 ± 71%	<0.084 ± 69%
S-5	<0.106 ± 94%	<0.139 ± 696%	<0.154 ± 124%	<0.234 ± 107%	*	*
S-6	<0.089 ± 78%	<0.156 ± 257%	<0 120 ± 70%	<0.134 ± 60%	<0.104 ± 85%	<0.082 ± 73%
S-7	<0.112 ± 69%	<0.063 ± 0%	0.225 ± 89%	<0.171 ± 152%	<0.139 ± 105%	<0.128 ± 63%
S-8	<0.064 ± 4%	<0.138 ± 234%	<0.238 ± 76%	<0.128 ± 101%	<0.099 ± 69%	0.170 ± 47%
S-9	<0.084 ± 68%	<0.063 ± 0%	<0.158 ± 101%	0.130 ± 80%	<0.072 ± 40%	<0.103 ± 72%
S-10	<0.103 ± 109%	<0.155 ± 201%	<0.177 ± 223%	<0.084 ± 81%	<0.097 ± 112%	<0.071 ± 35%
S-50	<0 102 ± 66%	<0.141 ± 216%	<0 238 ± 84%	<0.198 ± 121%	<0.093 ± 89%	<0.064 ± 4%
S-51	<0 150 ± 131%	<0.093 ± 131%	<0.178 ± 119%	<0.063 ± 0%	<0.106 ± 49%	<0.106 ± 50%
S-52	<0.063 ± 0%	<0.176 ± 277%	<0.211 ± 84%	0.102 ± 240%	<0.121 ± 99%	<0.093 ± 102%
Volume-weighted average	<0.103 ± 17%	<0.127 ± 26%	<0.188 ± 18%	<0.153 ± 20%	<0.099 ± 15%	<0.097 ± 14%

Station	July	August	September	October	November	December
S-1	<0.123 ± 52%	<0.108 ± 285%	<0.155 ± 146%	<0.122 ± 56%	0.041 ± 13%	0.062 ± 55%
S-2	<0.137 ± 57%	<0.197 ± 77%	<0.095 ± 33%	<0.141 ± 75%	<0.084 ± 0%	0.118 ± 13%
S-3	<0.123 ± 78%	<0.104 ± 36%	<0.092 ± 29%	<0.141 ± 79%	<0.084 ± 0%	<0.140 ± 53%
S-4	<0.185 ± 61%	<0.166 ± 59%	<0.169 ± 116%	<0.151 ± 71%	<0.132 ± 75%	<0.107 ± 73%
S-6	<0.136 ± 45%	<0.148 ± 50%	<0.151 ± 133%	<0.096 ± 40%	<0.084 ± 0%	<0.101 ± 52%
S-7	<0.167 ± 71%	<0.148 ± 86%	<0.143 ± 76%	<0.151 ± 83%	<0.103 ± 60%	<0.187 ± 105%
S-8	<0.136 ± 76%	<0.147 ± 57%	<0.138 ± 56%	<0.161 ± 75%	<0.092 ± 29%	<0.095 ± 138%
S-9	<0.148 ± 47%	<0.129 ± 50%	<0.097 ± 27%	<0.138 ± 75%	<0.129 ± 108%	<0.122 ± 15%
S-10	<0.092 ± 77%	<0.157 ± 71%	<0.142 ± 176%	<0.120 ± 47%	<0.105 ± 65%	<0.110 ± 9%
S-50	<0.113 ± 60%	*	<0.084 ± 0%	<0.111 ± 43%	<0.138 ± 87%	<0.151 ± 2%
S-51	<0.127 ± 43%	*	*	*	*	*
S-52	<0.108 ± 63%	<0.111 ± 49%	<0.216 ± 118%	<0.124 ± 52%	<0.028 ± 72%	0.046 ± 108%
Volume-weighted average	<0.135 ± 16%	<0.144 ± 15%	<0.135 ± 20%	<0.132 ± 12%	<0.062 ± 37%	<0.086 ± 28%

*Sampler out of service.

Table 4. Total Long-Lived Beta Activity in Rocky Flats Ambient Air. *(Continued)*

Volume-Weighted Station Averages Concentrations ($\times 10^{-12}$ μCi/ml).

January-June 1973 Summary

Station	n	Vol (m^3)	Concentration ($\times 10^{-12}$ μCi/ml) C_{min}	C_{max}	C_{avg}	% of RCG_a**
S-1	25	2037.5	<0.0629	0.248 ± 29%	<0.110 ± 23%	<0.11
S-2	25	2037.5	<0.0629	0.298 ± 27%	<0.120 ± 24%	<0.12
S-3	23	1874 5	<0.0629	0.563 ± 19%	<0.142 ± 41%	<0.14
S-4	25	2037.5	<0.0629	0.315 ± 26%	<0.145 ± 26%	<0.14
S-5	16	1304.0	<0.0629	0.420 ± 22%	<0.157 ± 43%	<0.16
S-6	25	2037.5	<0.0629	0.342 ± 25%	<0.112 ± 26%	<0.11
S-7	23	1874.5	<0.0629	0.508 ± 20%	<0.152 ± 32%	<0.15
S-8	24	1956.0	<0.0629	0.425 ± 22%	<0.144 ± 30%	<0.14
S-9	25	2037.5	<0.0629	0.376 ± 24%	<0.105 ± 28%	<0.10
S-10	23	1874.5	<0.0629	0.359 ± 24%	<0.110 ± 34%	<0.11
S-50	25	2037.5	<0.0629	0.464 ± 21%	<0.142 ± 34%	<0.14
S-51	20	1630.0	<0.0629	0.331 ± 25%	<0.125 ± 31%	<0.12
S-52	22	1793.0	<0.0629	0.403 ± 23%	<0.132 ± 37%	<0.13
Summary	301	24531.5	<0.0629	0.563 ± 19%	–	–
Volume-weighted average	–	–	–	–	<0.130 ± 8%	<0.13

July-December 1973 Summary

S-1	29	6601.5	0.0273	0.368 ± 28%	<0.075 ± 56%	<0.08
S-2	34	3097.0	<0.0839	0.434 ± 26%	<0.133 ± 25%	<0.13
S-3	31	2852.5	<0.0839	0.478 ± 24%	<0.117 ± 25%	<0.12
S-4	34	3097.0	<0.0839	0.604 ± 22%	<0.161 ± 28%	<0.16
S-6	34	3097.0	<0.0839	0.339 ± 29%	<0.125 ± 22%	<0.12
S-7	34	3097.0	<0.0839	0.714 ± 20%	<0.156 ± 30%	<0.16
S-8	34	3097.0	<0.0420	0.640 ± 21%	<0.130 ± 31%	<0.13
S-9	33	3015.5	<0.0839	0.398 ± 27%	<0.134 ± 21%	<0.13
S-10	28	2608.0	<0 0839	0 309 ± 30%	<0.115 ± 24%	<0.12
S-50	26	2445.0	<0.0839	0.294 ± 31%	<0.118 ± 22%	<0.12
S-51	11	1141.0	<0.0839	0.250 ± 34%	<0.127 ± 43%	<0.13
S-52	31	6764.5	<0 0120	0.449 ± 25%	<0.066 ± 66%	<0.07
Summary	359	40913.0	<0.0120	0.714 ± 20%	–	–
Volume-weighted average	–	–	–	–	<0.112 ± 10%	<0.11

January-December 1973 Summary

S-1	54	8639.0	0 0273	0.368 ± 28%	<0.083 ± 31%	<0.08
S-2	59	5134.5	<0 0629	0.434 ± 26%	<0.128 ± 17%	<0.13
S-3	54	4727.0	<0.0629	0.563 ± 19%	<0.127 ± 23%	<0.13
S-4	59	5134 5	<0.0629	0.604 ± 22%	<0.155 ± 19%	<0.16
S-5	16	1304.0	<0.0629	0.420 ± 22%	<0.157 ± 43%	<0.16
S-6	59	5134.5	<0.0629	0.342 ± 25%	<0.120 ± 16%	<0.12
S-7	57	4971.5	<0.0629	0.714 ± 20%	<0.155 ± 21%	<0.16
S-8	58	5053.0	<0 0420	0.640 ± 21%	<0.135 ± 21%	<0.14
S-9	58	5053.0	<0.0629	0.398 ± 27%	<0.122 ± 16%	<0.12
S-10	51	4482.5	<0.0629	0.359 ± 24%	<0.113 ± 19%	<0.11
S-50	51	4482.5	<0.0629	0 464 ± 21%	<0.129 ± 20%	<0.13
S-51	31	2771.0	<0.0629	0.331 ± 25%	<0.126 ± 24%	<0.13
S-52	53	8557.5	<0.0120	0.449 ± 25%	<0.080 ± 42%	<0.08
Summary	660	65444.5	<0.0120	0.714 ± 20%	–	–
Volume-weighted average	–	–	–	–	<0.119 ± 7%	<0.12

*Sampler out of service

**The Radioactivity Concentration Guide (RCG_a) value for total long-lived beta activity in ambient air accessible to incidentally exposed individuals is 100×10^{-12} μCi/ml.

Table 5. Plutonium in Two-to-Four-Mile-Distant Ambient Air.

Monthly Composite Station Concentrations (X 10^{-15} μCi/ml).

Station	January	February	March	April	May	June
S-26	0.161	0.094	0.045	0.038	0.015	0.151
S-27	<0.029	0.266	0.134	0.020	0.045	0.064
S-28	<0.018	0.190	<0.079	0.035	0.014	0.057
S-29	<0.031	0.777	0.127	*	*	*
S-30	<0.013	<0.156	*	*	*	*
S-31	<0.045	0.087	<0.111	0.059	0.021	0.043
S-32	<0.049	0.196	0.340	<0.002	0.027	0.044
S-33	<0.022	0.184	0.051	0.025	<0.002	0.174
S-34	<0 329	0.202	0.046	0.029	0.021	0.015
S-35	0.090	<0.251	<0.236	0.020	<0.005	0.053
S-36	0.238	<0.150	0.065	0.039	0 024	0.050
S-37	<0.177	<0.359	0.211	0.018	0.013	0.141
Volume-weighted average	<0.104 ± 87%	<0.195 ± 99%	<0.128 ± 72%	<0.029 ± 54%	<0.019 ± 65%	0.078 ± 72%

Station	July	August	September	October	November	December
S-26	0.007	0.003	0.013	0 020	0.014	<0.003
S-27	0.010	0.003	0.004	0.010	0.012	0.007
S-28	0.017	<0.002	0.005	0.265	0.005	0.011
S-29	*	*	*	*	*	*
S-30	*	*	*	*	*	*
S-31	0.020	0.002	0.006	0.005	0.023	<0.002
S-32	0.032	*	0.005	0.007	<0.003	0.009
S-33	0.008	0.003	0.010	*	*	*
S-34	0.012	<0.002	0.007	0.219	<0.003	0.008
S-35	0.007	0.006	0.005	0.014	0.022	0.009
S-36	0.017	0.003	0.006	0.012	<0.003	<0.003
S-37	0.008	0.018	0.105	0.008	<0.003	0.007
Volume-weighted average	0.014 ± 58%	<0.005 ± 118%	0.017 ± 187%	0.061 ± 183%	<0.010 ± 95%	<0.007 ± 53%

*Sampler out of service.

Table 5. Plutonium in Two-to-Four-Mile-Distant Ambient Air. (Continued)

Monthly Composite Station Concentrations (X 10^{-15} μCi/ml).

January-June 1973 Summary

Station	n	Vol (m^3)	Pu (Concentrations X 10^{-15} μCi/ml) C_{min}	C_{max}	C_{avg}**	% of RCG_a***
S-26	16	153965.5	0.015	0.161	0.073 ± 142%	0.36
S-27	16	151273.4	0.020	0.266	<0.089 ± 159%	<0.44
S-28	16	165765.2	0.014	0.190	<0 058 ± 181%	<0.29
S-29	7	21025.0	<0.031	0 777	<0.145 ± 1194%	<0.72
S-30	5	30119.0	<0 013	<0.156	<0.108 ± 938%	<0.54
S-31	16	164043.4	0.021	<0.111	<0.061 ± 80%	<0.30
S-32	12	156857.5	<0.002	0.340	<0.116 ± 164%	<0.58
S-33	16	165041.4	<0.002	0.184	<0.068 ± 188%	<0.34
S-34	16	162015.8	0.015	<0.329	<0.088 ± 234%	<0.44
S-35	16	156249.8	<0.005	<0.251	<0.103 ± 160%	<0.52
S-36	15	160923.7	0.024	0.238	<0 080 ± 171%	<0.40
S-37	16	125736.8	0 013	<0.359	<0.115 ± 200%	<0.58
Summary	167	1613021.5	<0.002	0.777	–	–
Volume-weighted average	–	–	–	–	<0.085 ± 54%	<0.42

July-December 1973 Summary

S-26	6	152010.0	0.003	0.020	0.009 ± 128%	0.04
S-27	6	146090.0	0.003	0.012	0.008 ± 65%	0.04
S-28	6	170610.0	<0.002	0.265	0.042 ± 375%	0.21
S-29	*	*	*	*	*	*
S-30	*	*	*	*	*	*
S-31	6	157830.0	<0.002	0.023	0.010 ± 129%	0.05
S-32	5	148940.0	<0.003	0.032	0.011 ± 200%	0.06
S-33	3	67265.0	0.003	0.010	0.007 ± 235%	0.04
S-34	6	145070.0	<0 002	0.219	0.034 ± 390%	0.17
S-35	6	157460.0	0 005	0.022	0.011 ± 72%	0.06
S-36	6	165195.0	<0.003	0.017	0.007 ± 138%	0.04
S-37	6	158550.0	<0.003	0 105	0.021 ± 286%	0.10
Summary	56	1469020.0	<0.002	0.265	–	–
Volume-weighted average	–	–	–	–	0.017 ± 104%	0.08

January-December 1973 Summary

S-26	22	305975 5	0.003	0.161	0.041 ± 129%	0.20
S-27	22	297368.4	0.003	0.266	0.049 ± 142%	0 24
S-28	22	336375 2	<0 002	0.265	<0.050 ± 156%	0 25
S-29	7	21025.0	<0.031	0.777	<0.145 ± 1194%	0.72
S-30	5	30119.0	<0.013	<0.156	<0.108 ± 938%	0.54
S-31	22	321873.4	<0 002	<0 111	<0.036 ± 87%	0 18
S-32	17	305797.5	<0 002	0.340	<0.065 ± 157%	0.32
S-33	19	227306.4	<0 002	0.184	<0.051 ± 158%	0.26
S-34	22	307085 8	<0.002	0.329	<0 063 ± 165%	0.31
S-35	22	313709.8	<0.005	0.251	<0.057 ± 142%	0.28
S-36	21	326118.7	<0 003	0.238	<0.043 ± 157%	0.22
S-37	22	284286.8	<0.003	<0.359	<0.063 ± 178%	0.32
Summary	223	3077041.4	<0.002	0.777	–	–
Volume-weighted average	–	–	–	–	<0.053 ± 53%	0.26

*Sampler out of service.

**Volume-weighted average

***RCG_a for soluble plutonium-239 in ambient air accessible to the population at large is 20 X 10^{-15} μCi/ml.

Table 6. Total Long-Lived Alpha Activity in Ambient Community Air.

Volume-Weighted Station Averages Concentrations (X 10^{-15} μCi/ml).

Community	January	February	March	April	May	June
Boulder	<6.1 ± 96%	< 4.8 ± 71%	<3.5 ± 206%	<2.4 ± 104%	2.6 ± 50%	2.5 ± 110%
Broomfield	*	*	<3 0 ± 145%	<1.8 ± 83%	1.9 ± 72%	2.1 ± 52%
Coal Creek	<1.3 ± 59%	< 1.2 ± 48%	3.1 ± 150%	1.9 ± 31%	2.1 ± 44%	<1.9 ± 163%
Denver	6 8 ± 76%	8.9 ± 133%	5.1 ± 168%	2.7 ± 55%	3.3 ± 63%	2.7 ± 23%
Golden	<5 4 ± 7%	< 6.8 ± 53%	4.1 ± 206%	<2.5 ± 92%	2.1 ± 28%	3.6 ± 42%
Lafayette	<7 8 ± 103%	< 5.0 ± 8%	3.8 ± 251%	2.1 ± 63%	1 7 ± 47%	<1.5 ± 80%
Marshall	<5 7 ± 2%	< 5 6 ± 3%	<3 7 ± 162%	1.9 ± 44%	1.9 ± 40%	2.2 ± 87%
Wagner	<4 5 ± 233%	< 3.7 ± 0%	3 8 ± 532%	1.5 ± 60%	2.1 ± 62%	2.2 ± 15%
Westminster	<8.9 ± 47%	<10.2 ± 38%	3 8 ± 213%	3.0 ± 66%	2.2 ± 62%	1.7 ± 108%
Volume-weighted average	<3.9 ± 45%	< 3.6 ± 53%	<3.7 ± 49%	<2.2 ± 17%	2.2 ± 12%	<2.3 ± 17%

January-June 1973 Summary

Community	n	Vol (m^3)	Concentration (X 10^{-15} μCi/ml)			% of RCG_a**
			C_{min}	C_{max}	C_{avg}	
Boulder	26	9990 7	<0.7	14.5 ± 39%	<3.0 ± 48%	<15.0
Broomfield	16	9193.9	<1.0	6.5 ± 75%	<2 1 ± 41%	<10.5
Coal Creek	26	13415.2	<0.8	6.6 ± 37%	<1 8 ± 33%	< 9.0
Denver	23	10083.5	<1.6	14.0 ± 49%	3.5 ± 52%	17.5
Golden	26	9833 5	<0.7	11.3 ± 34%	<3.1 ± 43%	<15 5
Lafayette	26	9605.5	<0.7	19.4 ± 39%	<2 5 ± 77%	<12.5
Marshall	26	7339.5	<1.3	7.3 ± 42%	<2.6 ± 46%	<13.0
Wagner	20	8045 1	<0.8	22 6 ± 34%	<2.3 ± 107%	<11.5
Westminster	25	8441.3	<0.9	13.3 ± 65%	<2.8 ± 77%	<14 0
Summary	214	85948.2	<0 7	22.6 ± 34%	–	–
Volume-weighted average		–	–	–	<2.6 ± 20%	<13.0

*Sampler out of service

**The RCG_a for soluble plutonium-239 in ambient air accessible to the population at large is 20 X 10^{-15} μCi/ml.

Table 7. Plutonium in Ambient Community Air.

Monthly Composite Station Concentrations (X 10^{-15} μCi/ml).

Community	July	August	September	October	November	December
Boulder	<0.020	0.018	0.064	<0.015	<0.015	0.035
Broomfield	<0.015	<0.015	<0.015	<0.020	0.017	0.033
Coal Creek	<0 020	<0.015	0.028	0.116	0.044	0.067
Denver	<0 020	*	<0.015	<0.020	<0.015	0.037
Golden	10 782	<0.015	0.017	<0.015	<0.020	<0.015
Lafayette	<0 020	<0.015	0.487	0.026	0.055	0 026
Marshall	<0.050	0.035	0.033	0.029	<0.030	0 068
Wagner	<0.030	0 033	0.055	<0.030	<0.020	<0.015
Westminster	<0.020	0.146	*	*	*	<0.030
Volume-weighted average	<1.328 ± 206%	<0.023 ± 181%	<0.093 ± 144%	<0.032 ± 89%	<0.027 ± 46%	<0.035 ± 45%

July-December 1973 Summary

Community	n	Vol (m^3)	Concentration (X 10^{-15} μCi/ml)			% of
			C_{min}	C_{max}	C_{avg}**	RCG_a***
Boulder	6	18095.0	<0 015	0.064	<0.028 ± 73%	<0.14
Broomfield	6	17919 0	<0.015	0.033	<0.019 ± 42%	<0.10
Coal Creek	6	15453.0	<0.015	0.116	<0.045 ± 93%	<0.22
Denver	5	13207.0	<0.015	0.037	<0.021 ± 53%	<0.10
Golden	6	16647.0	<0 015	10.782	<1.717 ± 270%	<8.6
Lafayette	6	16611.0	<0.015	0.487	<0.103 ± 192%	<0.52
Marshall	6	10660.0	<0.029	0.068	<0.040 ± 42%	<0.20
Wagner	6	12303.0	<0.015	0.055	<0.030 ± 51%	<0.20
Westminster	3	4625.0	<0.020	0.146	<0.040 ± 527%	<0.20
Summary	50	125520.0	<0.015	10.782	–	–
Volume-weighted average	–	–	–	–	<0.264 ± 163%	<1.3

*Sampler out of service

**Volume-weighted average

***The RCG_a for soluble plutonium-239 in ambient air accessible to the population at large is 20 X 10^{-15} μCi/ml.

Table 8. Total Long-Lived Beta Activity in Ambient Community Air.

Volume-Weighted Station Averages Concentrations ($\times 10^{-12}$ μCi/ml).

Community	January	February	March	April	May	June
Boulder	<0.061 ± 57%	<0 109 ± 118%	<0.032 ± 139%	<0.025 ± 69%	0.028 ± 93%	<0.027 ± 145%
Broomfield	*	*	0.043 ± 165%	<0 021 ± 121%	0.023 ± 120%	<0.021 ± 87%
Coal Creek	<0.024 ± 91%	<0 017 ± 148%	<0 028 ± 141%	<0.037 ± 88%	0.030 ± 79%	<0.020 ± 73%
Denver	<0 046 ± 113%	<0.051 ± 114%	<0.049 ± 577%	0.023 ± 57%	0.032 ± 26%	0.026 ± 54%
Golden	<0.094 ± 64%	<0.154 ± 170%	<0.053 ± 193%	<0.019 ± 120%	0.027 ± 40%	<0.030 ± 111%
Lafayette	<0.073 ± 40%	<0.128 ± 119%	<0 030 ± 145%	<0.033 ± 52%	0.029 ± 114%	<0.012 ± 36%
Marshall	<0 118 ± 83%	0 114 ± 72%	<0 044 ± 194%	<0.029 ± 94%	<0 022 ± 66%	<0.024 ± 221%
Wagner	<0.042 ± 15%	<0.042 ± 0%	0 034 ± 263%	<0.025 ± 174%	<0.028 ± 174%	0.033 ± 42%
Westminster	<0 110 ± 79%	<0.293 ± 179%	<0.035 ± 151%	0.029 ± 87%	0.026 ± 52%	<0.028 ± 148%
Volume-weighted average	<0 051 ± 47%	<0 067 ± 86%	<0.038 ± 58%	<0.026 ± 22%	<0.027 ± 18%	<0.024 ± 25%

Community	July	August	September	October	November	December
Boulder	0 086 ± 224%	0 051 ± 56%	0.035 ± 91%	<0.028 ± 101%	0.036 ± 55%	0 025 ± 90%
Broomfield	0.059 ± 42%	0 041 ± 63%	0 048 ± 83%	0.040 ± 38%	0 034 ± 61%	<0.026 ± 101%
Coal Creek	0.081 ± 100%	0 049 ± 68%	<0.017 ± 117%	0.056 ± 31%	0.026 ± 53%	<0 030 ± 136%
Denver	0.054 ± 147%	0.056 ± 68%	<0 038 ± 167%	<0.042 ± 95%	<0 028 ± 70%	<0.018 ± 87%
Golden	0 037 ± 64%	0 046 ± 20%	0.060 ± 118%	0.048 ± 56%	0.024 ± 62%	0.043 ± 53%
Lafayette	<0 045 ± 142%	0.048 ± 52%	<0 029 ± 201%	<0.041 ± 93%	<0.022 ± 53%	<0.026 ± 132%
Marshall	0.126 ± 194%	0.064 ± 50%	<0.036 ± 71%	<0.049 ± 181%	<0.030 ± 76%	<0.021 ± 46%
Wagner	0.084 ± 50%	<0 048 ± 60%	<0.048 ± 92%	<0.062 ± 92%	<0.032 ± 57%	<0.032 ± 104%
Westminster	0.065 ± 34%	0.022 ± 0%	*	*	*	<0.023 ± 212%
Volume-weighted average	<0 066 ± 37%	<0.049 ± 15%	<0 039 ± 26%	<0.044 ± 23%	<0.029 ± 16%	<0.027 ± 19%

*Sampler out of service.

Table 8. Total Long-Lived Beta Activity in Ambient Community Air. *(Continued)*

Volume-Weighted Station Averages Concentrations (X 10^{-12} μCi/ml).

January-June 1973 Summary

Community	n	Vol (m^3)	Concentration (X 10^{-12} μCi/ml) C_{min}	C_{max}	C_{avg}	% of RCG_a*
Boulder	26	9990 7	<0.0095	0 211 ± 26%	<0.033 ± 63%	<0.1
Broomfield	16	9193.9	<0.0079	0.089 ± 51%	<0.025 ± 57%	<0.1
Coal Creek	26	13415.2	<0.0090	0.075 ± 24%	<0.026 ± 30%	<0.1
Denver	23	10083 5	<0 0111	0.324 ± 26%	<0.031 ± 98%	<0.1
Golden	26	9833.5	<0 0079	0 399 ± 22%	<0.036 ± 101%	<0.1
Lafayette	26	9605.5	<0.0094	0.259 ± 27%	<0.032 ± 80%	<0 1
Marshall	26	7339.5	<0 0094	0.244 ± 30%	<0.037 ± 77%	<0.1
Wagner	20	8045.1	<0.0064	0.114 ± 38%	<0.030 ± 50%	<0.1
Westminster	25	8441.3	<0.0068	0.523 ± 26%	<0.036 ± 146%	<0.1
Summary	214	85948.2	<0.0064	0.523 ± 26%	–	–
Volume-weighted average	–	–	–	–	<0.031 ± 30%	<0.1

July-December 1973 Summary

Boulder	26	18843.4	<0.0089	0.265 ± 16%	<0 042 ± 49%	<0.1
Broomfield	26	18639.4	<0.0106	0.074 ± 20%	<0.042 ± 18%	<0.1
Coal Creek	25	15496.5	<0.0106	0.154 ± 17%	<0.042 ± 32%	<0.1
Denver	26	17140 2	<0.0091	0.125 ± 19%	<0.039 ± 32%	<0.1
Golden	26	17290.0	<0.0096	0.123 ± 16%	0.042 ± 21%	<0.1
Lafayette	26	17208.6	<0.0091	0.103 ± 19%	<0.035 ± 31%	<0.1
Marshall	26	10973.2	<0.0091	0.330 ± 19%	<0.050 ± 59%	<0.2
Wagner	26	12854.4	<0.0125	0.123 ± 21%	<0.049 ± 25%	<0.1
Westminster	7	4421.6	<0.0146	0.079 ± 20%	<0.047 ± 48%	<0.1
Summary	214	132867.3	<0.0089	0.330 ± 19%	–	–
Volume-weighted average	–	–	–	–	<0.042 ± 12%	<0.1

January-December 1973 Summary

Boulder	52	28834.1	<0.0089	0.265 ± 16%	<0.039 ± 36%	<0.1
Broomfield	42	27833.3	<0.0079	0.089 ± 51%	<0.036 ± 19%	<0.1
Coal Creek	51	28911.7	<0 0090	0.154 ± 17%	<0.035 ± 22%	<0.1
Denver	49	27223.7	<0 0091	0 324 ± 26%	<0.036 ± 41%	<0.1
Golden	52	27123.5	<0.0079	0.399 ± 22%	<0.040 ± 45%	<0.1
Lafayette	52	26814.1	<0.0091	0.259 ± 27%	<0.034 ± 39%	<0.1
Marshall	52	18312.7	<0.0091	0 330 ± 19%	<0.045 ± 44%	<0.1
Wagner	46	20899.5	<0.0064	0 123 ± 21%	<0.041 ± 22%	<0.1
Westminster	32	12862.9	<0.0068	0.523 ± 26%	<0.040 ± 100%	<0.1
Summary	428	218815.5	<0.0064	0.523 ± 26%	–	–
Volume-weighted average	–	–	–	–	<0.038 ± 14%	<0.1

*The RCG_a for total long-lived beta activity in ambient air accessible to the population at large is 33 X 10^{-12} μCi/ml.

Table 9. Annual Average Concentrations of Nonradioactive Constituents of Sewage Plant Effluent.

Parameter	Average	Most Restrictive Standard	Agency*	% of Standard
pH	7.5	6.0 to 9.0	CDH	In range
Fecal Coliform Count	168/100 ml	200/100 ml**	USEPA	84
Dissolved Oxygen	7.7 mg/l	>2.0 mg/l	CDH	In range
Residual Chlorine	1 4 mg/l	0.1 <(C1) <0 5 mg/l**	CDH	280
Suspended Solids	20 4 mg/l	30 mg/l	CDH	68
Settleable Solids	1 2 ml/l	0 5 ml/l	CDH	240
BOD_5	26.8 mg/l	30 mg/l	CDH	89
Turbidity	32 JTU	30 JTU	CDH	106
Color	24 Units	30 Units	CDH	80

*CDH – Colorado Department of Health, Water Pollution Control Commission,
USEPA – U. S. Environmental Protection Agency.

**The USEPA and CDH standards for fecal coliform count and residual chlorine concentration are in conflict because 0.5 mg/l residual chlorine has been determined as inadequate to reduce the fecal coliform count in Rocky Flats sewage plant effluent to the USEPA limitation value.

Table 10. Uranium + Plutonium and Plutonium in Pond A-3 Water Samples.

		U + Pu (Concentration × 10^{-9} μCi/ml)			Pu (Concentration × 10^{-9} μCi/ml)		
Sample Period	n	C_{min}	C_{max}	C_{avg}*	C_{min}	C_{max}	C_{avg}*
January	4	7.08	17.17	11.68 ± 51%	<0.01	1.34	<0.38 ± 238%
February	4	4.71	13.63	9.41 ± 64%	0.06	0.24	0.14 ± 89%
March	5	3.61	5.58	4.84 ± 18%	0.08	0.16	0 11 ± 31%
April	4	0.90	11.14	4.58 ± 140%	0.10	0.51	0.23 ± 115%
May	3	0.42	18.36	7.71 ± 225%	0.12	0.32	0 25 ± 81%
June	5	1.84	13.66	5.52 ± 102%	0.03	0.51	0.37 ± 62%
6-mo. Summary	25	0.42	18.36	–	<0.01	1.34	–
6-mo. Average*	–	–	–	7.10 ± 29%	–	–	<0.24 ± 48%
July	4	1 41	10.70	3.86 ± 164%	0.10	0.32	0.21 ± 73%
August	5	2 39	12.99	5.96 ± 80%	0.03	0.64	0 31 ± 111%
September	4	1 61	2 70	2.22 ± 29%	0.15	0.61	0.36 ± 89%
October	4	0.85	1.67	1.21 ± 43%	0.06	0.32	0.15 ± 111%
November	5	1.66	4.83	2.63 ± 56%	0.05	2.35	0.70 ± 156%
December	4	0.44	2.55	1.46 ± 99%	0.02	0.45	0 22 ± 120%
6-mo Summary	26	0 44	12.99	–	0 02	2.35	–
6-mo Average*	–	–	–	3.00 ± 39%	–	–	0.34 ± 55%
Annual Summary	51	0.42	18.36	–	<0.01	2.35	–
Annual Average*	–	–	–	5.01 ± 26%	–	–	<0.29 ± 37%
% of RCG_W**	–	–	–	0.31%	–	–	<0.15%

*Sample-weighted average

**RCG_W for soluble U + Pu is given by $\frac{C_U}{RCG_W} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ where $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml and $RCG_{Pu} = 1600 \times 10^{-9}$ μCi/ml.
RCG_W for soluble plutonium-239 is 1600×10^{-9} μCi/ml.

Table 11. Uranium + Plutonium and Plutonium in Pond B-4 Water Samples.

Sample Period	n	Vol (× 10^6 liters)	U + Pu (Concentration × 10^{-9} μCi/ml) C_{min}	C_{max}	C_{avg}*	Release (mCi)	Pu (Concentration × 10^{-9} μCi/ml) C_{min}	C_{max}	C_{avg}*	Release (mCi)
January	4	27.3	23.05	53.27	38.68 ± 57%	1 06	12 96	45.27	25.67 ± 84%	0.70
February	4	22.2	32.94	81.48	65.42 ± 47%	1.45	7.75	57.67	35.98 ± 84%	0.80
March	5	29.6	14.26	45.61	24.91 ± 56%	0.74	6 83	26 18	12.19 ± 80%	0.36
April	4	69.7	4.90	20.37	12.15 ± 73%	0.85	1.24	12.39	4.56 ± 161%	0 32
May	3	243.0	0.93	16.87	10.88 ± 146%	2.64	0.18	3.59	1.86 ± 169%	0.45
June	5	36.7	15.06	90.19	35.24 ± 101%	1.29	5.61	24.17	16.09 ± 54%	0.59
6-mo. Summary	25	428.5	0.93	90.19	–	8.03	0.18	57.67	–	3.22
6-mo. Average*	–	–	–	–	18.74 ± 55%	–	–	–	7.52 ± 86%	–
July	4	22.0	9.72	24.03	16.56 ± 49%	0.36	7.83	22.37	15.31 ± 54%	0.34
August	5	10.6	9.64	13.76	11.22 ± 16%	0.12	6.79	11.62	9.27 ± 27%	0.10
September	4	23.0	4.35	9.48	6.39 ± 52%	0.15	3.56	6.53	5.06 ± 40%	0.12
October	4	20.0	4.23	7.89	5.37 ± 44%	0.11	2.08	6.93	3.88 ± 76%	0.08
November	5	12.0	3.40	7.04	5.62 ± 30%	0.07	2.57	4 66	3.35 ± 29%	0.04
December	4	26.0	3.84	8.31	5.92 ± 44%	0.15	2.98	6.35	4.05 ± 53%	0 10
6-mo. Summary	26'	113.6	3.40	24.03	–	0.96	2.08	22.37	–	0.78
6-mo. Average*	–	–	–	–	8.43 ± 23%	–	–	–	6.81 ± 29%	–
Annual Summary	51	542.1	3.40	90.19	–	8 99	0.18	57.67	–	4 00
Annual Average*	–	–	–	–	16.58 ± 36%	–	–	–	7.37 ± 47%	–
% of RCG_W**	–	–	–	–	0.55%	–	–	–	0.46%	–

*Volume-weighted average.

**RCG_W for soluble U + Pu is given by $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ where $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml and $RCG_{Pu} = 1600 \times 10^{-9}$ μCi/ml.
RCG_W for soluble plutonium-239 is 1600×10^{-9} μCi/ml.

Table 12. Uranium + Plutonium and Plutonium in Pond C-1 Water Samples.

Sample Period	n	U + Pu (Concentration X 10^{-9} μCi/ml) C_{min}	C_{max}	C_{avg}*	Pu (Concentration X 10^{-9} μCi/ml) C_{min}	C_{max}	C_{avg}*
January	4	1 26	11 90	5 16 ± 128%	<0 01	1 67	<0.56 ± 194%
February	4	1 78	11.57	5.69 ± 108%	<0.01	0 12	<0.05 ± 139%
March	5	1.09	3.21	2.16 ± 49%	0 02	0.06	0 04 ± 57%
April	4	0 87	1 99	1 50 ± 52%	0 04	0 20	0 11 ± 88%
May	4	<0 01	7 30	<2 39 ± 193%	<0.01	0.09	<0.05 ± 111%
June	5	0 32	2 45	0 93 ± 109%	0 02	0.54	0.23 ± 100%
6-mo. Summary	26	<0 01	11.90	–	<0.01	1.67	–
6-mo Average*	–	–	–	<2.86 ± 45%	–	–	<0.17 ± 81%
July	4	0.25	0.92	0 59 ± 64%	0 05	0.07	0 06 ± 23%
August	5	0.52	3 83	1.49 ± 103%	0.04	0.41	0 23 ± 109%
September	4	0 69	2.02	1.15 ± 74%	0 09	0.13	0.11 ± 25%
October	4	0 41	2 81	1.23 ± 122%	0 06	0.22	0.11 ± 101%
November	5	0 62	1 21	0 87 ± 32%	0.04	0.52	0.30 ± 80%
December	4	0.67	1 57	0.96 ± 61%	0 03	0 61	0 31 ± 148%
6-mo. Summary	26	0 25	3.83	–	0.03	0.61	–
6-mo Average*	–	–	–	1 06 ± 29%	–	–	0.19 ± 40%
Annual Summary	52	<0 01	11 90	–	<0.01	1.67	–
Annual Average*	–	–	–	1 96 ± 35%	–	–	<0.18 ± 42%
% of RCG_W**	–	–	–	0.03%	–	–	<0 01%

*Sample-weighted average

**RCG_W for soluble U + Pu is given by $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ where $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml and $RCG_{Pu} = 1600 \times 10^{-9}$ μCi/ml.
RCG_W for soluble plutonium-239 is 1600×10^{-9} μCi/ml.

Table 13. Americium-241 in Water Samples.*

Location	n	Concentration X 10^{-9} μCi/ml C_{min}	C_{max}	C_{avg}**	% of RCG_W***
Pond B-4	19	<0.01	16.86	<1.79 ± 122%	<0.14
Walnut Creek at Indiana Street	20	<0.01	8.96	<1.31 ± 81%	<0.10
Great Western Reservoir	5	<0.01	0.45	<0.16 ± 148%	<0.01
Standley Lake	5	<0 01	0.78	<0 20 ± 185%	<0 02

*Analysis of water samples for americium-241 was discontinued in July 1973 because of poor americium recovery in the analytical procedure An improved procedure was developed and put into use in January 1974.
**The average for Pond B-4 is volume-weighted, all others are sample-weighted.
***RCG_W for americium-241 is 1300×10^{-9} μCi/ml.

Table 14. Uranium + Plutonium and Plutonium in Walnut Creek.

Sample Period	n	U + Pu (Concentration X 10^{-9} μCi/ml)			Pu (Concentration X 10^{-9} μCi/ml)		
		C_{min}	C_{max}	C_{avg}*	C_{min}	C_{max}	C_{avg}*
January	4	9 98	36.02	22.00 ± 74%	3.34	21.18	11.79 ± 102%
February	4	15.74	33.71	25.38 ± 41%	5.08	14.69	10.57 ± 53%
March	5	6.30	17.05	10.96 ± 54%	1.56	8.21	3.35 ± 95%
April	4	3.21	7.69	5.21 ± 56%	0.30	5.44	1.85 ± 183%
May	4	3.23	166.36**	51.55 ± 209%	0.09	1.01	0.63 ± 97%
June	5	2.20	16.92	7.93 ± 99%	0.78	10.21**	3.03 ± 153%
6-mo. Summary	26	2.20	166.36**	–	0.09	21.18	–
6-mo. Average*	–	–	–	19.65 ± 65%	–	–	5.05 ± 46%
July	4	1.34	3 60	2.84 ± 50%	1.09	2.30	1.56 ± 49%
August	5	0.73	2.62	1.65 ± 48%	0.30	0.84	0.52 ± 51%
September	3	0.98	4.28	2.34 ± 136%	0.46	3.62	1.64 ± 194%
October	4	1.68	6.41	3.01 ± 105%	0.26	0.88	0.60 ± 60%
November	5	1.54	3.26	2.19 ± 35%	0.59	1.39	0.78 ± 61%
December	3	2.78	4.21	3.56 ± 37%	0.39	3.01	1.39 ± 188%
6-mo. Summary	24	0.73	6.41	–	0.26	3.62	–
6-mo. Average*	–	–	–	2.51 ± 22%	–	–	1.01 ± 35%
Annual Summary	50	0.73	166.36**	–	0.09	21.18	–
Annual Average*	–	–	–	11.43 ± 60%	–	–	3.11 ± 43%
% of RCG_W***	–	–	–	0.27%	–	–	0.19%

*Sample-weighted average.

**Suspect data. The values as shown are included in the computation of averages.

***RCG_W for soluble U + Pu is given by $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ where $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml and $RCG_{Pu} = 1600 \times 10^{-9}$ μCi/ml.

RCG_W for soluble plutonium-239 is 1600×10^{-9} μCi/ml.

Table 15. Uranium + Plutonium and Plutonium in Public Water Supplies. Annual Average* Concentrations (X 10^{-9} μCi/ml).

Reservoirs	n	U + Pu C_{min}	U + Pu C_{max}	U + Pu C_{avg}*	U + Pu % of RCG_w**	Pu C_{min}	Pu C_{max}	Pu C_{avg}*	Pu % of RCG_w**
Great Western	15	0.26	9.38	3.00 ± 49%	0.03	<0.01	0.31	<0.08 ± 59%	<0.005
Standley Lake	14	0.13	9.33	3.63 ± 48%	0.04	<0.01	0.17	<0.04 ± 69%	<0.002
Finished Water									
Arvada	15	0.04	23.60	3.64 ± 93%	0.04	<0.01	0.20	<0.03 ± 93%	<0.002
Boulder	15	<0.01	2.55	< 0.68 ± 70%	<0.01	<0.01	0.57	<0.09 ± 98%	<0.006
Broomfield	14	0.09	13.23	2.73 ± 84%	0.03	<0.01	0.49	<0.11 ± 74%	<0.007
Denver	15	0.09	9.75	2.88 ± 57%	0.03	<0.01	0.55	<0.08 ± 114%	<0.005
Golden	15	0.11	14.06	3.01 ± 70%	0.03	<0.01	0.12	<0.02 ± 79%	<0.001
Lafayette	15	0.02	3.85	0.95 ± 69%	0.02	<0.01	0.85	<0.11 ± 105%	<0.007
Louisville	15	<0.01	2.14	< 0.44 ± 75%	<0.01	<0.01	0.29	<0.05 ± 90%	<0.003
Thornton	13	0.11	113.12	21.74 ± 91%	0.22	<0.01	0.70	<0.12 ± 105%	<0.008
Westminster	15	0.08	5.35	1.02 ± 76%	0.01	<0.01	0.32	<0.04 ± 108%	<0.002
Reservoir Summary	29	0.13	9.38	–	–	<0.01	0.31	–	–
Reservoir Average*	–	–	–	< 3.31 ± 32%	<0.03	–	–	<0.06 ± 45%	<0.004
Finished Water Summary	132	<0.01	113.12	–	–	<0.01	0.85	–	–
Finished Water Average*	–	–	–	< 3.87 ± 54%	<0.04	–	–	<0.07 ± 34%	<0.004

*Sample-weighted average

**RCG_w for soluble U + Pu is given by $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ where $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml and $RCG_{Pu} = 1600 \times 10^{-9}$ μCi/ml.

RCG_w for soluble plutonium-239 is 1600×10^{-9} μCi/ml

Table 16. Uranium + Plutonium and Plutonium in Regional Lakes, Reservoirs, and Streams. September 1973 Average* Concentrations (X 10^{-9} μCi/ml).

Distance from Rocky Flats Plant	n	U + Pu C_{min}	U + Pu C_{max}	U + Pu C_{avg}*	U + Pu % of RCG_w**	Pu C_{min}	Pu C_{max}	Pu C_{avg}*	Pu % of RCG_w**
Less than 5 miles	14	0.03	2.50	0.71 ± 68%	0.03	<0.01	2.08	<0.38 ± 96 %	<0.02
Greater than 5 miles	16	0.04	10.04	2.81 ± 57%	0.04	<0.01	2.40	<0.25 ± 137 %	<0.02
Summary of all samples	30	0.03	10.04	–	–	<0.01	2.40	–	–
Average of all samples*	–	–	–	1.82 ± 51%	0.03	–	–	<0.31 ± 0.76%	<0.02

*Sample-weighted average

**RCG_w for soluble U + Pu is given by $\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$ where $RCG_U = 10{,}000 \times 10^{-9}$ μCi/ml and $RCG_{Pu} = 1600 \times 10^{-9}$ μCi/ml.

RCG_w for soluble plutonium-239 is 1600×10^{-9} μCi/ml).

Table 17. Tritium in Water Samples.*

Station	n	Tritium (Concentrations X 10^{-6} μCi/ml) C_{min}	Tritium C_{max}	Tritium C_{avg}**	% of RCG_w***
Pond A-3	65	0.913	6.709	2.885 ± 9%	0.29
Pond B-4	58	<0.500	5.733	<2.664 ± 10%	<0.27
Pond C-1	72	<0.500	5.994	<1.409 ± 19%	<0.14
Walnut Creek at Indiana Street	57	1.020	17.280	6.698 ± 12%	0.67
Great Western Reservoir	10	6.713	9.888	8.221 ± 9%	0.82

*Samples collected during October-December 1973.

**Sample-weighted average.

***RCG_w for tritium in water released to uncontrolled areas is 1000×10^{-6} μCi/ml.

FIGURES 1 through 9

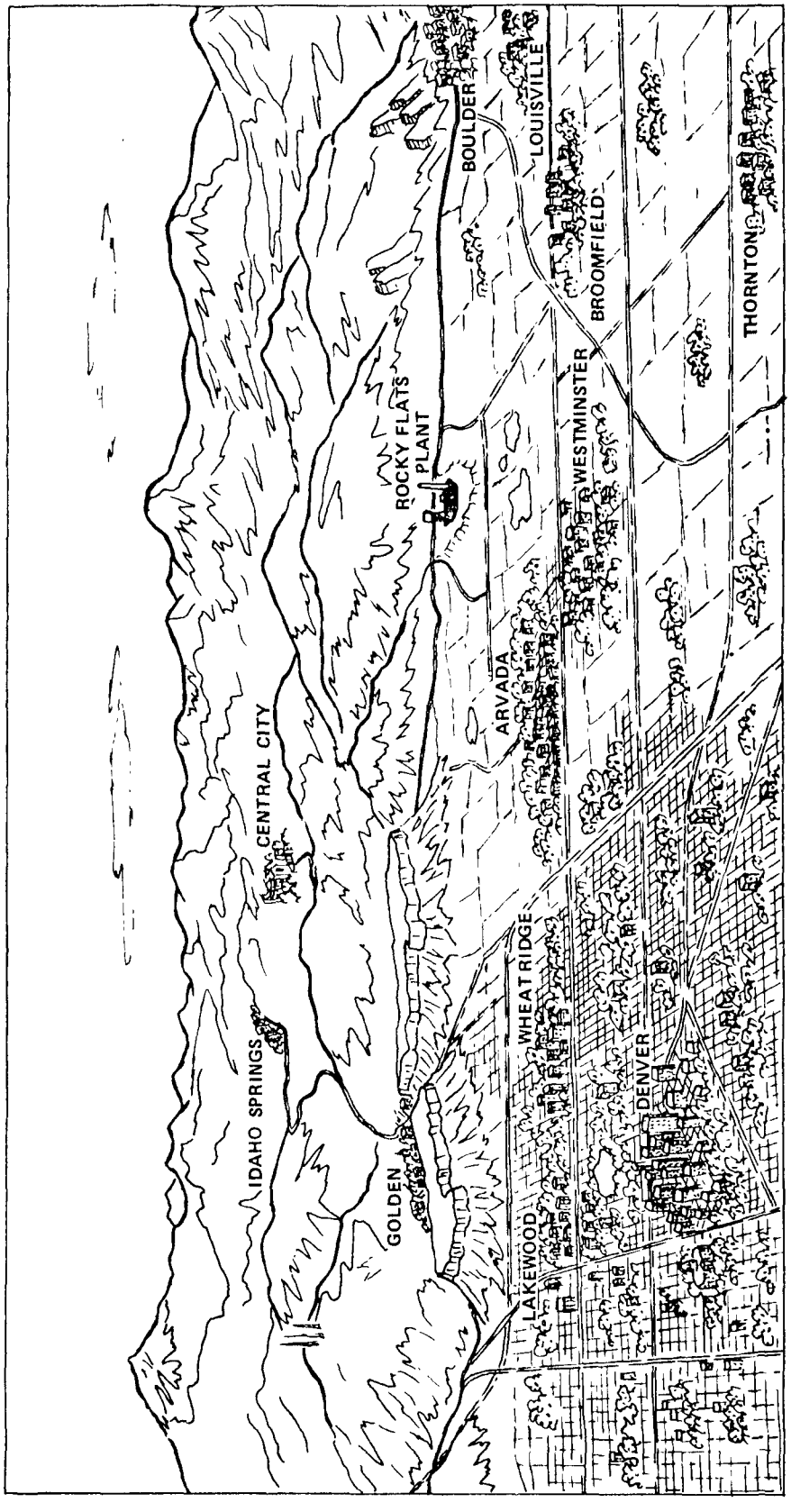


Figure 1. Location of the Rocky Flats Plant and Surrounding Communities.

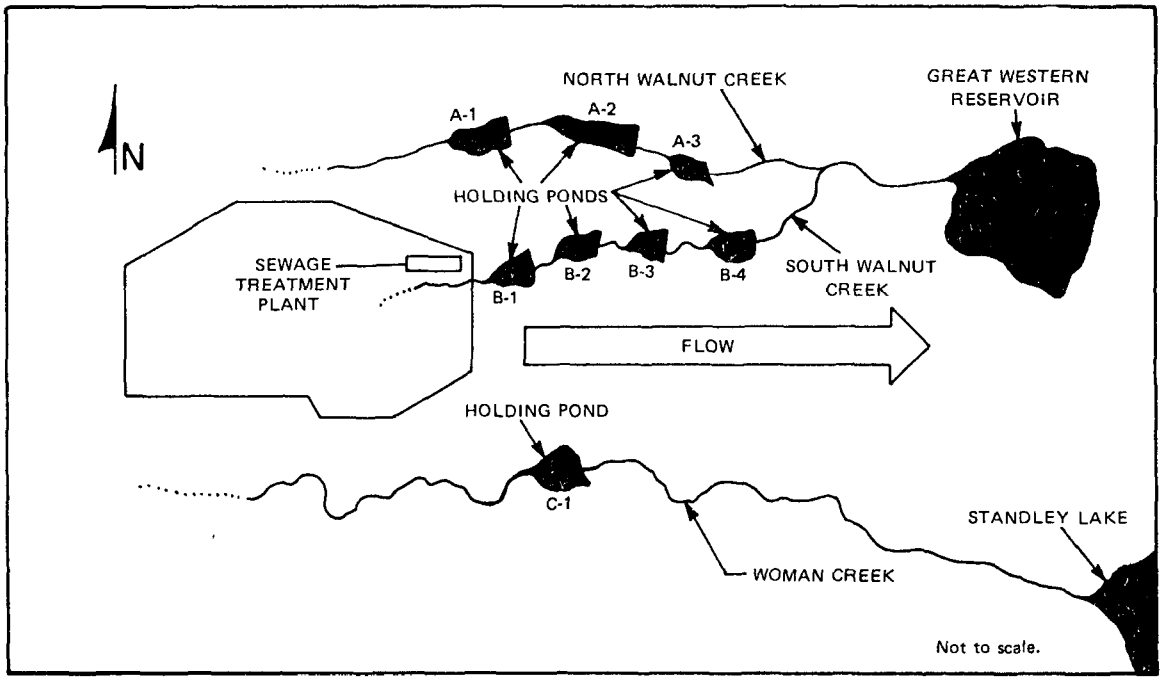


Figure 2. Liquid Effluent Water Courses.

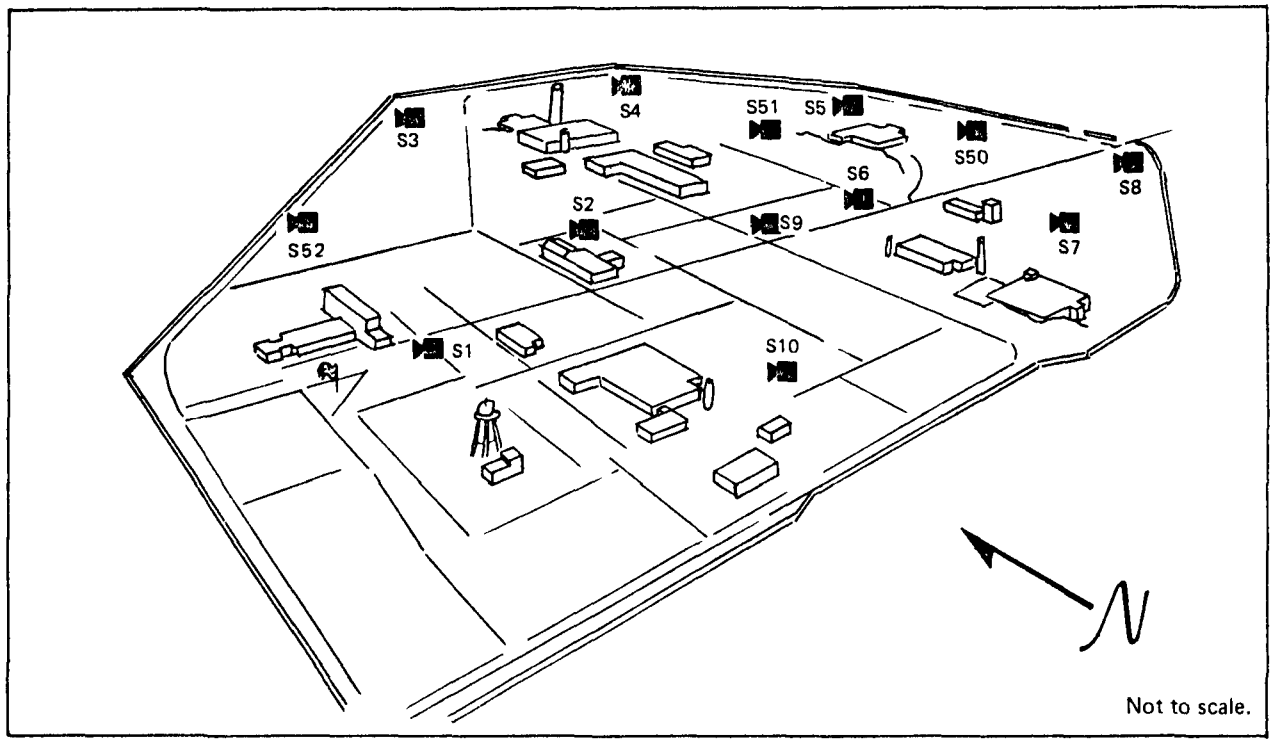
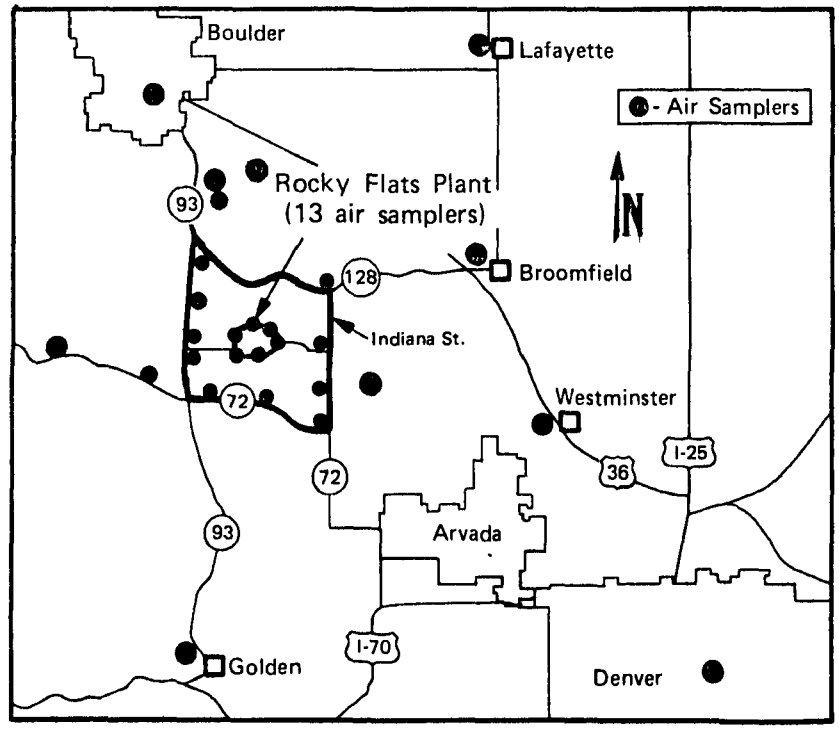


Figure 3. On-Site Air Sampling Stations.

Figure 4. Off-Site Air Sampling Stations. The larger dots represent community samplers.



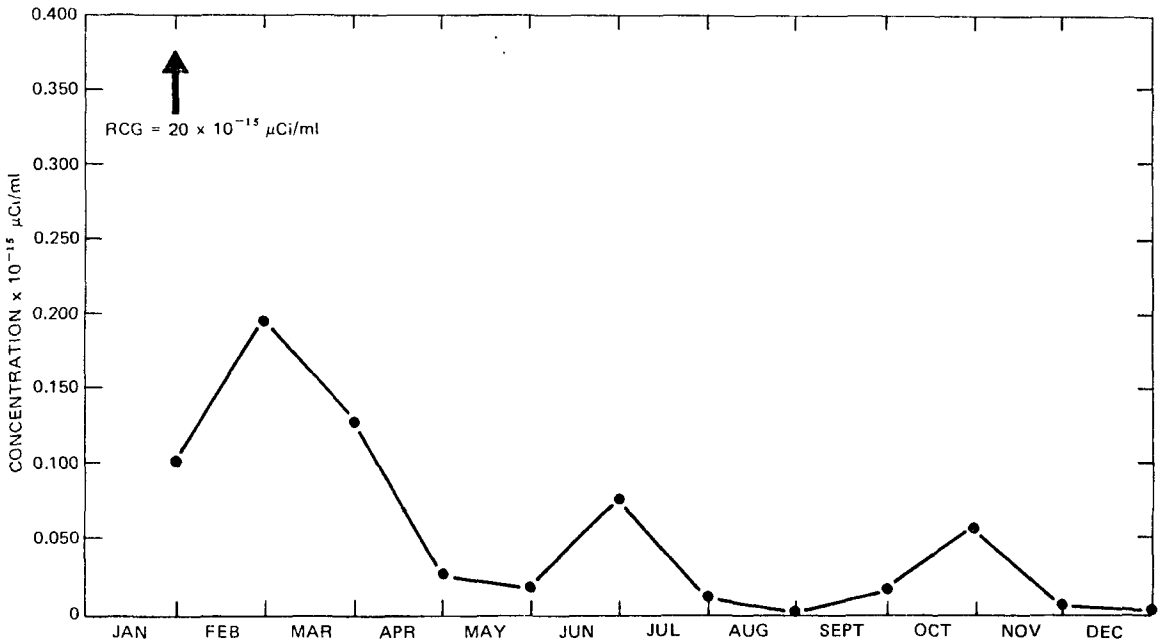
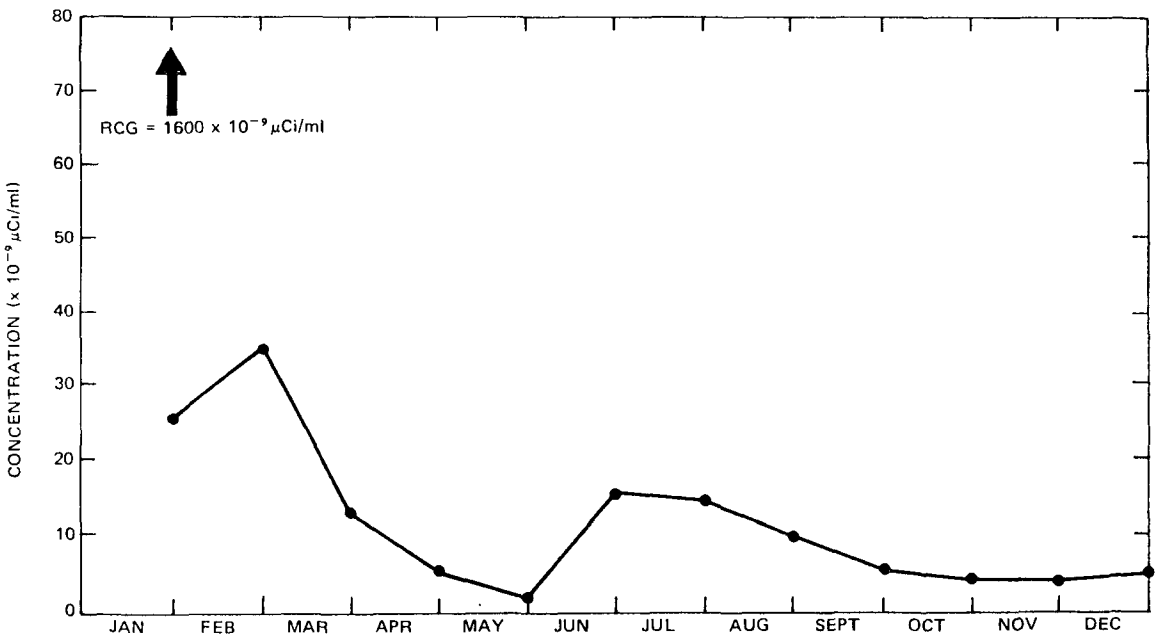


Figure 5. Plutonium-239 in 2- to 4-Mile Distant Ambient Air.
(Volume-Weighted Monthly Average Concentrations.)

Figure 6. Plutonium-239 in Pond B-4 Water Samples.
(Volume-Weighted Monthly Average Concentrations.)



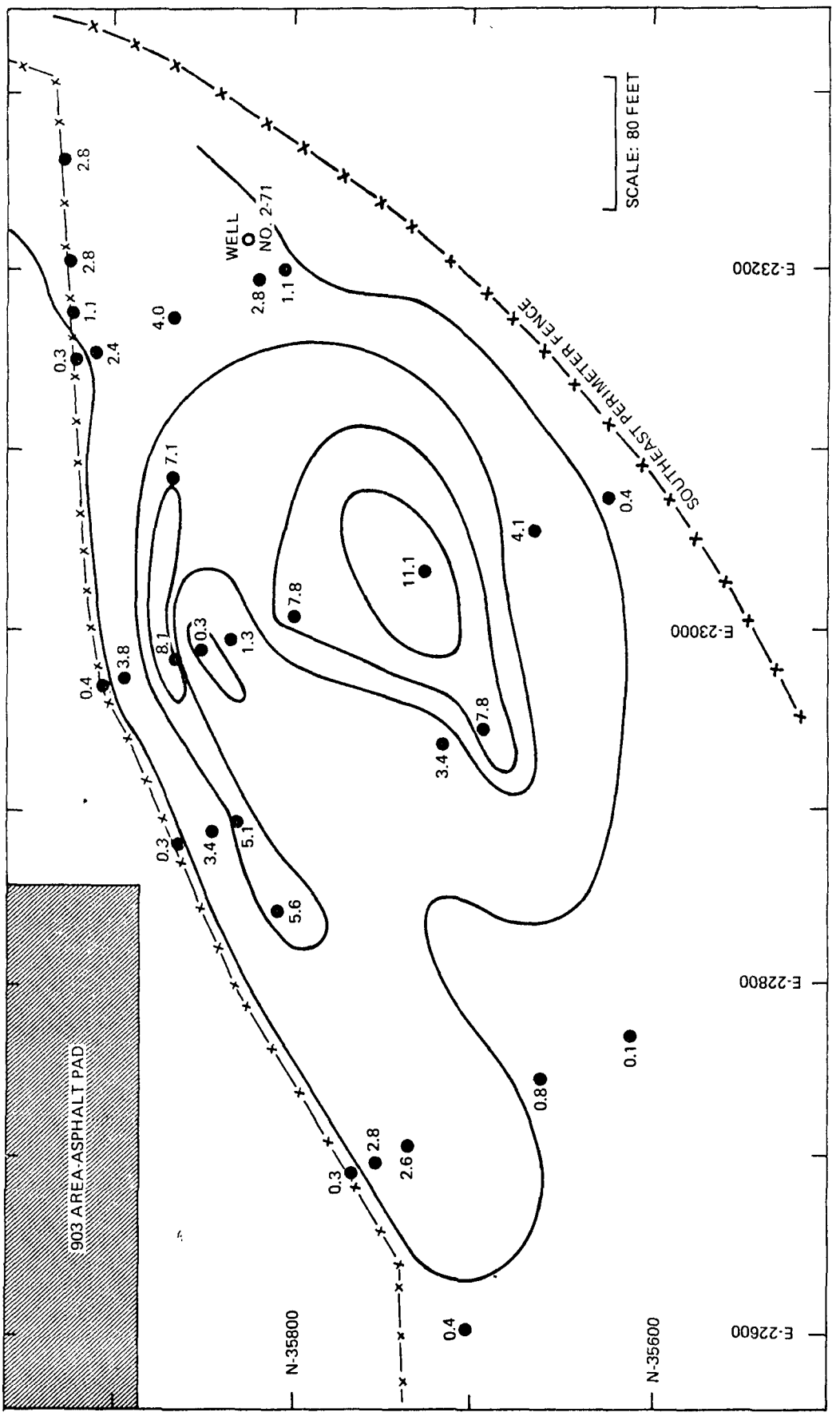


Figure 7. Americium Concentrations ($\mu Ci/m^2$) Detected by FIDLER Survey. Multiply concentrations by 10 to obtain approximate plutonium concentrations in $\mu Ci/m^2$.

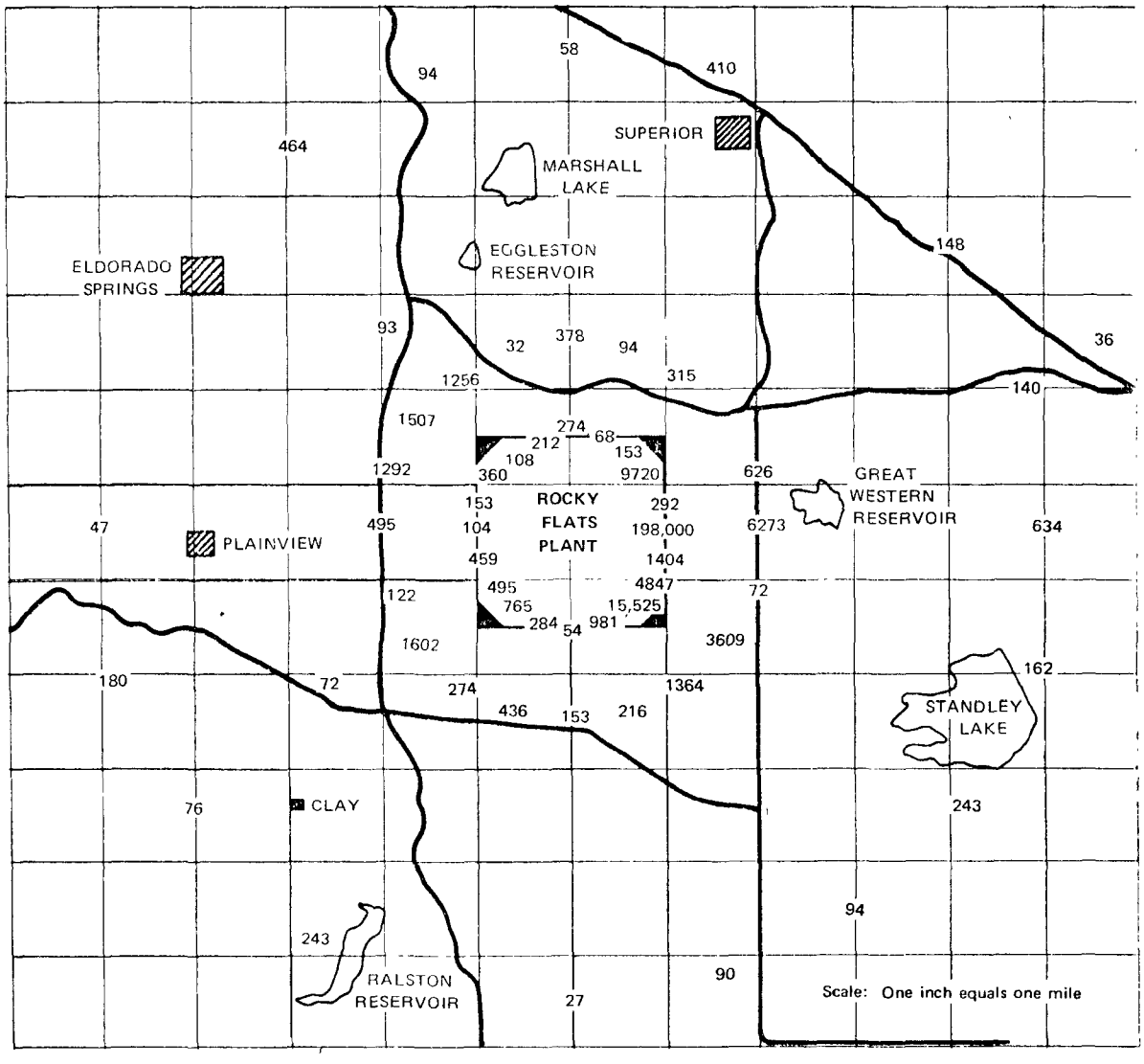


Figure 8. Plutonium Concentrations in Soil. Concentrations X 10^{-6} μCi/m^2 = d/m/g X 4.5 X 10^{-3}. The average worldwide background from fallout is 225 X 10^{-6} μCi/m^2.

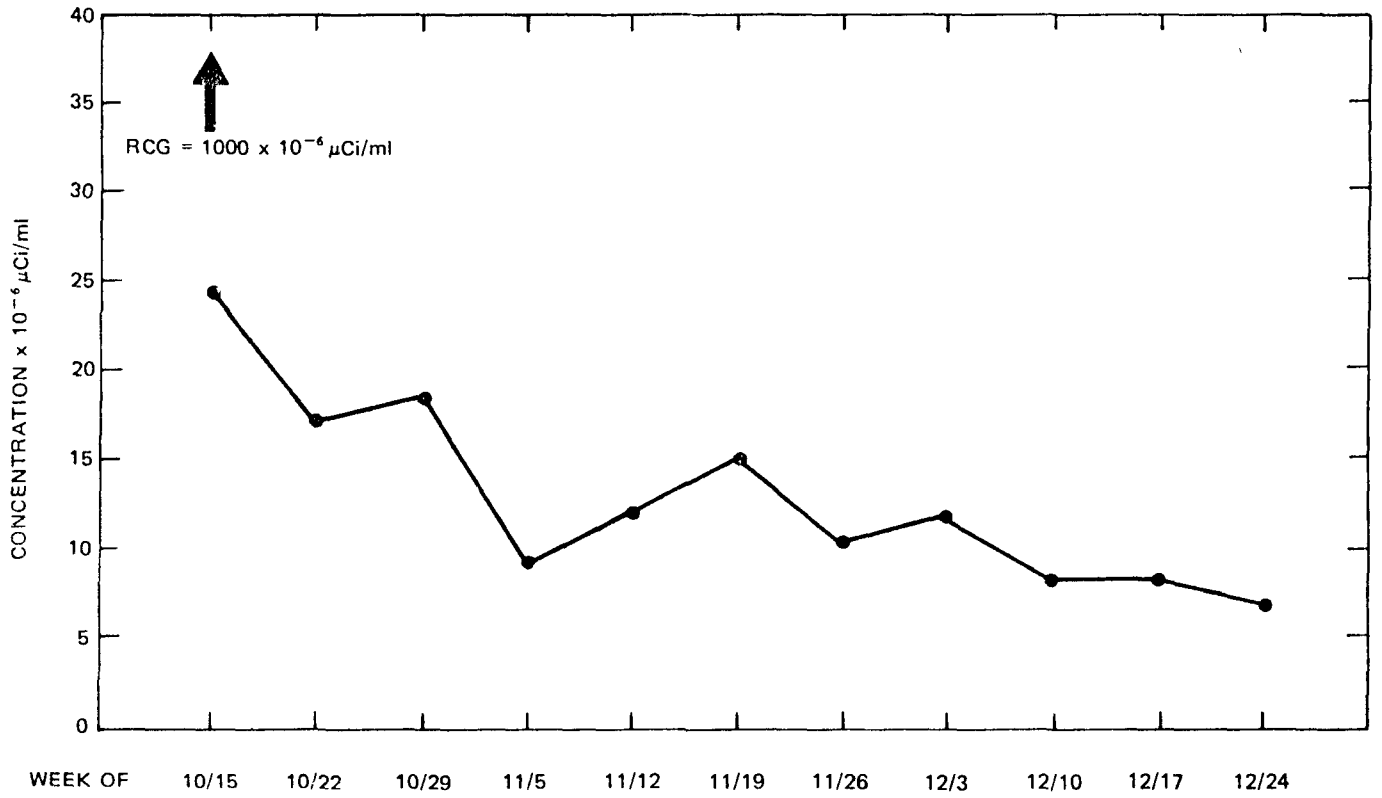


Figure 9. Tritium in Landfill Seepage. (Weekly Average Concentrations).

THIS PAGE INTENTIONALLY LEFT BLANK

Dr. Mills: We next have the Colorado Department of Health. This is Mr. Al Hazle from the Colorado Department of Health.

Mr. Hazle: My name is Albert J. Hazle. I am the Director of the Division of Occupational and Radiological Health with the State Department of Health.

STATEMENT

U. S. ENVIRONMENTAL PROTECTION AGENCY, DENVER, COLORADO HEARINGS ON PLUTONIUM STANDARDS DEVELOPMENT

BY

THE COLORADO DEPARTMENT OF HEALTH

THE DEPARTMENT WISHES TO TAKE THIS OPPORTUNITY TO INFORM THE HEARING OFFICERS OF WHAT COLORADO EXPERIENCED IN SETTING ITS PLUTONIUM-IN-SOIL STANDARD AND ITS FEELINGS ON THE NECESSITY OF HAVING CONSERVATIVE STANDARDS WHEN THE GENERAL PUBLIC'S HEALTH IS AT RISK.

IN FEBRUARY OF 1970, THE COLORADO DEPARTMENT OF HEALTH INITIATED A SOIL SAMPLING PROGRAM TO EVALUATE PLUTONIUM CONTAMINATION IN THE VICINITY OF THE USAEC' ROCKY FLATS PLANT. THIS PROGRAM WAS UNDERTAKEN AFTER IT WAS IDENTIFIED BY THE COLORADO COMMITTEE FOR ENVIRONMENTAL INFORMATION, THAT PLUTONIUM FROM THIS FACILITY HAD BEEN RELEASED TO THE ENVIRONS. THE DEPARTMENT DESIGNED A SOIL SAMPLING PROGRAM TO PROVIDE THE MOST MEANINGFUL DATA WITH REGARD TO ANY POTENTIAL PUBLIC HEALTH HAZARD. IN THIS INSTANCE, THE HAZARD ASSOCIATED WITH PLUTONIUM IN SOIL RESULTS FROM THE INHALATION OF THE RADIOACTIVE MATERIAL WITH SUBSEQUENT DEPOSITION IN THE LUNGS AND OTHER ORGANS. ANNUAL SAMPLING IS NOW CONDUCTED NORMALLY IN THE SPRING WHEN SNOW HAS MELTED AND WHILE VEGETATION IS AT ITS SEASONAL MINIMUM.

THE DEPARTMENT'S SOIL SAMPLING PROGRAM HAS DIVIDED THE AREA AROUND THE PLANT SITE INTO 13 SECTORS. THESE SECTORS ARE LOCATED AT 1, 3 AND 6 MILE RADIAL DISTANCES FROM THE PLANT BOUNDARY. 25 SOIL SAMPLES ARE COLLECTED IN EACH SECTOR. MOST IMPORTANTLY, THE SAMPLES ARE COLLECTED FROM THE TOP 1/8 INCH OF UNDISTURBED SOIL WHICH WOULD BE INDICATIVE OF THE HEALTH HAZARD POTENTIAL. SAMPLING OF LOCATIONS WHERE PLOWING OR OTHER DISTURBANCES HAVE

OCCURRED IS AVOIDED DUE TO THE QUESTIONABLE RESULTS OF SUCH SAMPLING FOR IDENTIFICATION OF THE POTENTIAL HAZARD. SAMPLING IS NOT ACCOMPLISHED EITHER UNDER OR IMMEDIATELY ADJACENT TO BUNCH-GRASS CLUMPS WHICH ARE COMMON TO THE NATURAL VEGETATION OF THE AREA. THIS IS DONE TO PRECLUDE THE WIDE VARIANCES OF RESULTS WHICH WOULD ARISE DUE TO THE DEPOSITION AND RETENTION OF MATERIAL IN SUCH CIRCUMSTANCES WITH REGARDS TO RESUSPENSION TO AN AIRBORNE HAZARD. THE 25 SOIL SAMPLES COLLECTED IN EACH SECTOR ARE COMPOSITED FOR A SECTOR ANALYSIS. A TOTAL OF 325 SOIL SAMPLES ARE COLLECTED IN THE 13 SECTORS IN THE IMMEDIATE ROCKY FLATS PLANT ENVIRONS.

TO ESTABLISH THE CONCENTRATION OF PLUTONIUM IN THE TOP 1/8 INCH OF UNDISTURBED SOIL THAT IS ATTRIBUTABLE TO WORLD-WIDE FALLOUT, 8 "BACKGROUND" AREAS ON THE EASTERN SLOPE OF COLORADO ARE SAMPLED WITH A TOTAL OF 200 ADDITIONAL SAMPLES COMPOSITED ANNUALLY FOR THOSE 8 AREAS.

IN 1970, PLUTONIUM ANALYSIS OF SAMPLES WAS PERFORMED FOR COLORADO BY THE U. S. ENVIRONMENTAL PROTECTION AGENCY'S LABORATORY IN LAS VEGAS, NEVADA. THE SPECIFIC PLUTONIUM ANALYSIS DONE ON THE SAMPLES FROM 1971 TO THE PRESENT HAS BEEN ACCOMPLISHED BY THE COLORADO DEPARTMENT OF HEALTH AT ITS OWN COUNTING FACILITY IN DENVER. THE METHOD OF ANALYSIS IS THROUGH THE USE OF A PROCEDURE DEVELOPED BY N. A. TALVITIE, EPA, LAS VEGAS, NEVADA.

IN ADDITION TO THE SOIL SAMPLING DONE BY THE COLORADO DEPARTMENT OF HEALTH, VARIOUS OTHER AGENCIES AND GROUPS HAVE DONE SOIL SAMPLING IN REGARD TO THE PLUTONIUM CONTAMINATION IN THE ROCKY FLATS PLANT ENVIRONS. THE HEALTH AND SAFETY LABORATORY OF THE USAEC HAS ACCOMPLISHED SEVERAL STUDIES IN THE DENVER METROPOLITAN AREA. THE SOIL SAMPLING ACCOMPLISHED BY THESE STUDIES IS LIMITED, AND DIFFERENT SOIL SAMPLING TECHNIQUES HAVE BEEN USED WITH SOME SOIL ALIQUOTS BEING TAKEN AT DEPTHS DOWN TO 20 CENTIMETERS OR ABOUT 8 INCHES. THE MAJOR

IMPACT OF THESE STUDIES WAS TO IDENTIFY THE AREA IMPACTED BY THE SPREAD OF PLUTONIUM FROM THE ROCKY FLATS PLANT AND TO ESTIMATE THE INVENTORY OF PLUTONIUM LOST.

DOW CHEMICAL U. S. A., ROCKY FLATS DIVISION, THE PRESENT PLANT OPERATOR, HAS PERFORMED ANALYSIS ON MANY INDIVIDUAL SOIL SAMPLES COLLECTED BY VARIOUS MEANS THROUGHOUT THE PLANT ENVIRONS AND IN AREAS AWAY FROM THE IMPACT OF PLANT OPERATIONS. THE RESULTS OF THEIR SAMPLING PROGRAMS HAVE BEEN PUBLISHED IN THEIR ANNUAL SURVEILLANCE SUMMARIES.

DR. STEWART POET AND DR. EDWARD MARTELL OF THE COLORADO COMMITTEE FOR ENVIRONMENTAL INFORMATION ALSO DID SOIL SAMPLING IN THE ENVIRONS OF THE ROCKY FLATS PLANT. THE TECHNIQUE USED WAS TO SELECT INDIVIDUAL SAMPLE LOCATIONS AND SAMPLE THE TOP ONE CENTIMETER DEPTH OF SOIL. SOME DEPTH SAMPLING WAS ALSO ACCOMPLISHED, AND THE RESULTS OF THEIR SAMPLE ANALYSIS HAS BEEN PUBLISHED IN THE SCIENTIFIC LITERATURE.

OF ALL THE SOIL SAMPLING PROGRAMS THAT HAVE BEEN DESCRIBED, THE COLORADO DEPARTMENT OF HEALTH'S PROGRAM APPEARS TO BE THE ONLY ONE SPECIFICALLY ADDRESSED TO THE RESUSPENSION OF PLUTONIUM FROM THE TOP LAYER OF SOIL AND LENDS ITSELF TO LARGE SCALE LAND USE EVALUATION OF THE POTENTIAL PLUTONIUM HAZARD. BECAUSE HAZARD ANALYSIS BASED ON SOIL DATA NORMALLY UTILIZES ARBITRARY RESUSPENSION "AIR CONCENTRATION HALF-LIFE" FACTORS WHICH MAY NOT BE APPROPRIATE TO THE SPECIFIC SITUATION EXISTING IN THE ENVIRONS OF ROCKY FLATS, THE ONLY PROPER METHOD TO EVALUATE THE SITUATION IS BY AIR SURVEILLANCE.

AIR SAMPLING SURVEILLANCE STATIONS OF THE COLORADO DEPARTMENT OF HEALTH HAVE BEEN ESTABLISHED ON THE ROCKY FLATS PLANT SITE AND HAVE BEEN IN OPERATION SINCE MAY, 1970, IN AN AREA IMMEDIATELY ADJACENT TO THE SOURCE OF THE PLUTONIUM FOUND IN THE OFFSITE ENVIRONS. THE AIR SAMPLING STATIONS IMMEDIATELY ADJACENT TO THE

MOST HIGHLY CONTAMINATED GROUND INDICATE AN ANNUAL AVERAGE OF 0.006 PICO-CURIES PER CUBIC METER OF AIR AS A COMPOSITE AVERAGE OVER THE PERIOD OF TIME THAT HAS BEEN SAMPLED AND ANALYSED TO DATE. MAXIMUM INTEGRATED SAMPLE CONCENTRATIONS OBSERVED OVER THE YEARS HAVE BEEN IDENTIFIED TO BE DUE TO VEHICULAR TRAFFIC OR EXCAVATION WORK IN THE IMMEDIATE VICINITY OF THE AIR SAMPLERS AND NOT SPECIFICALLY DUE TO THE OCCURRANCE OF HIGH WINDS. INSTANTANEOUS MAXIMUM CONCENTRATIONS WOULD BE IN EXCESS OF THE MAXIMUM PERMISSIBLE CONCENTRATION FOR LARGE SEGMENTS OF THE GENERAL POPULATION (0.02 pCi/M^3) BY SEVERAL ORDERS OF MAGNITUDE. IT MUST BE REMEMBERED, HOWEVER, THAT CONCENTRATIONS IN SOIL IN THIS AREA ARE CONSIDERABLY HIGHER THAN THOSE FOUND OFFSITE, AND, THAT REFERENCE TO AIR CONCENTRATION STANDARDS FOR THE GENERAL POPULATION WOULD NOT BE APPLICABLE.

EVALUATIONS FOR HEALTH IMPACT DONE BY THE COLORADO DEPARTMENT OF HEALTH ARE PRIMARILY BASED ON RESULTS OF AIR SAMPLING ANALYSIS. THE AIR SAMPLING THAT WAS ESTABLISHED BY THE DOW CHEMICAL COMPANY AND THE STATE HEALTH DEPARTMENT IDENTIFIED THAT THE RURAL SITUATION WHICH PRESENTLY EXISTS IN THE IMMEDIATE ROCKY FLATS ENVIRONS DOES NOT POSE A SERIOUS THREAT TO HEALTH. HOWEVER, THE RURAL SAMPLING RESULTS CANNOT BE EXTRAPOLATED TO AN UNKOWN URBAN ENVIRONMENT SITUATION WHICH IS BEING ANTICIPATED FOR THE AREA.

DURING THE 1972 SESSION OF THE COLORADO STATE LEGISLATURE AN AMENDMENT TO CHAPTER 106 OF THE COLORADO REVISED STATUTES WAS ENACTED (SENATE BILL 35). AS THE DEPARTMENT VIEWS THIS ACT, IT WAS THE INTENT OF THE LEGISLATURE THAT ANY PLATTING AGENCY, BE IT MUNICIPAL OR COUNTY, REQUIRE A RADIATION EVALUATION FROM A SUB-DIVIDER WHERE THERE IS A POTENTIAL RADIATION HAZARD KNOWN OR PRESUMED KNOWN TO EXIST IN THE AREA TO BE DEVELOPED. A MEETING WAS HELD AT THE STATE HEALTH DEPARTMENT ON OCTOBER 25, 1972, WITH THE AEC AND EPA IN ATTENDANCE AT THE REQUEST OF THE STATE HEALTH DEPARTMENT. THE PURPOSE OF THIS MEETING WAS TO DISCUSS THE

AVAILABILITY OF STANDARDS FOR PLUTONIUM IN SOIL TO MEET THE REQUIREMENTS OF THE ABOVE STATED LAW. IT WAS DETERMINED THAT THERE WERE NO NATIONAL OR INTERNATIONAL ACCEPTED STANDARDS FOR PLUTONIUM CONTAMINATION IN SOIL, AND THAT THE ONLY AVAILABLE INFORMATION WAS FROM INDIVIDUALS WITH NO OFFICIAL RESPONSIBLE-AGENCY STATUS. THE REPRESENTATIVE FROM EPA, STANDARDS AND CRITERIA BRANCH, OFFICE OF RADIATION PROGRAMS, STATED THAT HIS AGENCY HAD ESTABLISHED A PRIORITY FOR THE GENERATION OF A PLUTONIUM-IN-SOIL STANDARD AT THE REQUEST OF THE STATE HEALTH DEPARTMENT. HOWEVER, IT WAS ANTICIPATED THAT THIS STANDARD WOULD NOT BE AVAILABLE FOR APPROXIMATELY 2 YEARS.

IN DECEMBER OF 1972, a "SUGGESTED INTERIM GUIDANCE" WAS PROVIDED TO THE COUNTY COMMISSIONERS INFORMING THEM OF THE DEPARTMENT'S FEELING TOWARD THE CONTENT OF THE REQUIRED RADIATION EVALUATION. THIS GUIDANCE DID NOT INCLUDE A STANDARD. AN "AREA OF CONCERN" WAS IDENTIFIED FOR THE ENVIRONS OF THE ROCKY FLATS PLANT USING THE THEN AVAILABLE SOIL CONCENTRATION DATA FROM ALL PARTIES AND WAS INCORPORATED IN THE GUIDELINES. A REVIEW OF THE SUBMITTED DATA AND RECOMMENDATIONS REGARDING LAND USE WERE TO BE ACCOMPLISHED BY THE STATE HEALTH DEPARTMENT. IT WAS HOPED BY ALL CONCERNED THAT THERE WOULD BE NO DEVELOPMENT OF LAND WHICH HAD A SIGNIFICANT CONCENTRATION OF PLUTONIUM IN SOIL UNTIL THE EPA STANDARDS WERE AVAILABLE.

THE DEPARTMENT WAS SUBSEQUENTLY INFORMED OF PLANS FOR THE DEVELOPMENT OF AN AREA LOCATED APPROXIMATELY FROM WEST 98TH AVENUE TO WEST 104TH AVENUE, AND FROM ALKIRE STREET TO SIMMS STREET, (EAST OF THE PLANT SITE), THAT WERE TO BE PRESENTED TO THE WESTMINSTER CITY PLANNING COMMISSION. AS THE LAW SPECIFICALLY REFERRED TO ACTIONS BY BOARDS OF COUNTY COMMISSIONERS, THE DEPARTMENT NOTIFIED ALL ADJACENT MUNCIPALITIES TO THE ROCKY FLATS ENVIRONS OF THE REQUIREMENTS OF SENATE BILL 35 AND PROVIDED THE "SUGGESTED GUIDANCE" WHICH HAD BEEN PREVIOUSLY

SENT TO THE BOARDS OF COUNTY COMMISSIONERS.

BECAUSE OF THE NEEDS OF THE LAND OWNER, THE DEVELOPER, THE CITY AND COUNTY PLANNING COMMISSIONS, AND PLATTING AGENCIES, AND THE SEEMINGLY INCONSISTENCY OF SENATE BILL 35 WITH REGARD TO MUNICIPALITIES AND COUNTY GOVERNMENTS, THE COLORADO DEPARTMENT OF HEALTH ESTABLISHED, AT THE REQUEST OF THE BOARD OF HEALTH, AN EMERGENCY INTERIM STANDARD FOR PLUTONIUM IN SOIL IN JANUARY OF 1973. THIS EMERGENCY STANDARD, WHICH BY LAW COULD BE IN EFFECT FOR 90 DAYS, READ AS FOLLOWS: "IN UNCONTROLLED AREAS WHERE THE TOTAL CONCENTRATION OF PLUTONIUM IN THE SOIL IS IN EXCESS OF 0.2 DISINTEGRATIONS PER MINUTE PER GRAM OF DRY SOIL, SUCH LAND SHALL BE UNFIT FOR RESIDENTIAL USE, SUBDIVISION DEVELOPMENT, OR COMMERCIAL AND INDUSTRIAL USES." ON JANUARY 24, 1973, A NOTICE OF PUBLIC HEARING BEFORE THE STATE BOARD OF HEALTH WAS ANNOUNCED REGARDING PUBLIC HEARINGS ON THE ADOPTION OF RULES AND REGULATIONS PERTAINING TO THE PERMISSIBLE LEVELS OF RADIOACTIVE MATERIAL IN UNCONTROLLED AREAS (PLUTONIUM). A PROPOSED STANDARD, AND THE EMERGENCY STANDARD THEN IN FORCE, WAS BASED ON THE BACKGROUND CONCENTRATIONS IDENTIFIED FOR AREAS OUTSIDE OF THE POSSIBLE INFLUENCE OF THE ROCKY FLATS PLUTONIUM CONTAMINATION. AN AVERAGE BACKGROUND CONCENTRATION OF 0.08 DISINTEGRATIONS PER MINUTE OF PLUTONIUM PER GRAM OF DRY SOIL WAS MULTIPLIED BY A FACTOR OF 2 AND ROUNDED TO THE NEAREST SIGNIFICANT DIGIT TO A CONCENTRATION OF 0.2 DISINTEGRATIONS PER MINUTE OF PLUTONIUM PER GRAM OF DRY SOIL. THIS STANDARD WAS BASED ON THE SAMPLING PROCEDURES AND RESULTS ESTABLISHED BY THE DEPARTMENT. THE DEPARTMENT'S SAMPLING TECHNIQUE IS RELATIVELY SIMPLE, AND SAMPLING AND MEETING THE REQUIREMENTS OF THE LAW AND ITS RADIATION HAZARD EVALUATION COULD BE ACCOMPLISHED WITH RELATIVE EASE.

STANDARDS PROPOSED OR USED BY SPECIFIC GROUPS OR AGENCIES FOR THEIR OWN PARTICULAR NEEDS, WHICH HAD BEEN FACTORED DOWN FROM OCCUPATIONAL EXPOSURES TO LEVELS FOR THE GENERAL POPULATION AT THE MAXIMUM PERMISSIBLE DOSE ARE UNACCEPTABLE.

EXAMPLES OF SUCH EFFORTS ARE AS FOLLOWS: DR. WRIGHT LANGHAM PROPOSED IN 1968 THAT A SOIL CONCENTRATION OF 100 MICRO-GRAMS OF PLUTONIUM PER SQUARE METER (OR 1380 DPM PER SQUARE CENTIMETER) WAS APPROPRIATE FOR A ONCE-IN-A-LIFE-TIME INCIDENT. THE RECOMMENDATION WAS BASED ON A 110 DAY AIR CONCENTRATION HALF-LIFE, INSOLUBLE PLUTONIUM 239, AND A RESUSPENSION FACTOR OF 7×10^{-6} PER METER. (IT SHOULD BE NOTED HERE THAT DENMARK, REGARDING THE THULE INCIDENT, REQUIRED THE USE OF A RESUSPENSION FACTOR OF 1×10^{-3} PER METER.) IN A 1969 PAPER, DR. LANGHAM MADE NO RECOMMENDATION FOR SOIL CONTAMINATION LEVELS; HOWEVER, USING A NEW ICRP LUNG MODEL, HE MADE RECOMMENDATIONS BASED ON DOSE, AND THE SIZE OF POPULATION AFFECTED. IN HIS JUDGEMENT, AS THE DOSE COMMITMENT INCREASED, THE NUMBER OR SIZE OF POPULATION SHOULD BE APPROPRIATELY REDUCED. HERE, AGAIN, THE RECOMMENDATIONS WERE BASED ON A ONCE-IN-A-LIFE-TIME INCIDENT. IN A PAPER ENTITLED "TOWARD INTERIM ACCEPTABLE SURFACE CONTAMINATION LEVELS FOR ENVIRONMENTAL PLUTONIUM OXIDE" BY R. L. KATHREN, PUBLISHED IN APRIL, 1968 (A BATTELLE NORTHWEST LABORATORIES PUBLICATION) AN URBAN STANDARD WAS PROPOSED. THE PROPOSAL IS A VALUE EQUIVALENT TO AN AVERAGE OF 10 DISINTEGRATIONS PER MINUTE PER SQUARE CENTIMETER. IT SHOULD BE NOTED THAT THE PROPOSAL IS BASED ON THE MAXIMUM PERMISSIBLE DOSE TO AN INDIVIDUAL OF THE POPULATION AND NOT BASED ON THE VALUE THAT SHOULD BE THE DOSE WHICH IS ACCEPTABLE FOR GENERAL POPULATION EXPOSURE. IN A LOS ALAMOS SCIENTIFIC LABORATORY REPORT DATED JANUARY, 1974, J. W. HEALY PUBLISHED "A PROPOSED INTERIM STANDARD FOR PLUTONIUM IN SOILS". AS A RESULT OF THE AUTHOR'S INVESTIGATION, A SOIL CONTAMINATION STANDARD OF 500 DISINTEGRATIONS PER MINUTE PER GRAM OF DRY SOIL IS PROPOSED AND IS BASED UPON THE DELIVERANCE OF THE MAXIMUM PERMISSIBLE DOSE TO A SIZEABLE PORTION OF GENERAL POPULATION. THE MAXIMUM PERMISSIBLE DOSE TO THE GENERAL POPULATION IS FOR EXPOSURES FROM ALL SOURCES AND NOT PLUTONIUM-IN-SOIL ALONE, AND THEREFORE ITS USE IS

UNACCEPTABLE.

AS A JUSTIFICATION FOR THE THEN PROPOSED COLORADO STANDARD, AN EXAMPLE OF A REASONABLE SCALING DOWN OF AN OCCUPATIONAL EXPOSURE TO LEVELS FOR EXPOSURES OF GENERAL POPULATIONS WAS PROVIDED; IF A CONTAMINATION LEVEL OF 300 DISINTEGRATIONS PER MINUTE OF PLUTONIUM PER SQUARE CENTIMETER OF SURFACE AREA IS APPROPRIATE FOR AN OCCUPATIONAL EXPOSURE, CONSISTENT WITH THE MAXIMUM DOSE TO THE CRITICAL ORGAN OF 15 REMS PER YEAR, (FOR INSOLUBLE PLUTONIUM), AN ACCEPTABLE LIMIT FOR A GENERAL POPULATION WOULD BE 0.3 DISINTEGRATIONS PER MINUTE PER GRAM OF DRY SOIL BASED ON 1 GRAM PER CUBIC CENTIMETER AS THE SOIL DENSITY AND A SAMPLING DEPTH OF 1 CENTIMETER. THE REDUCTION FACTOR OF 1000 WOULD REDUCE THE ORGAN DOSE WELL BELOW THAT IDENTIFIED BY NATIONAL AND INTERNATIONAL GROUPS AS THE MAXIMUM PERMISSIBLE DOSE FOR LARGE SEGMENTS OF THE GENERAL POPULATION. SUCH A FACTOR (1000) IS USED BY LICENSING AGENCIES IN THE REGULATION OF MANUFACTURE OF GAS AND AEROSOL DETECTORS USING RADIOACTIVE MATERIAL (PRIMARILY AMERICIUM 241) AND THEIR DISTRIBUTION TO PERSONS EXEMPT FROM REGULATORY CONTROL (TITLE 10, CODE OF FEDERAL REGULATIONS 32.27).

AS A RESULT OF PUBLIC HEARINGS ON FEBRUARY 14 AND MARCH 21, 1973, BEFORE THE STATE BOARD OF HEALTH, THE DEPARTMENT'S RULE MAKING BODY, DURING WHICH TESTIMONY WAS PRESENTED BY SPOKESMAN FOR FEDERAL, STATE AND LOCAL GOVERNMENTS, INDUSTRY, AND ENVIRONMENTAL ORGANIZATIONS, AND BY "CONCERNED CITIZENS", AND LAND OWNER REPRESENTATIVES, THE BOARD OF HEALTH ADOPTED A STANDARD OF 2 DISINTEGRATIONS PER MINUTE PER GRAM OF DRY SOIL. THE ACTUAL WORDING OF THE COLORADO STANDARD IS AS FOLLOWS: "PERMISSIBLE LEVELS OF RADIOACTIVITY IN UNCONTROLLED AREAS. PLUTONIUM. CONTAMINATION OF THE SOIL IN EXCESS OF 2 DISINTEGRATIONS PER MINUTE OF PLUTONIUM PER GRAM OF DRY SOIL OR SQUARE CENTIMETER OF SURFACE AREA (0.01 MICRO-CURIES OF PLUTONIUM PER SQUARE METER) PRESENTS A SUFFICIENT HAZARD TO THE PUBLIC HEALTH TO

REQUIRE THE UTILIZATION OF SPECIAL TECHNIQUES OF CONSTRUCTION UPON THE PROPERTY SO CONTAMINATED. EVALUATION OF PROPOSED CONTROL TECHNIQUES SHALL BE AVAILABLE FROM THE DEPARTMENT OF HEALTH UPON REQUEST." THIS STANDARD WAS NOT ADOPTED UPON EXTENSIVE TECHNICAL AND CONCLUSIVE EVIDENCE WHICH WAS LACKING, BUT UPON THE JUDGMENT THAT REASONABLE CONSERVATISM WAS NECESSARY AT THIS POINT IN TIME AND REALIZING THAT OTHER TRANSURANIC MATERIAL ALSO WAS ASSOCIATED WITH THE PLUTONIUM SOIL CONTAMINATION. THE STANDARD ALSO SERVES AS A CAUTION TO DEVELOPMENT, PLANNING AND PLATTING AGENCIES OF THE NEED FOR PROPER LAND-USE PLANNING DUE TO THE PUBLIC HEALTH HAZARD POTENTIAL PRESENTED BY THE PLANT'S EXISTANCE. IT IS ANTICIPATED THAT SUBDIVIDED LAND HAVING SOIL CONCENTRATION APPROXIMATING THIS STANDARD WOULD NOT EXPERIENCE AIR CONCENTRATIONS SIGNIFICANTLY DIFFERENT THAN THOSE OBSERVED DUE TO WORLD-WIDE FALLOUT.

SINCE THE ADOPTION OF THE ABOVE PLUTONIUM-IN-SOIL STANDARD, THE COOPERATION OF THE AGENCIES, DEVELOPERS, AND OTHERS HAS ALLOWED ORDERLY APPLICATION OF THAT STANDARD.

BECAUSE THE STATE OF COLORADO HAS HAD CONSIDERABLE EXPERIENCE REGARDING LUNG EXPOSURE BY OTHER ALPHA EMITTERS, SPECIFICALLY RADON DAUGHTER EXPOSURES OF URANIUM MINERS AND THE ADOPTION OF ADEQUATE PROTECTION STANDARDS FOR THESE INDIVIDUALS, THE DEPARTMENT FEELS THAT THE BODY OF PLUTONIUM-IN-MAN DATA IS NOT SUFFICIENT AT THIS TIME TO ESTABLISH STANDARDS WHOLLY BASED ON THE BIOLOGICAL EFFECTS FROM PLUTONIUM OBSERVED TO DATE. THE LATENT PERIOD TO OBSERVE THE EFFECTS OF THIS MATERIAL WITHIN THE BODY IS SUCH THAT ONLY TRULY CONSERVATIVE STANDARDS CAN BE SET FOR PLUTONIUM WHEN A LARGE SEGMENT OF THE GENERAL POPULATION IS AT RISK.

THE AEC HAS SET IN MOTION PROCEDURES TO ACQUIRE ADDITIONAL LAND SURROUNDING THE PLANT SITE AS A BUFFER AREA. THE ACQUISITION OF THIS LAND WILL PRECLUDE THE

194

USE OF LAND CONTAMINATED SIGNIFICANTLY IN EXCESS OF THE STANDARDS ADOPTED BY COLORADO. THE PRESENT DISTRIBUTION OF PLUTONIUM IN SOILS GIVES US INSIGHT AS TO THE LONG TERM RELEASE OF PLUTONIUM FROM DAILY OPERATIONS AND IN ANY INCIDENT WHICH MIGHT OCCUR. ANY DISTRIBUTION OR REDISTRIBUTION WILL ESSENTIALLY BE IN THIS SAME PATTERN. HOPEFULLY PROGRESSIVE AND AGGRESSIVE MANAGEMENT ACTIONS BY BOTH THE AEC AND ITS CONTRACTOR WOULD PRECLUDE THE RELEASE OF ANY ADDITIONAL SIGNIFICANT INVENTORIES OF RADIOACTIVE MATERIAL FROM THE PLANT TO ITS ENVIRONS. A MAJOR INCIDENT RELEASING SIGNIFICANT QUANTITIES OF MATERIAL TO THE OFFSITE ENVIRONS COULD DRASTICALLY CHANGE THE CONCENTRATIONS IN SOIL WHICH ARE PRESENTLY BEING OBSERVED, AND THEREFORE, MAKE ALL EFFORTS IN REGARD TO PROPER REZONING USING THE COLORADO STANDARD INVALID.

THE DATA AND INFORMATION PRESENTED IN THIS STATEMENT NATURALLY EMPHASIZED AIR AND SOIL PARAMETERS. THE DEPARTMENT HAS ACQUIRED CONSIDERABLE DATA ON SURFACE WATERS AND POTABLE WATER SUPPLIES IN THE DENVER METROPOLITAN AREA. ADDITIONALLY, EPA HAS ASSISTED THE STATE IN DETERMINING THE BUILDUP OF PLUTONIUM IN A NUMBER OF RAW WATER RESERVOIRS IN THE AREA. OUR INFORMATION AND DATA ARE AVAILABLE FOR YOUR PERUSAL AND USE.

THE DEPARTMENT WISHES TO EXPRESS ITS APPRECIATION FOR THE BRINGING OF THESE HEARINGS TO THE DENVER AREA AND THE PRIVILEGE OF MAKING A PRESENTATION. AGAIN, WE WOULD REQUEST THAT ANY STANDARDS REGARDING EXPOSURE OF THE GENERAL PUBLIC BE OF NECESSITY TRULY CONSERVATIVE.

THANK YOU.

1/8/75
AJH/pc

SUGGESTED INTERIM GUIDANCE
for
EVALUATION (Nov. 1972)
required under Chapter 106, CRS 1963, as amended
(106-2-34(3)(a) and 106-2-34(3)(c)(iv)

To assist the Board of County Commissioners in fulfilling the requirements of the Act, the following is provided by the Colorado Department of Health.

I. Information to be provided in the required evaluation:
- A. Prior land use history of proposed plat
  - 1. Specify for the proposed plat and any portion thereof, the different land use histories in relation to solid disturbance.
    - a. Situations to be considered
      - (1) Virgin or undisturbed ground
      - (2) Disturbed ground (specify depth of disturbance)
        - (a) Single (date)
        - (b) Routine
          - ((1)) Yearly
            - ((a)) Contour Plowing
            - ((b)) Strip Plowing
          - ((2)) Others (specify)
        - (c) Others (specify)

- B. Method of taking representative samples
  - 1. Detailed description of sample acquisition and its justification in relation to hazard analysis.
    - a. Items to be considered (but not limited to)
      - (1) Depth of sample
        - (a) Disturbed soil situation
        - (b) Undisturbed soil situation
      - (2) Involved surface area of indivudal sample
      - (3) Number of samples taken per unit land area
        - (a) Increase or decrease number due to
          - ((1)) Different land forms
          - ((2)) Water bodies and streams

- C. Method of Analysis
  - 1. Describe in detail, or if documented procedure, reference the procedure and qualify any changes in that referenced procedure.
  - 2. Specify quality control procedures for the analytical procedure employed.
    - a. Number of analyses per sample (replicates)
    - b. Participation in inter-laboratory cross-check programs (AEC or EPA)
    - c. Standards traceable to nationally recognized source

D. Evaluation
1. Results of analyses to be presented by table and map with specific sampling sites and land use histories identified.
2. Methods for "averaging" and handling anomalous data specified.
3. Criteria or guidelines used in the hazard evaluation specifically described or referenced.
4. Specify all assumptions used and qualify their use.
5. Specify appropriate methods for control of the radiation hazard.
6. Specify the name and qualifications of the individual performing the radiation hazard evaluation.

II. A. Prior to a subdivider, or an agent for a subdivider performing or causing to perform the required evaluation, the information required under Item I, with exception of I. D. 1. and I. D. 5., shall be submitted to the Board of County Commissioners for review and comment.

B. The Colorado Department of Health shall assist the Board of County Commissioners in their review of the proposed evaluation. Upon approval as appropriate to fulfill the requirements of the Act, the evaluation may proceed.

III. Upon completion of the required evaluation and submission to the Board of County Commissioners, the Colorado Department of Health shall assist the Board in its deliberations as to the efficacy of the proposed land use in relation to the radiation hazard identified. Disposition of this matter may take various forms:
A. Unqualified approval
B. Qualified approval
C. Postponed or deferred decision (taken under advisement)
D. Disapproval or rejection.

IV. Areas of Concern (Specific for each county)
A. General areas of natural deposits of uranium and/or thorium
1. Locations identified by the U. S. Geological Survey as possessing significant quantities and concentrations or as otherwise identified.

B. General areas surrounding nuclear facilities
1. Production and/or utilization facilities, as defined by U. S. A.E.C. regulations.
2. Uranium and thorium mill towns.
3. Areas as otherwise identified.

Thank you.

Chairman Mills: Thank you, Mr. Hazle. Most of us are well aware of the considerable effort that the State of Colorado has put into the detection of plutonium, and I commend the Health Department in this regard.

In your monitoring followup, have you found any appreciable change in the movement of the plutonium in the soil?

Mr. Hazle: There is before the Board of County Commissioners a parcel of land which is in excess of two, and there were proposed to have techniques used, namely plowing in this particular circumstance. Action has not been taken by the County Commissioners, therefore there has been no change in that land.

Chairman Mills: What my question referred to, in doing your sampling, you have been sampling I think in the first eighth of an inch?

Mr. Hazle: That is correct.

Chairman Mills: Have you seen any movement of the plutonium down in the soil? I am raising the question from the standpoint that there is concern that resuspension of plutonium in soil, any resuspension numbers used should be different from fresh plutonium deposits as opposed to that which might have been aged somewhat.

Mr. Hazle: The information which we have seen does not

really show, because of the statistics involved, the gross movement of the plutonium downwind. The resuspension terms, which we generated realizing the accuracy of these terms, approximate $1x10^{-9}$ per meter. The air concentration half-times which we are observing, now realizing full well when we started observing this, the plutonium was already aged in the soil because the leakage from the storge material which was stored from 1957 to approximately 1968, and we started sampling in 1970. So, you already have aged plutonium in the soil. But the air concentration half-times which we are seeing, and subtracting out the worldwide fallout which has also a half-time, we see approximately 2.7 years air concentration at this occurrence rate, if you will.

Chairman Mills: One other question. Your background level I guess in the determination of your .2 disintegrations per minute per gram of soil, you basically doubled the .08. You mentioned this as an average concentration --

Mr. Hazle: Right.

Chairman Mills: Could you give us some indication of what the range is, not just the average?

Mr. Hazle: The range really did not vary very much, as I remember. I think it went from .11 down to .04 or .06. Is that correct, Bel? (Belmont S. Evans - nodded concurrence.)

Chairman Mills: Any question by the Panel?

Dr. Morgan: Dr. Hazle, you indicated that the vehicular traffic and excavation resulted in instantaneous concentrations that would be in excess of maximum permissible concentrations for large segments of the population by several orders of magnitude. You are saying then, I would assume this by factors of thousands or tens of thousands to make it several orders of magnitude, but that this would be in the restricted areas and would not apply to the offsite situation. Since these levels were quite high, I would assume that even further out there are people living near highways or industrial areas, and they might have fairly large concentrations as a consequence; and then later you indicated that the purchase of this land extending the area under control would mean that these levels would not exceed those adopted by Colorado.

Mr. Hazle: That is correct.

Dr. Morgan: I would ask you, then, was this the reason for the purchase of this additional land, because there were areas then that exceed the levels of adopted by Colorado?

Mr. Hazle: Going back to the area around the oil spill which is the source of the contamination offsite, we have samplers which run there continuously. Day-long integrated samples are now changing to every other day. We have seen concentrations which go up to .4 picocurie per cubic meter of air when we do have vehicular traffic or when they are

doing excavation to lay tie lines. Those have been observed. But, these are integrated samples going through a nighttime period when there would not be any real concentration of material, it would be resuspended. My statement regarding many orders of magnitude is regarding an adjustment statement that an integration would dilute the concentration.

Dr. Morgan: But this land that was recently purchased or added to the site, were the levels there above the Colorado standard?

Mr. Hazle: Yes, sir, the concentrations which are experienced and which have been identified by a number of groups, these would go up into the hundred or two hundred disintegrations per minute per gram.

Dr. Morgan: One other question, I believe you indicated that Wright Langham's resuspension factor of $7x10^{-4}$, whereas in some other cases values as high as 10^{-3} have been used. What does your data seem to indicate as a reasonable factor for resuspension factor for dry soils?

Mr. Hazle: What we have experienced based on a yearly average is $1x10^{-9}$ per meter.

Dr. Morgan: This would include the wet conditions as well as dry?

Mr. Hazle: That is correct, and we do see during the later stages of summer and the first of fall, which normally is our dry time, an increase of air concentrations over the contaminated soil areas.

Dr. Morgan: What would be an average for dry conditions?

Mr. Hazle: I have not calculated that out, sir. Also, thank you for the Doctor, I am not a Doctor.

Chairman Mills: Dr. Taylor has a question.

Dr. Taylor: I found this a very interesting presentation, and I am going to study it more so my question may have been answered, and I may have missed the point. I believe that the standards which you have arrived at which you consider acceptable here are basically derived from those worked out by the NCRP and ICRP Tripartite Conferences for Occupational Exposure and for Population Exposures.

Mr. Hazle: I am afraid not, sir. We essentially took the background information and said this is a little bit ultraconservative, and a reasonable adjustment of those figures because the number would be completely arbitrary down that low, the reasonable adjustment up to a level which the likelihood of getting concentrations in excess of world-wide fallout would be approximately two, and so the two (2 dpm/g) was the number grabbed out of the air, in all practicality.

Dr. Taylor: This was related back as being substantially smaller than the international ones?

Mr. Hazle: Yes.

Dr. Taylor: There have been, of course, no observed effects of international or on the NCRP or ICRP standards,

and obviously no observed effects of any kind on your particular standards. This is correct, is it not?

Mr. Hazle: As far as the occupational exposures to date, there has been no observalbe effects.

Dr. Taylor: That is your understanding also?

Mr. Hazel: That is correct.

Dr. Taylor: I just wanted to be sure that this was then a matter of largely judgment and is not based on any technical findings we know of as yet.

Mr. Hazle: That is correct. Truly a conservative approach, sir.

Dr. Taylor: Thank you.

Dr. Snyder: I would like to direct a comment really just to get your response to it. It is for reasons of this kind that the ICRP has adopted a different term than the maximum permisssible dose in connection with exposure of population. Because your standard is based on a an existing situation which is not controllable by us or this country, and therefore it may need to be changed in the future. Of course, it can be changed as it has to be. But, I just point out that they, therefore, discourage the use of this term in this connection.

Dr. Taylor: You are referring to the use of the term "dose limit"?

Dr. Snyder: That is correct.

Mr. Hazle: If I might comment a little further, most of these people who have done those kinds of calculations have used those particular terms and have used factored-down situations, but have not used the recent recommendations of NCRP using the somatic dose of 170 milligrams per year.

Chairman Mills: Mr. Hazle, for the completeness of the record, I wonder if you would add to the record your complete citation of the references that you used, Dr. Langham and Mr. Healy, and so forth?

Mr. Hazle: I will send that information to you, and additionally I would like to comment that we have provided the suggested interim guidance which was provided to the County Commissioners and the people involved. (Note: the references are included in the section on additional material submitted for the hearing record.) (Volume 3)

Chairman Mills: That would be part of the record. Thank you very much.

Dr. Mills: The next speaker represents the City of Boulder. Are you Ms. Correll?

Ms. Correll: Yes. I am Ruth Correll, member of the City Council of Boulder.

Members of the Board, Ladies and Gentlemen:

The City of Boulder appreciates this opportunity to address the United States Environmental Protection Agency on a matter of concern to our citizens and their political

leaders. Our statement is brief because it is our desire to focus your attention on the two issues of primary concern to us.

As we attempt to assess the effects of a plutonium processing facility located only ten miles from our city limits, we are faced with the question of the results of prolonged exposure to low levels of radiation -- a question which, given the current level of technical and scientific knowledge, is, as you know, difficult to answer. Yet, it is imperative that the political leaders charged with protecting the health and safety of our citizens be able to determine three things: (1) what is an acceptable level of exposure to plutonium radiation? (2) to what level is the community of Boulder and Metro Denver now exposed, and (3) what are the definable and possible consequences of that exposure? The responsibility for that determination falls most heavily, we think, on the Federal Government, which is ultimately responsible for the existence of any potential hazard.

The necessary scientific investigations to answer these questions are well beyond the financial and jurisdictional scope of the City of Boulder. Therefore, we request that the Environmental Protection Agency insure that studies to answer these questions and to define the effects of prolonged exposure to low levels of radiation be made and that

those reports and those investigations be given fully to the public. We emphasize our willingness as a city to participate with other agencies to carry out these vital studies.

The work which has to be performed is highly technical. It requires a great deal of skill and experience in the area of health physics. It is important that we build on previous research.

Our second concern as a city is the lack of public input in past decisions regarding such important factors as the location of nuclear processing facilities; the establishment of radiation protection standards, nuclear employee job safety protection; the responsibility for emergency services in case of a major disaster; and whether the city itself has some responsibility. We are concerned about any other issues which may have a direct bearing on our city and its citizens. Hopefully today's hearings are only the first in a new era of openness and public participation in these kinds of decisions. We trust that they do signal a new attitude of cooperation between local citizens and their governments and the Federal agencies, such as the Atomic Energy Commission, who are responsible for the decisions.

A factor in determining how much risk citizens are willing to accept is the planning for development of alternative energy sources, and we believe it is important for the EPA and other Federal agencies to unite in the

support of research in the development of additional energy options.

Again, on behalf of our citizens of Boulder, we thank you for this opportunity to present our concerns to you and we look forward to the decisions and the actions which you will take in our behalf and in behalf of the citizens of Colorado.

Chairman Mills: Thank you very much, Ms. Correll. Are there any questions? Dr. Morgan?

Dr. Morgan: You indicated that the distance was about ten miles from the city limits. Is this ten miles from the boundary of Rocky Flats, or is it ten miles to the nearest operating facility?

Ms. Correll: Are you talking about the center --

Dr. Morgan: From the city limits of Boulder, is the distance ten miles to the nearest operating facility or to the fence boundary?

Ms. Correll: As far as I know, it is the distance to the operating facility. I have not actually measured that.

Dr. Morgan: You mentioned some concern about emergency plans. Do you in the City of Boulder have emergency plans which have been coordinated with the Rocky Flats operations personnel?

Ms. Correll: No, we have not, and this is one of our concerns. Is a city, any city in the area, somewhat

responsibile in case there were a major disaster, and should we be informed and aware of what our responsibility might be? It does make a great deal of difference.

Chairman Mills: In that regard, have you worked any with the State Health Department in this regard for protection action guides or emergency action guides?

Ms. Correll: We have what I would call the standard provisions for disasters. They have not been particularly coordinated in relation to a nuclear disaster; and one of our concerns is the fact that as the population thickens around the plant, we might perhaps need to do this. Does this then indicate an expenditure of local funds for this kind of coordination, or what is our burden, and what is the burden actually of other cities?

Chairman Mills: I think you have emphasized that it does need a great deal of cooperation between the Federal Government and the states and local government.

Thank you very much.

The next speaker is Dr. Carl Johnson, the Health Officer for Jefferson County, Colorado.

MEMORANDUM

TO: Director, Criteria and Standards Division
Office of Radiation Programs
United States Environmental Protection Agency
Washington, D.C. 20460

FROM: Carl J. Johnson, M.D.
Director of Health
Jefferson County Health Department
260 S. Kipling Street
Lakewood, Colorado 80226

RE: Public Hearing Concerning Plutonium and the Transuranium Elements, on January 10, 1975 in the Denver Post Office Building, Denver, Colorado

There is an urgent need for the establishment of maximum permissable levels of contamination of soil by Plutonium. In Jefferson County there is a plan to develop for residential use, land nearly a square mile in area downwind from the Rocky Flats facility of the Dow Chemical Company. The degree of contamination of the soil by Plutonium in this area has been evaluated and has been found to range as high as 560 times the background level for Colorado, which is 0.08 discharges per minute per gram of dry top soil (DPM/gram). There is an area approximately one and one-half miles upwind which reportedly has soil contamination ranging as high as 20,000 DPM per gram, or about 250,000 times the background level. The general area is dry and dusty and noted for strong winds ranging up to 80 miles per hour and higher.

The table below contains estimates of the dimensions and the area of the land that is contaminated, from a map illustrating Plutonium 239 accumulation in soils surrounding the Rocky Flats plant [U.S.A.E.C. Report HASL-235 (1970)].

Table 1

Estimated dimensions and area of land contaminated with Plutonium 239 around the Rocky Flats facility, by amount of contamination expressed in disintegrations per minute per gram of dry topsoil, and compared to the background level for Colorado[1].

Contamination with Plutonium 239 in disintegrations/min/ gram of dry topsoil	Contamination with Plutonium 239 in relation to typical background levels for Colorado	Approximate dimensions of area of contamination in miles	Estimated area contaminated in square miles
20,000	250,000 x	-	-
8,000	100,000 x	-	-
> 440	> 5,500 x	1/3 x 1/2	0.14
> 110	> 1,400 x	0.6 x 1	0.5
> 11	> 140 x	1 x 2.7	2.5
> 4.4	> 55 x	1.5 x 3.5	4.9
> 2.2	> 27 x	4 x 6	20
> 1.1	> 14 x	5 x 7	28
> 0.6	> 7 x	7 x 8	44

(1) Estimated from P.W. Krey and E.P. Hardy, Plutonium in soil around the Rocky Flats plant, USAEC Report HASL - 235 (1970)

Subsequent maps showing the extent of plutonium contamination indicate that a smaller area is involved, or that significant dispersion has occurred.

Because of interest in developing land near the Rocky Flats facility, the Colorado State Health Department was requested to establish temporary maximum permissable levels of plutonium contamination in 1973. The maximum permissable level was recommended to be 0.2 DPM/gram of dry top-soil, or 2 1/2 times the background level. Where this level was exceeded, construction for residential purposes was not to be permitted. I believe that these recommendations reflected the best judgement of the State Health Department personnel who were trained in the field of radiological health. However, because this level was felt to be unduly restrictive, the State Board of Health set the official maximum allowable level at 2.0 DPM/gram or about 25 times the background level. In addition, residential construction could be permitted where plutonium contamination was in excess of these levels, if State guidelines for treatment of the soil were followed to reduce levels of contamination.

However, such treatment of soil (plowing or removal of top-soil), does not prevent subsequent recontamination of the area by dust blown from adjoining lands, after the area has been developed for residential use. In addition, since accidental releases of radioactive material have occurred on several occasions, it does not seem possible to rule out subsequent accidental releases of radioactive material, recontaminating areas that have been so treated.

We do not appear to have sufficient information about long-term effects resulting from exposure to plutonium to establish definitive standards. However, interim standards are essential if large numbers of people are to be protected from unnecessary exposure to plutonium. Past experience with standards for maximum permissable exposures or doseages established for radioactive materials indicates that a very high safety factor should be con-

sidered where there is insufficient information about the long-term effects of exposure.

There is considerable data available concerning the toxicity of plutonium for experimental animals and there is some data relative to the meaning of industrial exposures for human adults (usually 40 hours weekly for a period of several years or more). However, I do not believe any work has been done to demonstrate the hazards of continuous exposure to low levels of plutonium for the developing fetus or child. This portion of the population is most susceptable to damage to chromosomes and genetic injury, and exposure to increased levels of radiation will result in an increase in the incidence of developmental defects at birth and neoplasms in later life.

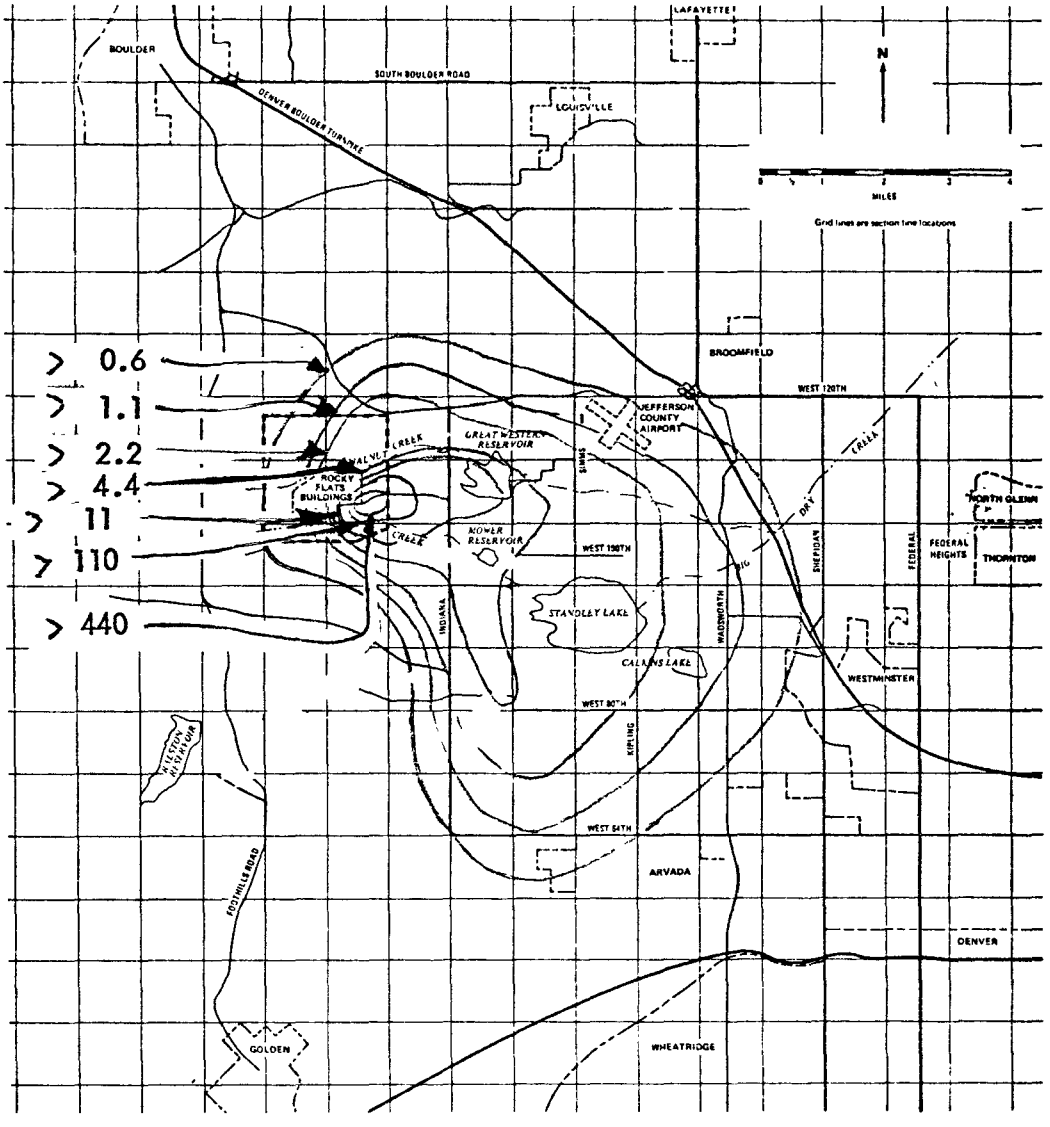
A generous safety factor is allowed when considering the maximum allowable concentration of hazardous chemical substances to which one may be exposed without risk of injury. Because of the insidious nature and long-delayed effects of exposure to radioactive substances, a safety factor many orders greater should be accepted, especially for situations inwhich the most susceptable part of the population will be subjected to a continuous exposure for many years, as in a residential development. In considering acceptable levels of exposure to radiation in a residential setting, it is much better to err on the side of caution.

For these reasons I urge the Environmental Protection Agency to establish maximum permissable levels for plutonium contamination of soil in areas that are to be used for residential purposes. I recommend that these maximum permissable levels include a safety factor many orders greater than that accepted for exposure to hazardous chemical substances.

Dr. Johnson: An additional point I wanted to make is that where an area is developed and you have paved surfaces, I think the resuspension factor would be much larger than that for soil.

PLUTONIUM-239 AND AMERICIUM-241 CONTAMINATION IN THE DENVER AREA(1)

Plutonium levels expressed in disintegrations per minute per gram of dry topsoil



(1) Poet, S.E. and Martell, E.A.: Plutonium-239 and Americium-241 contamination in the Denver area Health Phys. 23:537-548 Oct., 1972

Chairman Mills: Thank you, Dr. Johnson. I wonder if you could clarify for me, expand on your last statement, that is, "I recommend that these maximum permissible levels include a safety factor many orders greater than that accepted for exposure to hazardous chemical substances." Would you expand on that? I assume you are talking about not any chemical toxicity associated with the radioactive material, but nonradiating emitting substances?

Dr. Johnson: Yes, I think there is a fundamental difference between the two types of hazards. The hazard from a chemical such as carbontetrachloride can be easily evaluated by doing tests on liver function, and then you can enter an appropriate safety factor to bar hazard from industrial exposure. Now, for hazardous substances such as plutonium (which I understand is fifteen times more hazardous than radium) as with any other radioactive element, the effects may not be fully experienced for 30 years or perhaps longer. In fact, the effects induced by exposure to radiation are quite difficult to estimate.

Chairman Mills: Dr. Taylor has a question.

Dr. Taylor: I am interested in that same point that you have brought out and would point out that in the case of some chemical substances, I am not sure I could name them at the moment, you also have long latent periods of effect showing after the injury.

I wanted to ask about the statement in the last page, "...considerable data available concerning the toxicity of plutonium for experimental animals..." This, of course, is quite true but extremely large doses compared to any amounts that we are concerned with in the general environment. Also, "...some data relative to the meaning of industrial exposures for human adults...," and there I believe it can be said quite safely that there has been no identifiable injury to radiation workers containing body burdens of plutonium that are within the standards, whatever you want to call them, maximum permissible dose limits. I do not see how you can expect any possibility as you sort of imply here of demonstrating effects at much lower levels than these. These have been studied for many, many years. Hundreds of millions of dollars have been spent on trying to find low-level effects of radiation. So far largely -- well, I would not say largely, I would say entirely without success at the sort of background levels that we are talking about.

Dr. Johnson: I really feel the sort of information we need can be gotten from a large scale epidemiological evaluation of the lifetime experience of people who have had these occupational exposures, looking for significant increases in the incidence of neoplasms of various types. We should also study the offspring, including the second and third generations, looking for significant changes in the

frequency of developmental defects.

Dr. Taylor: There are such studies that have been in progress for years now. The Mancusso Study is an example where so far at levels much higher than we are talking about in this environment today have been, I believe, unproductive in showing anything definitive. Now, if you get down to exposures which are still even lower, I gather from your remarks, than the fetal exposures and so on, I just do not think there is any practical likelihood of this being accomplished in the many lifetimes that are ahead of any of us here today. This is not to say, do not do something about it, but do not kid yourselves into thinking that you are going to get some tangible biomedical evidence that will stir you on this.

Dr. Johnson: I guess that all I really want is some definite standards established which can be identified as interim standards, that can be enforced, in order to limit development of land for residential use in the areas where significant levels of plutonium are found, and so prevent any unforeseen effects. We do have some indication from experience with radiation for diagnostic and therapeutic purposes of pregnant women that exposure to ionizing radiation is not good. I think we can extrapolate from that and say that a safety factor many orders larger than that for an occupational setting is required for a residential environ-

ment. That is really all I want, some standards which reflect a very large order of safety.

Dr. First: We had some information from the people at Rocky Flats a little earlier to the effect that the environmental measurements over the past several years, I believe they said, were less than 1%, considerably less than 1% in most cases of the currently-established standards. I wonder why the concern with establishing standards for soil contamination when the effects of this have not been measured in spite of the high numbers which you have cited. What is the connection, have you made a connection between soil contamination and the exposure of people?

Dr. Johnson: Well, of course, I have not conducted any studies myself. I am speaking as a Health Officer for Jefferson County. I do think dust quite often is resuspended in this area. It is a rather dry area. There are strong, gusty winds at intervals which blow dust about. If the area is developed and there are paved streets and sidewalks, the dust which is subsequently redeposited on these paved surfaces are much more likely to be resuspended and inhaled. In addition, I think we will have dust drifting inside homes, and once you have dust inside a house, as you know, it is going to be resuspended almost daily by vacuum cleaners.

Dr. First: Do you dispute in any way the information

that the Rocky Flats people have presented to us that the measurements in the communities and at the boundary line of the plant itself have consistently been less than 1% of the current standard?

Dr. Johnson: I am not aware of what the current standard is. In fact, I wonder if there is such a standard, and if such a standard really is realistic or adequate.

Dr First: Well, the measurements currently are at least two orders of magnitude below the current standard. Would you not say that provides a safety factor of some degree and that the establishment of standards for soil contamination is not responsive to the problems that we are facing, namely, human exposure over long periods? I do not understand how you get from soil contamination to a danger to populations when the measurements show that the levels are close to background or are at background. Can you explain that to me?

Dr. Johnson: I have just tried to illustrate using data generated by the Atomic Energy Commission that the levels of plutonium in this area are much in excess of background levels for plutonium.

Dr. First: In the air?

Dr. Johnson: This refers to the soil. I think the very fact that we have seen that plutonium has moved from the original site on the Rocky Flats facility downwind for,

I believe, a total distance of five or six miles or more constitutes evidence that the material is suspended in the air, and could be inhaled or find itself inside a home if construction were permitted in this area.

Dr. First: It is your conclusion then that the mere fact that there is plutonium in the soil regardless of what its subsequent fate is is a danger to the population; it that correct?

Dr. Johnson: Yes, I do think the topsoil can be resuspended in the air and be inhaled.

Dr. First: But, it has not been so demonstrated?

Dr. Johnson: There is a study with dairy cattle which I do not think has been officially released. Some feel that hazards have been overstated. I think what the study does demonstrate is that cattle can inhale this dust into the lungs, and I think that humans can too. (Note added: I have since learned that this study herd came from north of the Rocky Flats Plant, and was exposed to much lower amounts of plutonium than is present downwind, to the east and southeast.)

Dr. First: Mr. Chairman, if it is permitted, and this is at your discretion, I would like to turn this question over to the people who gave us the information from Rocky Flats to get their response to this point.

Chairman Mills: Mr. Bean, are you here? Do you have any comment to make, Mr. Bean?

Mr. Bean: Why don't I take the microphone.

(Whereupon, Mr. Bean came to the microphone.)

Mr. Bean: Would you make the point specifically? Is it the cattle or the air that you are concerned with?

Dr. First: I am concerned with the question of the connection between the contamination of soil, which I assume you do not dispute the figures that have been produced as cited by Hazle, and the measurements that you people have made over the past several years showing these very low concentrations in the environment which you have cited, and the thing that worries me is what is the connection between the two in terms of human exposures? Is this a danger? The Doctor has said that he is quite concerned about it. I wonder what your attitude is about this?

Mr. Bean: Number one, let me talk about the way the plutonium got there. The plutonium was spilled from these oil drums on the ground. Now, since that time the area where the plutonium was spilled was covered with an asphalt pad. The plutonium is fixed under the pad. So, the original source material has been eliminated. It is not there any more. Plutonium was distributed downwind during the time the oil drums were there. So, the source material is much different today than it was then. That is number one.

The air sampling results that we see are, as we said before, less than 1% of the standard, and our air sampling

results can be verified by the Colorado Department of Health who do the same kind of air sampling in communities and around the plant, and we do not see the relationship between the soil and the air.

Dr. First: You are not worried about this as is the Health Commissioner, I take it?

Mr. Bean: I would not say that we are not concerned about the soil and the contamination of the air. I think our job is to assure that there is no further, no additional material added to the soil that would create another problem.

Dr. First: Would you not advocate, or would you, that the soil is suitable for development in the ways which have been discussed?

Mr. Bean: I think the AEC has previously testified at the original hearings with the Colorado Department of Health that their standard of .2 of a DPM per gram was unduly restrictive.

Dr. First: Thank you.

Dr. Garner: I want to resist very strongly the suggestion that is being made that we apply different kinds of value judgments to the development of standards for radioactive material and for chemical substances. The implication here is that we know a great deal more about the biological effects of chemical substances than we do of

radioactive materials. Whereas, the converse is true, as I think any of us who have been involved with radioactive materials know very well. One particular substance was mentioned, carbontetrachloride. It was said that it was very easy to establish the biological effects of carbontetrachloride on the basis of liver function tests and so forth. It is perfectly true that one can establish the short-term effects of carbontetrachloride very easily. Equally true that one can establish the effects of radioactive material very easily. But, it is just as difficult to establish the long-term effects of carbontetrachloride which is a carcinogent just like plutonium. It is just as difficult to establish the long-term effects of carbontetrachloride as it is of plutonium. In fact, we know very little indeed, very little of the long-term effects of many chemical environmental pollutants, and therefore I would suggest that if we are going to apply conservative safety factors, we apply them all around, not just to radioactive materials, but also to other chemical carcinogents in the environment.

Dr. Snyder: I would like to comment, if I may, that in the AEC's testimony they did present evidence on some placental discrimination, so that the question of the fetus and the child have not been ignored completely. However, I would not pretend that this answer all possible questions, but

still there has been some study of this question; and second, I would agree with the last speaker that I think we have a handle on radioactivity through the dose concept that we do not have with carbontetrachloride or practically any other chemical pollutant, and therefore we would not be well advised to use that as our standard. By the same standard for radioactivity, then, the occupational levels would be of no concern because no effects have been found in the people at and above these levels, and so presumably then we would say they are harmless. But, we do not quite buy that philosophy because we feel that there is some probability these people have not lived out their lives yet and there is perhaps some possibility that in the future they may develop something, and even if they do not, they are not a terribly large group. They number in the hundreds, and one cannot establish a probability effect of the order of say 10^{-4} or ^{5} or something of this kind in a study of the size of 100 people. So, I think we need to keep our perspective a little clear.

I think the difficulty in the statement here that the comparisons you are making with these high numbers was with the proposed standard by the State Board of Health, and this is essentially the background, and so the comparison really was with the background level and not with the standard for the MPC, so to say, from the plant.

Dr. Johnson: I have just one final comment. I do want to emphasize that the figures I gave were in relation to background. The Colorado State Department figures are also in relation to background, so the figures do sound rather high, and I think they are of interest.

In response to Mr. Bean, I understand there was an additional large area outside the area that has been paved to cover the original spot where the barrels were located. This area still has contamination equivalent to 2000 DPM per minute per gram of topsoil, or 25,000 times the background level. In addition, if you will look at the little table in my written testimony, you will see that there are larger areas with rather high levels of concentration, and all of these are still subject to wind erosion.

In response to the sampling of the air, I have some question about this procedure. In view of the fact that there are strong gusty winds in this area, I wonder if the actual monitoring instrument is going to reflect the actual movement of this material along the soil? (Plutonium has density similar to lead.) I am not an engineer, so I do not know. That is all I have to say.

Chairman Mills: Dr. Morgan?

Dr. Morgan: Dr. Johnson, you indicated that there are plans underway in Jefferson County for residential development about in a one-mile square area, and that this was

downwind from the Rocky Flats Plant. Question one, how far is it from a facility in the Rocky Flats Plant, and two, as the Health Officer in Charge in Jefferson County, have you been working with the Rocky Flats people in the preparation of an emergency plan, especially in view of this new development?

Dr. Johnson: In response to your first question, if you will turn to the last page of my written testimony, there is a copy of a map of this area. On it you will see an outline of the present land owned by the Rocky Flats facility. The land in question to be developed borders Indiana Avenue, which you will see approximately one mile east of the eastern boundary of this plant. This plot would extend from 96th Street to 108th Street.

Dr. Morgan: Have you been working with the Rocky Flats people in the preparation of an emergency plan?

Dr. Johnson: In response to your second question, I have not, and I think such a plan should be developed.

Chairman Mills: Thank you, Dr. Johnson. We will have a ten-minute recess. We will reconvene in ten minutes.

(Whereupon, a short recess was taken.)

Chairman Mills: The next speaker for the day is Dr. John Selner from the Colorado Medical Society. Dr. Selner?

Dr. Selner: Gentlemen: I would first off like to point out that I am going to make a statement for the Medical

Society. This statement is on behalf of the Medical Society. Any comments I might make aside from that,, I have not been authorized to make by the Colorado Medical Society.

We understand the intent of these hearings is to inquire into the need for establishing additional standards for transuranium substance exposure. The Colorado Medical Society appreciates the opportunity to address itself to this subject.

Colorado, it would seem, is in a unique and dubious position regarding exposure to these toxic materials. Because of the irreversible nature of a miscalculation in this area, the degree of competence demanded in decision making when ionizing radiation is concerned is extreme. The mining, processing, and distribution of waste materials with these capabilities has resulted in important health threats to Coloradoans. Some of these health threats have been predictable and result from failure to demonstrate demanded competence and responsibility on the part of the atomic industry, the AEC and its congressional controllers, and the Joint Committee on Atomic Energy. The experience with the uranium miners, the use of uranium tailings for home and public buildings in the Grand Junction area, the ongoing contamination of Colorado surface in subterranean water supplies, and the local plutonium contamination by the Rocky Flats Plant names but a few such instances. The attempt to

cover up the potential hazards that the 1969 fire at Rocky Flats Plant held for the front range of Colorado should give pause to all charged with the safety and well-being of the citizens of this state.

The Colorado Medical Society in conjunction with the State Health Department has studied these matters in great detail. We conclude that there is a need for establishment of a working principle regarding ionizing radiation. The exposure of living things to unnatural radiation is harmful.

Given the validity of this premise, we believe that the nine general principles summarized in the BEIR report of the "National Academy of Science," 1972, serves as an appropriate guideline from which to establish subsequent standards. We endorse the concept of consideration of relative risk against relative gain. Relative risk here has to be defined both in potential for genetic and somatic damage to living organisms. We feel that total body exposure consideration is appropriate to certain types of ionizing radiation but that isolated fixed exposure can become a primary consideration. We would like to focus specific attention on Section G, Page 9, of the BEIR report under Summary and Recommendations. Here occupation exposure would apply to individuals living in close proximity to facilities such as the Rocky Flats Plant. Given the natural climate and atmosphere conditions peculiar to the location of this facility, standards established for

another locality might not apply here. The arid conditions that promote the suspension of particulate matter as an airborne dust together with the wind velocity experienced in this locality create conditions for an increased probability of the inhalation of radioactive materials from this facility.

Assuming there would be no risk of an accident similar to the 1969 experience at Rocky Flats, which could have resulted in a massive release of radioactive material, one still must deal with the probability of inadvertent release of toxic materials. Disclosures of release from stockpiled waste materials was predictable. The more recent discovery of contamination of municipal water supplies distant from the plant and cattle on the grounds of the plant all support the reality of this concern.

The recent discussions of acceptance of safe lung loads for workers at the Rocky Flats Plant is a good case in point. Plutonium materials can reach human beings by ingestion, i.e., water, plant, animal, or food where it can be concentrated in the process of plant and animal metabolism. Plutonium can be inhaled. In either case, it is either a soluble substance that then can locate in regional lymph nodes and bone marrow on a very permanent basis, or it is inhaled as a particulate substance, again on a very permanent basis. Cells proximal to the implantation area are subjected to a constant radiation exposure. All evidence

suggests that this affords optimal conditions for the induction of a malignant change whether we are discussing lymph, bone marrow, or lung cellular exposure. The Colorado Medical Society does not view this as a speculative consideration. Rather we consider this type of exposure an imminent threat to health. We believe this position is supported by the overwhelming weight of presented evidence.

Reassurance of Dow officials of the relative safety of known lung exposures based on prospective data is not convincing. Current methodology for assessing exposure on the basis of total body counting and extrapolation to approximate lung burdens and systemic estimations based on urinary excretion analysis could be at best described as educated guessing. A persuasive parallel to this dilemma can be made with the recent experience with asbestos. It is now known that 20 to 25 years after the inhalation of asbestos dust particles an alarming incidence of mesothelioma has been described. This is a highly malignant tumor of the lung. This is only realized, however, after many years of apparent good health on the part of these workers. With the evidence that has been accumulated establishing the risk of chronic long-term exposure of cellular materials to radiations, as would be the case with the inhalation of plutonium particles, the Colorado Medical Society is forced to conclude that the only safe level for a given individual is zero. We are very

aware that this ideal is not achievable because of the background plutonium contamination which is now worldwide as a result of atmospheric explosions of atomic weapons. We are also very cognizant of the predictable increase in background levels as atmospheric contamination continues to precipitate on the earth. Therefore, we recognize that the risk of inhalation and general exposure to transuranium substances will be with us regardless of establishments of standards at this time. The average background concentrations for plutonium in the front range area is 0.08 disintegrations per minute of plutonium per gram of dry soil. The 0.2 DMG standard recommended by the Colorado Health Department in March of 1973 was considered ultra-conservative. This figure was raised to 2 DMG after considerable analysis. The Colorado Medical Society views any attempt to further raise this standard at this time as inconsistent with efforts to assure the safety of the people of this area.

Considering relative risk versus relative benefit, the Colorado Medical Society strongly urges the Congress of the United States and the Environmental Protection Agency now charged with overseeing environmental implications of radiation exposure to consider the following:

1. The operation of the Rocky Flats Plant is directed

almost solely at the development of component parts for nuclear warheads.

2. The defense establishment of this government presently possess in deliverable form capabilities of destroying all human life on this planet many times over.

3. Further development of this nuclear potential and further sophistication of available delivery systems is implicit in the continued operation of the Rocky Flats facility and the recent agreement between the United States and the Soviet Union.

Although we recognize the imperative need for a strong defense position in this country, the medical community of Colorado is not convinced that the continuing acceleration of our nuclear defense posture is in the best interest of the people of this country. We believe this capability cannot be employed without assuring the very destruction of the people it has been developed to protect. We do not recognize the rationale of subjecting our citizenry to a technical endeavor that in our judgment would only guarantee an unacceptable risk.

That is the end of the statement.

Chairman Mills: Thank you, Dr. Selner.

In your statement, and correct me if I am wrong, but I understood you to say that you had determined that non-

natural radioactivity is harmful?

Dr. Selner: Yes.

Chairman Mills: Are you making a distinction between natural radioactivity and non-natural radioactivity?

Dr. Selner: Well, first I want to say that I am not engaged in either study or research in nuclear medicine, and I am not a nuclear physicist. I am a practicing medical doctor. I am not a radiologist. I would like for you to understand that.

Yes, I think you have to make that distinction, because there is nothing you can do about the background that is already there, yes.

Chairman Mills: Do you also see that there is a need for any kind of distinction to be made between situations that may require some corrective action as in the case of contaminated soil as opposed to that for plant releases of material, what might be effluent guidelines? Do you in your own mind make a distinction between the needs? These two needs are somewhat different.

Dr. Selner: If the problem already exists, and it is there, and you are talking about a possibility of additions, yes, I think they are two different things.

Chairman Mills: Any other questions? Dr. First?

Dr. First: I am not sure I understand what the recom-

mendations of the Colorado Medical Society are outside of the area of global strategy, just what standards the Society is advocating, assuming that we are going to continue to use plutonium for at least military purposes and research for some foreseeable period?

Dr. Selner: I will leave a copy of the statement. What we are recommending is that the level of 2 DMG which was recommended by the Colorado Health Department be supported, and we do support that recommendation.

Dr. First: On what basis? Do you have some information which would translate this into human exposures and projected or predicted human illnesses, or is this just in response to the State's presentation of an earlier time this morning?

Dr. Selner: I think I am familiar with some of the research which has led to that recommendation, and the thought processes that has gone into that recommendation on the part of the Health Department, and I would say, yes, this is basically one of the most important of our thoughts. However, I think it is also very important to recognize that a good deal of data that some of these statements I heard being made with the previous speaker are based on exposure evidence on very small numbers of people for obvious reasons. You cannot go out and expose a large group of folks to radioactivity in order to find out if it is harmful.

Statistically it is extremely difficult to draw conclusions on the basis of those limited sample populations. One thing that is known, and I think there is good documentation for this and references can be provided if you so desire, is that there is an extreme variability in individuals and their tolerance for various toxic things, and certainly radioactivity is no exception to that. So, you need a very large population of people in order to draw some conclusions for safety that have been drawn.

Dr. First: Well, I think we all recognize that. I must say that I am a little disappointed that the entire medical fraternity of the State of Colorado makes a statement with no medical toxical information contained in it. I had hoped that this would be a good medical review of the problems of bringing out points which would be particularly pertinent to medical concerns.

Dr. Selner: I think it was the judgment of the Society that that information is being brought out by such as the Department of Health for the State.

Dr. Garner: I would like to point out that although you may like to try to distinguish between natural and what you call perhaps unnatural radioactivity, the body cannot distinguish between the two, and the effects of any naturally-occurring activity are indistinguishable from those of the effects of any man-made activity. You said

that we could not reduce the intake by inhalation to zero because of background plutonium. In fact, we could not if there were no background plutonium because regrettably, and perhaps to some in this area there is an awful lot of uranium in the rocks, and so dust, anything you breathe, will contain naturally-carrying uranium, which also and its daughters emit alpha activity just like plutonium. So that, come what may, if we breathe dust in this area, we are exposed to alpha activity.

Dr. Taylor gave a figure, he said about 10 curies per square mile in daughter products. Now, my arithmetic may well be in fault, because I have just scribbled that out, but that works out to me to about 4 microcuries per square meter, and the Colorado Health Department standard, you will recollect, is 2 DPM plutonium, which is the equivalent of about .01 microcuries per meter square. This figure has been lowered by a factor of four-hundred from what occurs naturally. I am just trying to get this thing into perspective. We are here worrying about man-made activity, which is in fact a small fraction of what is there unavoidably. The body cannot distinguish.

Dr. Synder: I too would like to comment on your use of the threat to health. As I understand it, the State standard was not based on any demonstrated or even suspected threat to health. It was based on the levels found in the environ-

ment, and consequently there was no threat to health except by extrapolation from higher numbers, and as has been pointed out, this extrapolation would lead one to find higher threats to health from the natural emitting alpha nuclides.

Dr. Selner: Doctor, the reference to threat to health was not in reference to this standard. The reference to threat to health was in reference to other occurrences in this state where I think the threat to health has been very clearly established. If you recall, it was in reference to the experience with uranium miners and the situation in Grand Junction with regard to radon gas and its daughters. That is what the reference was about.

Chairman Mills: Thank you very much, Dr. Selner.

The next speaker is Dr. John Cobb of the University of Colorado Medical Center.

Dr. Cobb: I believe you have copies of my paper?

Chairman Mills: Yes, we have.

Dr. Cobb: My name is John C. Cobb. I am Professor of Preventive Medicine at the University of Colorado Medical School.

As a member of the Rocky Flats Task Force appointed by Governor-elect Lamm and Congressman-elect Wirth, I have spent much of the Christmas and New Year holidays reading reports, documents, books and papers related to plutonium pollution as a possible danger to the health of citizens of

Colorado. I do not recommend this for a Christmas vacation. Never, in a rather varied career of more than 30 years in medical and public health, have I come upon a field with so much controversy and so little well-substantiated information. Part of the trouble, of course, stems from the secrecy which necessarily surrounds the atomic weapons program; but much of the trouble evidently has come from the public's growing concern that citizens are being exposed to an unknown, invisible, odorless, silent peril as a result of mistakes, carelessness and accidents in the handling of plutonium. People suspect that the facts about these occurrences have been unnecessarily kept secret in order to protect those who were responsible. Repeated denials and attempts to cover up, followed by later admissions by the AEC and its contracting agencies, and given vigorous coverage by the news media, have gradually built up an aura of suspicion and mistrust of the AEC. The whole "Watergate Affair" has evidently not improved the public's feeling of trust in our Government.

Another reason for the mistrust is the unfortunate inadequacy of checks and balances on the AEC. The very same agency that was involved with promoting the expansion of all kinds of uses of atomic energy was also responsible for establishing controls under conditions where secrecy could be used to prevent scrutiny by outside experts and to prevent public discussion of issues such as health and

safety of citizens.

Value decisions of life and death importance to citizens of today and to future generations of all living things were made virtually without public discussion. The public had no opportunity to weigh the risks of plutonium pollution against the benefits of atomic weapons or atomic power plants. We were simply left in the quiet dark with our fears. Each whisper of information leaking to scared people was amplified in the reverberating circuit of public alarm. Now in this atmosphere of alarm and mistrust, it is most difficult for a reasonable value decision to be made. Nevertheless, it must be done. The recent reorganization of the AEC, the court case leading to the legal involvement of the EPA, the creation of the Rocky Flats Task Force are welcome developments. Citizens can now look forward to less secrecy and more opportunity to be involved in decision making. Scientists like myself have the duty to present as clearly as possible what the known facts are, what the uncertainties are, and what research is necessary to get the answers we need. The public then, through its representative government, must decide what to do. No scientist or AEC administrator should be allowed to make such decisions involving human values like sickness and health, like the protection of our way of life from foreign powers, or possible destruction of a large part of the living things in the

world, without input from ordinary citizens who have had an opportunity to be thoroughly informed on all sides of the question.

It is my intention, therefore, at this public hearing, to do my best to summarize some of the evidence and uncertainties regarding the difficult job of setting safety standards for minute particles of the oxide of plutonium-239 such as are being blown from Rocky Flats into the air breathed by the citizens of Colorado.

Let us review some of the data. The most liberal point of view regarding safety standards that I have encountered comes from data on a 27-year study of 25 selected Los Alamos plutonium workers. These men got relatively heavy doses plutonium in various forms. (Unfortunately the details of the amount or the form in which the plutonoum was inhaled was known only very roughly because of the lack of sophisticated monitoring equipment which was available at that time, 1944 to 1945.) The estimated body burdens of plutonium ranged from 0.1 to 1.2 micrograms of plutonium, that is 6,000 to 80,000 picocuries, a very large dose by today's standards. The authors of this study, Hempelmann, Richmond and Voelz, in their informal report state that "to date, none of the medical findings in the group can be attributed definitely to internally deposited plutonium ...we conclude," I am still quoting, "that the body has protective mechanisms

which are effective in discriminating against these materials following some types of occupational exposures."

Certainly the fact that these 25 men with such a body burden have survived 27 years without serious effects proves that such plutonium exposure is not uniformly harmful nor even necessarily carcinogenic. This is reassuring to those who have been exposed. Does this mean that doses of this level or less are harmless? Certainly not. It would be somewhat comparable to say that because 25 men returned safely from an expedition to climb Mt. Everest, that climbing mountains was therefore safe and that exposure to high altitude and cold is harmless.

A more pertinent question would be: What is the smallest exposure to plutonium which has been clearly shown to cause harm? Perhaps the smallest reported harmful human exposure was that of a machinist who received 0.08 micrograms, that is 30 millionths of an ounce, of plutonium-239 from a puncture wound in his hand. Lushbaugh and Langham (1962) reported that after four years it produced a nodule which displayed precancerous changes. Numerous animal experiments suggest that even smaller amounts of plutonium-239 inhaled as very small particles, that is, 0.1 - 0.5 microns diameter, into the deepest recesses of the lung may cause lung cancers. These data may or may not be applicable to man.

Now the most pertinent question is the following: How small a dose of plutonium is likely to be harmful to enough people, so that the risk to society, I am talking about an exposure to a large number of people, so that the risk to society would not be worth the possible benefit? Here we get into the difficult area of estimating probabilities and the more difficult area of value judgments. Unfortunately, we cannot get a very good estimate of the probable risk involved in very low plutonium exposures because the people who have had such low exposures, like the people who live downwind from Rocky Flats, have not been adequately followed and studied. I might add that even the people who have worked at Rocky Flats have not been adequately studied. That is, the whole population has not been studied. Those who have left employment there cannot be followed because there is no legal way of forcing them to be followed. Futhermore, for those few employees of Rocky Flats with known exposures who have been followed and studied, the time interval is too short. It evidently takes about 30 years for cancers of the lung to develop as a result of this kind of radiation.

Much more serious for the long-term future of mankind, is the possibility that plutonium-239, with a half-life of over 24,000 years, may find its way from the lung into the gonads where it may affect the germ cells and cause con-

genital defects in future generations. In fact, appreciable concentrations of plutonium have been reported by Campbell and others in the gonads of deceased men who came to autopsy via the medical examiner's office, this was due to accidents, crime, etc., in New York City. They were not considered to have been occupationally exposed to plutonium, but their occupations were not reported in the data available to me. Measurements of the amount of plutonium-239 found in the testicular tissue of 26 subjects from New York City revealed that three of them showed more than 7 disintegrations per minute per kilograms of tissue and one of them showed 19.0 dpm/kg, whereas the highest measurement on the lungs of the same subjects was only 2.27 dpm/kg. These data suggest that plutonium inhaled from the air passes through the lungs to the gonads in appreciable concentration. There it may damage the chromosomes of sperm cells which could lead to serious congenital defects of the offspring and of future generations. Further research on this is greatly needed. And, in addition, we need to review, as I mentioned before, the history of the people who have been exposed, not just the ones who are still working, but the ones who were working in the past at Rocky Flats and other places and those who live nearby. We need to review the data that is available from the Rocky Flats sponsored study of chromosome breaks in people who are now working at Rocky Flats, and we

need to probably start many more studies. But, we do need to find out as much as possible about this danger.

A number of researchers are now looking at various possibilities that very small amounts of plutonium-239, perhaps 1-thousand times less than present standards, inhaled in the form of plutonium oxide, may cause cancer in the lungs. Dr. Martell will report on his hypothesis and related findings later today. I have been asked to review briefly the "hot particle" hypothesis of Tamplin and Cochran (1974).

I would like to emphasize that this "hot particle" hypothesis has not been proven nor is it generally accepted. At the same time, data are lacking to disprove it. I asked Professor William Hendee to review Tamplin and Cochran's paper critically. He is head of the Division of Therapeutic Radiology at the University of Colorado Medical School and is more conversant than I with these matters. I would like to include his comments in the written testimony which I am submitting today, with his permission; and it is attached to the document that you have. Briefly he concludes that there are so many uncertainties in the basic data on which the hypothesis is supported in this paper, that the "hot particle" controversy remains unfortunately still unresolved. Furthermore, there are theoretical reasons for questioning this hypothesis, as Dr. Martell pointed out to me. These same

theoretical considerations regarding the "hot particle" hypothesis do, however, lead him, that is Dr. Martell, to recommend an approximately equally stringent set of standards for small insoluble plutonium particles in air.

Now let me briefly summarize this hot particle hypothesis: Briefly this hypotehsis is that a very small insoluble particle of plutonium 239 of about 0.1 to 0.5 microns in diameter containing at least 0.07 picocuries, if it were inhaled and lodged in the deepest recesses of the lungs, would remain there for some years and continue to radiate the surrounding cells with alpha rays. Because the range of these alpha rays in lung tissue is very short (about 45 microns), just a few cells, this would result in a relatively large dose of radiation (at least 1000 rem/yr) to a small number of cells. Assuming that the likelihood of cancer production is dependent on the intensity of radiation of those few cells, Tamplin and Cochran reason that such small "hot particles" of plutonium are more likely to cause cancer than if the same amount of radiation were evenly dispersed in the lung tissue. On this basis they argue that for nonoccupational exposure, the maximum permissible lung particle burden of plutonium-239 should be set at 0.2 hot particles, on the average, per person; with the corresponding maximum permissible concentration in the air being 9×10^{-18}

micro curies per cm^3, and the corresponding maximum permissible surface concentration for unrestricted areas being 1 hot particle per square meter. For comparison, monthly composite measurements of the ambient air in Denver run about twice this suggested limit according to the 1973 Annual Environmental Monitoring Report of Dow Chemical, and the concentration in the soil just to the east of Indiana Avenue near the east entrace to the Rocky Flats plant outside the perimeter of the property runs about 0.1 microcuries per square meter which would be more than one million hot particles per square meter, assuming that all of the plutonium were in particles of the size referred to above, that is containing 0.07 picocuries each. It is, of course, more likely that the large particles have settled out near the Rocky Flats Plant, while the smallest and most dangerous according to the hypothesis, the most dangerous ones have blown into Denver for us to breathe.

Now, as to a basis for setting standards. Obviously the Tamplin and Cochran hypothesis does not present a suitable basis at the present time. It is based on data which as I have said is not reliable enough, and it has not been generally accepted. Yet, it has not been disproved, and I feel that we have to remember this and work to get the data that we need to settle these questions.

As one who is primarily concerned with the health of

the public, now and for future generations, I feel it would be desirable to assume the worst, set temporary standards accordingly now, and get on with the needed research. Let me re-emphasize that I am particularly concerned about the possible effect of plutonium on sperm and egg cells in the gonads and its consequent possible harmful effects on future generations. If we should make a mistake now, and inadvertently allow plutonium to seriously contaminate our environment to a level of say 1000 times too high, which some researchers believe to be the case, including Tamplin and Cochran, we would have to wait for a quarter of a million years before it would decay back down to the acceptable level. By that time the human race might long be gone from this earth. We are gambling with the future of life on this earth; the probability of losing may be very, very low, but the stakes are very high; I urge a conservative and cautious approach to the setting of plutonium standards.

Now, we have heard about risk versus benefit analysis. I would like to add another aspect to what has already been said. I would like to return now to my opening remarks about risk versus benefit analysis. I think it will help to clarify the issues and to make decisions if we try to answer these questions.

First of all, who and how many are the ones who would benefit from continued plutonium production allowing con-

tinued pollution at present levels?

And the second question, who and how many are the ones who would benefit from setting conservatively safe standards now for plutonium in the environment with the possibility that we might change them later to a higher level.

First to take those who would stand to benefit from plutonium production, they are not only the 2,900 people who work at Rocky Flats, not only the stockholders of Dow Chemical and Rockwell International, but all of the people of the United States of America who, according to George Wald, (1974) are spending twenty million dollars a day on nuclear arms for the "MAD" program, twenty million dollars a day. This "MAD" stands for Mutual Assured Destruction. That is not a joke. We are making about three new hydrogen bombs every day, and the USSR is keeping pace with us. The purpose, on both sides, is to preserve a way of life -- Democracy or Communism or something -- which from our present perspective we think is more important than life itself. Using these hydrogen bombs would assure our mutual destruction. MADness indeed!

Now to look at the other side of the ledger, setting conservatively safe standards might mean that we would have to stop making nuclear weapons. If the whole world could agree, none would be the losers except those who are now making a living or a profit from the nuclear weapons

industry. Who and how many are the ones who would stand to benefit?

Those who would stand to benefit from such rigorous standards that might require stopping nuclear production would be not just all the people who are breathing air contaminated with plutonium, not just the people living, laughing and loving in the United States or Russia or any other place, any other "hostile" country who would be spared mutual assured destruction, not just the total population of the world today who would be spared from the killing and crippling radioactive fallout; those who would stand to benefit are all the people and animals and plants of future generations -- the descendents of ourselves and every living thing which might live in the world in the next million years. These are the ones who would benefit most from setting a plutonium standard safely and conservatively, and of course from preventing nuclear war.

Some say that increasing the radiation exposure that everyone gets would speed up evolution and would be a good thing. By causing congenital anomalies, it might even reduce the birth rate and thereby control the overpopulation of humans, which some think would also be a good thing. But fortunately, and this is in my particular field, there are better and surer and far safer ways to accomplish both these things -- if we should decide they really would be good.

The change that any mutation or chromosome break caused by ionizing radiation might be beneficial, thereby advancing our evolution, is approximately the same as the chance that a clock would keep better time if you were to shoot at it with an elephant gun. You would have to shoot holes in millions or billions of clocks, spoiling almost all of them in the process, in order to get one that actually kept better time as a result. This is not the way I would choose to do it.

I urge the EPA, in setting standards for plutonium in the environment, to be cautious and conservative and respectful of all living things, now and for forty thousand generations of human life to come. A million years from now, they will thank you.

Thank you.

(Applause.)

REFERENCES

Campbell, E. E, Milligan, M. F., Moss, W. D., Schulte, H. F., and McInroy, J. F. (1973), "Plutonium in Autopsy Tissue", Report LA-4875, UC-48, January 1973 of the Los Alamos Scientific Laboratory, US AEC.

Dow Chemical 1973 Annual Environmental Monitoring Report, REP-ENV-73 issued April 27, 1974.

Hempelmann, L. H., Richmond, C. R., and Voelz, G. L. (1973), "A Twenty-Seven Year Study of Selected Los Alamos Plutonium Workers", Informal Report LA-5148-MS of the Los Alamos Scientific Laboratory, US AEC. (Available from National Technical Information Service U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151)

Lushbaugh, C. C. and Langham, J. (1962), "A Dermal Lesion from Implanted Plutonium", Archives of Dermatology 86, pp. 121-124.

Tamplin, A. R. and Cochran, T. B. (1974), "Radiation Standards for Hot Particles" a Report to the EPA and AEC, available from the Natural Resources Defense Council, 1710 N Street, N. W., Washington, D. C. 20036.

Wald, G., Editorial, Bull. Atom Scientists, Dec. 1974.

Form 365

UNIVERSITY OF COLORADO MEDICAL CENTER

Inter-office Communication

TO Jock Cobb DATE 1/6/75

FROM Bill Hendee

SUBJECT: Comments on the Paper "Radiation Standards for Hot Particles" by Arthur R. Tamplin and Thomas B. Cochran

With but one exception, radiation protection standards for internally deposited radioactive materials are based upon the assumption that the materials are distributed in such a manner that the radiation dose to the critical organ is relatively uniform. The one exception to this practice is the standard for ^{226}Ra, where the maximum permissible skeletal burden of 0.1 μg is based upon extensive studies over many years of the relationship between the skeletal burden of ^{226}Ra and the incidence of osteogenic sarcoma. A second radionuclide for which the uniform dose model may not be appropriate is ^{239}Pu in insoluble form as small particles (<0.6 μ) which may be inhaled and deposited in the deep respiratory tract for long periods of time. Unfortunately, the types of human experience which gave rise to the 0.1 μg skeletal limit for ^{226}Ra are not available for ^{239}Pu.

Because of the absence of experimental data concerning the biological risks associated with deposition of insoluble ^{239}Pu particles in the lung, controversy has surrounded the application of radiation protection guidelines based upon uniform dose assumptions to this health physics problem. This controversy has existed for a considerable period of time, and is now identified as the "uniform dose vs. hot particle" controversy. This controversy is the focal point of Tamplin's and Cochran's paper.

In their paper, Tamplin and Cochran call for some remarkable changes in present radiation protection standards in terms of their applicability to hot particles, particularly $^{239}PuO_2$. For example, the authors propose that the maximum permissible lung burdens and maximum permissible concentrations in air for occupational and non-occupational exposure all be reduced by a factor of 115,000 for ^{239}Pu in the form of insoluble hot particles. Furthermore, Tamplin and Cochran suggest that the exclusion areas for nuclear reactor sites, nuclear fuel processing plants, and nuclear energy research establishments should be expanded so that no individual at the exclusion site boundary for 2 hours immediately after accidental release of radioactive material would receive a lung particle burden in excess of 10 hot particles. I am unsure of all of the implications of these recommendations with respect to the development of nuclear power facilities and maintenance of a nuclear weapons program, but suspect that the proposed recommendations would seriously handicap, if not cripple, both industries. Whether either industry could continue to function, and at what cost

to the taxpayer in terms of the improvements required in safety procedures, should be investigated thoroughly before any actions are taken on the proposed standards. The final decision will undoubtedly be a matter of judgment rather than objective appraisal of data, because good data related to this problem simply are not available.

Nowhere is the lack of good data more apparent than in the paper by Tamplin and Cochran. For example, the paper by Albert et al. is quoted extensively (Figures 1 and 2), but the decrease in tumor incidence with dose above 2000 rads is not mentioned, although this feature certainly has some importance with respect to extension of Albert's data to the $^{239}PuO_2$ problem, particularly in relation to the dose to tissue near a plutonium particle. Also, no particular attention is directed to the influence of dose rate on tumor induction, except to say that the tissue repair time is probably 1 year for the lung, an assumption based upon a model for the lung which is founded on very little biologic data. These and other difficulties cause me to question the 1000 rems/year threshold dose rate postulated in the paper as the criterion for defining a hot particle. Because of these difficulties, the explanation by the authors as to why none of the 25 Manhatten Project workers has developed lung cancer (i.e., the dose rates are lower than 1000 rem/year) seems to rest upon a rather arbitrary criterion. Animal data quoted by Tamplin and Cochran as most relevant to any consideration of radiation standards for hot particles are those collected by Bair and his colleagues on studies of $^{239}PuO_2$ inhalation in beagles. The authors conclude from these data that induction of lung cancer is a certainty during the life span of the participating animals. Interestingly, Bair is also one of the three authors of a report entitled WASH-1320: A Radiobiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium (November 1974). Conclusions in this report include:

1. Recognizing the importance of spatial distribution, researchers have continued to study its radiobiological aspects, but "continued examination...especially as regards alpha-emitting particles, has not led to major changes" in standards.

2. "...truly uniform distributions of inhaled radionuclides in lung seldom, if ever, occur. However, because of the mobility of plutonium within lung, there is some biological justification for averaging the radiation dose to the total tissue."

3. Comparisons of uniform and nonuniform distributions "suggest a biological sparing effect for both acute and late responses to the non-uniform distribution. Available experimental data indicate that averaging the absorbed alpha radiation dose from plutonium particles in lung is radiobiologically sound."

4. "Consideration of mechanisms of radiation carcinogenesis suggests that there has been no change in direction or strength of data which would compel departure from the concept that average lung dose for alpha particles provides a reasonable and conservative base for protection."

5. Over thirty years of experience with plutonium indicates "there is no evidence that the mean dose lung model on which occupational radiation protection standards for plutonium are based is grossly in error or leads to hazardous practices." Since data from exposed persons indicates non-homogeneous distribution does not result in greater risk than uniform distribution," empirical considerations lead to the conclusion that the non-uniform dose distribution is not more hazardous, and may be less hazardous, than if the plutonium were uniformly distributed...."

I believe that in essentially all of the animal and human data which Tamplin and Cochran quote in support of their proposal to reduce radiation protection standards for plutonium particles, one can find similar uncertainties regarding the data on the ways in which the data are used in defense of the proposed standards change. Similarly, I believe that risk estimates based upon multiplication of a small estimated risk times a large population have an equally uncertain significance. Hence, I am unable to get very excited about Tamplin and Cochran's paper. This unwillingness does not reflect a blasé attitude on my part about the uniform distribution versus hot particle dose controversy. It means simply that I do not believe Tamplin and Cochran have contributed anything very meaningful towards its resolution.

cc: Theodore T. Puck, Ph.D.
Arthur Robinson, M.D.
Marvin L. Daves, M.D.

EDITORIAL Arise, Ye Prisoners

(Reprinted by permission of the Bulletin of the Atomic Scientists and the author.)

(Copyright (c) 1974 by the Educational Foundation for Nuclear Science.)

GEORGE WALD

I have come halfway across the world to speak what I believe to be the truth. It is a dreadful truth, hard to live with. But if we do not live with it, we shall die by it.

I speak here as an American, but even more as a fellow human being, a scientist concerned with life, a teacher deeply troubled for my students, a parent fearing for my children and for their children.

Human life is now threatened as never before, not by one but by many perils, each in itself capable of destroying us, but all interrelated, and all coming upon us together. I am one of those scientists who does not see how to bring the human race much past the year 2000. And if we perish—as seems more and more possible—in a nuclear holocaust, that will be the end not only for us but for much of the rest of life on the Earth.

We live—while that is permitted us—in a balance of terror. The United States and the Soviet Union together have already stockpiled nuclear weapons with the explosive force of 10 tons of TNT for every man, woman and child on the Earth. You might think that enough, but both countries are now in the midst of further escalation, replacing every single nuclear warhead with multiple warheads and devising new and more devastating weapons.

My country at present is making three new hydrogen warheads per day. The Soviet Union keeps pace with us. We are told that our security (strange thought) lies in Mutual Assured Destruction—MAD. It is well-named.

The bomb that destroyed Hiroshima, and ended by killing about 100,000 persons, was a small one by present standards, with the explosive power of about 15,000 tons of TNT.

One of my friends about 10 years ago was able to look up what we then had targeted upon a Russian city about the size of Hiroshima. It was in the megaton range, several hundred times as large. Why? One can only destroy a city. One can only kill a person. It is insane—but the insanity of the practical and calculating persons who run our lives. It is insane—unless one holds an arms contract. Then it is business, and the bigger the better.

The United States now budgets about $22 billion a year on new arms. A rapid rate of turnover assures that this business will go on. Our arms sales abroad doubled in 1973–74 over the year before—$8.5 billion, about $7 billion going to the Middle East. When early in 1971 the Joint Economic Committee of Congress asked a general from our Department of Defense how much military hardware the department then held that had been declared surplus, mainly to be sold as scrap, he replied $17 billion worth.

The nuclear arms contracts alone are worth about $7 billion a year. Seven billion dollars talks more loudly than any number of humanitarian declarations or terrified people or children facing extinction. That money is real, hard cash. Where it changes hands, those consequences are out of sight, hence out of mind—mere abstractions.

The Big Hunger

But arms, and war, and nuclear weapons are only part of the crisis. The big hunger is now upon us, the great famines that scientists have been predicting for years past: hunger among the poor in the developed countries, starvation in Africa, South Asia and South America.

The Green Revolution, so recently begun, has already collapsed. It depended on huge supplies of cheap oil and coal to prepare the artificial fertilizers and pesticides that alone made it work. And oil and coal are no longer cheap. The profits of the major oil companies—which also own most of the coal and are now developing nuclear power—doubled and tripled during the past year as the peoples of the Third World began to starve. It seems possible that 20 million persons will die of famine during the next 12 months in India, Pakistan and Bangladesh alone.

All those problems are made more terrible by the population explosion. We have not yet quite taken in what that means. Even if all the developed nations reached the replacement level—an average of two children per producing pair—by the year 2000 and if all the nations of the Third World came to the same state by 2050 (both conditions highly unlikely), then the world population, which is now at about 3.7 billion, would rise by 2120 to about 13 billion.

Development, so-called, has meant mechanization. The work that used to be done by human and animal muscle is increasingly done by machines. That is true even in agriculture. It is another aspect of the Green Revolution. Farming is rapidly being replaced by 'agribusiness.'

In the United States the same huge corporations that make aircraft, control our oil and gas and run our transportation, also grow our food. Such agribusiness now controls 51 percent of our vegetable production, 85 percent of our citrus crops, 97 percent of our chicken-raising, and 100 percent of our sugarcane. That is happening all over the world. It means more food, but many fewer jobs. And only those who find work can eat and feed their families. Unemployment, that child of the Industrial Revolution, is rising throughout the world.

George Wald delivered this speech last August in Tokyo at the 20th World Conference Against Atomic and Hydrogen Bombs. He is Higgins Professor of Biology at Harvard University, and a 1967 Nobel laureate in physiology or medicine.

And a new phenomenon has developed that is much worse. With increasing mechanization, increasing numbers of persons have become not only unemployed but superfluous. There is no use for them in the free-market economy. They are wanted neither as workers nor customers. They are not wanted at all. Their existence is a burden, an embarrassment. It would be a relief if they vanished—parents and children.

In his report to the International Bank for Reconstruction and Development (World Bank) in September 1970, its president, Robert McNamara, former Ford executive and U.S. Secretary of Defense, spoke of such persons as "marginal men." He estimated that in 1970 there were 500 million of them—twice the population of the United States—and that by 1980 there would be one billion, and by 1990, two billion. That would be half the world population.

It is too late for declarations, for popular appeals, here or anywhere. All that matters now is political power.

We call here for the abolition of nuclear weapons. Even in the remote chance that that would happen, it would not protect us from nuclear war. Those nations that have already learned how to make nuclear weapons would produce them in quantity within a few months of the outbreak of a new war. Getting rid of the nuclear stockpiles would defuse the present threat of instant annihilation; it would gain us a little time. That would be an important gain, but only a step toward what must be the ultimate aim: to abolish war. War is obsolete in the modern world. It has become intolerably dangerous.

The only thing that can save us now is political power—for the peoples of this world to take that power away from their present masters, who are leading our world to destruction.

Who are our masters? In the so-called 'free world' it is not the governments. They are only the servants, the agents. Nor is it the generals; they too are only servants.

The free world is run by such enterprises as General Motors, ITT, the Chase Manhattan Bank, Exxon, Dutch Shell and British Petroleum, Mitsubishi and Mitsui. Their wealth and power exceed any previously known throughout human history.

We think of General Motors as a private business; but only 18 nations in the world have gross national products as large as the annual sales of General Motors, $36 billion in 1973.

Those giant corporations can buy and sell, can make and break governments. They stop at nothing. A year ago Chile was taken over by a military junta, its President Allende murdered, its great folk singer Victor Jara beaten to death. But now ITT, which offered our CIA $1 million to keep Allende from becoming President, can operate freely. And Anaconda Copper has just settled its claims with the new Chilean dictatorship for $253 million.

And what of the 'socialist' world? It offers us an imperialism of the left to balance that of the right. We have had hard lessons to learn during the past years. One of them is that private wealth and personal political power are interchangeable, bureaucracies are interchangeable, generals and admirals, corporate executives and industrial commissars—all interchangeable.

Hence no nation so closely resembles the United States of America as the Soviet Union. That is what Andrei Sakharov told us a few years ago; he proposed that both nations now join forces to work for the good of humanity. For that he is virtually a prisoner in his own country. Policy in the modern world, right or left, is not made by the Sakharovs.

We are often told indeed that even the experts do not know how to deal with the problems that now threaten worldwide disaster, that "all the facts are not yet in," that more research must be done, and more reports written.

By all means let us have more research. But that must not be allowed to become a trap, an excuse for endlessly putting off action. We already know enough to begin to deal with all our major problems: nuclear war, overpopulation, pollution, hunger, and despoliation of the planet Earth.

The present crisis is a crisis not of information but of policy. We could begin to cope with all the problems that now threaten our lives. But we cannot cope with any of them while maximizing profits. And a society that insists before all on maximizing profits for the few thereby threatens disaster for all. But not for all at the same time.

As matters now stand, the peoples of the Third World are to perish first. They have already begun to starve. All that is asked of them is to starve quietly. If they make trouble, they will be exterminated by other means.

The developed nations are armed to the teeth, and they mean not only to hold on to what they have but to grasp whatever more they can, while they can—for example, the last of the world's rapidly dwindling natural resources. Another example. As the great famines begin, the grain that might feed a hungry peasantry throughout the Third World is fed instead to cattle and hogs to supply the rapidly increasing demand for beef and pork in the affluent countries. But the developed nations' turn will come too—first, of course, to their poor, already hard-hit by worldwide inflation and unemployment. And if there should be another major war, as seems likely, a nuclear holocaust would swallow up everything.

Unless the people of this world can come together to take control of their lives, to wrest political power from those of its present masters who are pushing it toward destruction, then we are lost—we, our children and their children.

Arise, ye prisoners of extinction. Peoples of the world, unite. You have nothing to lose but your terror, your exploitation and ceaseless deception, your alienation and dehumanization, your helplessness and hopelessness.

And a world to win. □

Chairman Mills: Could I ask, are you aware of the Transuranic Registry for Plutonium?

Dr. Cobb: I am aware of it, yes.

Chairman Mills: Does that meet some of the requirements you think for the study of population?

Dr. Cobb: It certainly meets some of the requirements, but I would say not all.

Chairman Mills: With regard to the question of induction of lung cancer from transuranics, in your statement it

evidently takes about 30 years for cancers of the lung to develop as the result of this kind of radiation. What is the basis for the 30 years as a latent period?

Dr. Cobb: This I got -- first let me say I am not an expert in this field, and I have been reading up on it during the past month, and I think I got it from talking with Dr. Martell, who will be addressing you later today.

Chairman MIlls: I will address Dr. Martell.

Another question, you are aware that Dr. Tamplin and Dr. Cochran did present testimony?

Dr. Cobb: Yes, I understood you have the document.

Chairman Mills: On Page 5 of your testimony you speak to the fact, "Measurements of the amount of plutonium-239 found in the testicular tissue of 26 subjects from New York City revealed that three of them showed more than 7 disintegrations," and so on. I take it that you are drawing here the inference that all the plutonium that deposited itself in the gonads arose from air inhalation? No other pathway was considered, that is, any kind of ingestion?

Dr. Cobb: The occupational history of the individuals in this study was not in the data that I saw, so how could I tell? But, I assume if they were not working with plutonium, that they must have breathed it from the ambient air.

Chairman Mills: Any other questions?

Dr. First: I would like to ask one.

Chairman Mills: Dr. First has a question.

Dr. First: Doctor, on Page 6 of your testimony, you make a statement, that there are "...more than a million hot particles per square meter" based on the measurements of radioactivity in the soil, and you make the statement further, and you relate this in your testimony to Tamplin and Cochran's standard of a fifth of a particle per human. We are talking about a million particles in a square meter of soil, and you are referring this to a fifth of a particle in the lung. Now, how do you make this connection?

Dr. Cobb: The standards that Tamplin and Cochran recommended were two. One for the soil and another for the lung, and I simply took their figures and related them to the measurements made near Rocky Flats. Now, the standard for the soil, as I said, was one hot particle per square meter. The dose out there, the amount of plutonium in the soil out there now would be about a million hot particles if they were all of that very small size, which we do not know. In fact, I suspect they are all large particles.

Dr. First: Well, Doctor, just for the sake of getting on with this, let us assume there are a million particles out there.

Dr. Cobb: Right.

Dr. First: Let us assume that Tamplin and his associates have stated that one fifth of a particle for a lifetime

dose. Now, my question to you specifically, how do you relate one million particles in a square meter of soil to a fifth of a particle in somebody's lung?

Dr. Cobb: Really what you are asking me is, "how do Tamplin and Cochran do this?"

Dr. First: No, I do not think so, because I do not ever remember them saying anything about a million particles in a square meter of soil. But, I may have missed it.

Dr. Cobb: In their report, they did recommend one particle per square meter of soil as a standard, and they discussed the resuspension factor which we discussed this morning. They pointed out that there is a variation of what people consider to be right for resuspension factor of many orders of magnitude. I think the variation is something like maybe as many as 10 orders of magnitude in different opinions.

Dr. First: I am suggesting that the connection between these two has not been made by you or by Tamplin?

Dr. Cobb: Exactly why we need research. We need to know what size the particles are outside of the Rocky Flats Plant, and we need to know how many of them get resuspended, not an average over 24 hours, but the peak concentraction. We need to have many more monitoring stations along Indiana Street and around the plant, because as the wind tunnel studies done for the Dow Chemical Company have shown, you

need to have one monitoring station for every five-hundred feet along that road in order to be sure you are really measuring the blow away from any single point in the plant. There is actually one monitoring station about every mile, so there should be ten times as many monitoring stations and more sensitive monitoring devices in order to be sure that the amount of radioactivity coming out of the plant for a short period of time in a single place is not exceeding dangerous limits and endangering people downwind.

Dr. First: Do you consider yourself a scientist, Dor?

Dr. Cobb: I think that we do not need to comment on that.

Dr. First: I ask this purposely because not all physicians consider themselves a scientist, and I am a little bit concerned about the manner in which you are treating the data here. I still cannot understand how you can state in a single sentence that there are two facts, one, there is a million hot particles per square meter in the soil --

Dr. Cobb: I did not say that, correction, excuse me. I said there was an amount equivalent to a million hot particles, and they were probably large particles.

Dr. First: And the fact there is a standard of particles in the soil without making some connection between the two. How does one relate to the other, can you tell me that?

Dr. Cobb: I think it is fairly obvious --

Dr. First: This is a quantitative analysis, and there is no quantitation connecting the two. The equation has not been completed.

Dr. Cobb: The study that has to be done is to go out to that particular piece of soil --

Dr. First: You are saying that it has not been done, and you do not know?

Dr. Cobb: That is the whole thrust of my paper, if you understand it. There is much research that needs to be done before good standards can be set that we all can be happy with.

Dr. First: Let me ask you another question then, in your medical practice what is the certainty factor in your prescribing of remedial measures for someone who comes to you with an ailment, what is your factor of certainty that the diagnosis and treatment will be --

Dr. Cobb: Oh come on, I am not a practicing physician. I am a Professor of preventive medicine, and I do not treat patients.

Dr. First: You are a medical person, what would you say would be the general medical considerations of these factors? Now you are talking in the earlier part of your testimony about certainty and about error, and I wonder if you have a good understanding of what these are in the

context of the particular subject that we are supposed to be discussing today?

Dr. Cobb: I presume that you, like myself, have taken courses in biometrics and statistics in your training, and I think our training was probably very similar.

Dr. First: I do not think so, I am an engineer.

Dr. Cobb: Well, if you have not, then maybe I should explain some of these statistical implications here. I am not quite sure what your question is focusing on. I would like to be more specific.

Dr. First: Let me make it more specific then.

Chairman Mills: One more question.

Dr. First: Okay, fine. What factor of certainty or uncertainty would you accept in this matter of setting standards? How close should we be, how certain should we be, even after the research is completed, understanding as you have stated that biological organisms react in different ways, etc., etc.?

Dr. Cobb: My feeling is that we should be as sure as we possibly can, and this probably would involve studies which might take several generations before we could be sure of the lack of or presence of mutations or chromosome abnormalities resulting from plutonium getting into gonads; and if we found, for example, that the rate of mutations or the rate of chromosome abnormalities several generations from

now, (in those who were descendants of those who had been exposed) was twice the rate for those who had not been exposed, I would think that would be a significant finding, and this would mean that the exposure had been too high.

Chairman Mills: Dr. Garner, do you have one?

Dr. Garner: Just a comment. It is very difficult to comment upon a paper, a presentation which is slanted to have such an emotional appeal, but it does have some misrepresentations in it, I would say. There is one rather blatant one, and that is, the suggestion is there that we are considering plutonium only as a component of nuclear weapons. In fact, as I see it, these hearings are being held because plutonium, whether we like it or not, is a by-product of the use of nuclear fuel for the production of energy, and we are concerned with the use of plutonium itself as a nuclear fuel. What we have to do is decide whether we want, in fact, to use nuclear energy as an optional energy source in place of fossil fuel. We have to decide whether we are going to do this, whether we are going to subject people to the hazards of the use of fossil fuel, whether we are going to deprive future generations of natural resources by using up all the fossil fuel supplies, or whether in fact it is better to use nuclear power and expose people to -- I agree with you -- the not yet established hazards from plutonium compounds. This is really the ques-

tion, this is the question we are trying to decide. We have a choice to make. What choice are we going to make? We are not just here to talk about plutonium as a component of nuclear weapons. That is my only comment.

Dr. Cobb: I certainly agree, and I feel the same things that I have said should be applied and can be of concern to the nuclear power industry, and I think that Dr. Edward Teller's recommendation that all nuclear power plants should be put two-hundred feet underground is a reasonable proposal, and I would think that the same thing might be true of Rocky Flats if we find we have to keep that plant.

Chairman Mills: Thank you, Dr. Cobb.

Clarification of Testimony of Dr. John C. Cobb, with particular reference to the questions asked by Dr. First:

I would like to amplify my emphatic disagreement with the panelists' implied suggestion that there is no need for standards for maximum permissible plutonium and americium levels in the soil. This was implied by members of the panel, in view of the existing supposedly adequate standards for air and water.

I think Dr. First was trying to make the point that we don't know much about the resuspension by wind of plutonium from the soil. This is certainly true; but that does not mean that we could not find out what factors are involved, make measurements under varying conditions, and then be able to make reasonable predictions.

In regard to Denver's particular problem of wind-blown plutonium oxide dust from Rocky Flats, the fact is that the present air-monitoring system is inadequate to detect even rather large gusts of highly contaminated dust blowing from the "lip area" east of the plant where 50,000 dpm/g of plutonium alpha activity has been measured by the researchers at Colorado State University under contract with AEC. (Ref. 1)

The wind tunnel studies done for Dow Chemical at Rocky Flats (Ref. 2) looked into the optimal spacing of air monitors to detect plumes of contamination coming from the plant. Their conclusion #4 (Part I, p. 37) reads as follows:

> "An array of monitoring devices arranged along the north-south road which exists to the east of the plant site should intercept plumes if they are placed at 500 ft. intervals or closer"

This implies that monitoring stations at intervals greater than 500 ft. along Indiana Street could miss detection of a plume of contaminated air coming from

a point source in one of the buildings at Rocky Flats. From my study of the map published on pg. 29 of the Annual Environmental Monitoring Report of Rocky Flats Plant, (REP-ENV-73), dated April 26, 1974, I conclude that the four monitoring stations are placed approximately 5,000 to 7,000 ft. apart along this road. That is, according to the wind tunnel studies, there would need to be at least ten times as many monitoring stations as now exist in order to be sure to detect a plume of contaminated air coming from a point source. To be sure to detect a plume coming from a contaminated area approximately 500 ft. in diameter like the "lip area", one would need monitoring stations at least every 1,000 ft. along Indiana Street.

What I conclude from this rough preliminary analysis is that a strong gust of wind from the west could pick up a lot of dust from the contaminated area and blow it past the monitoring stations in such a way that very little, if any, abnormal rise in radioactivity would be detected. This is particularly true because the monitors, I understand, measure only the total amount of radio-activity accumulated over a 24-hour period. A brief gust or dust devil containing a large amount of plutonium and seriously contaminating the residential areas east of Rocky Flats might therefore escape detection completely by the present monitoring system.

The same wind tunnel studies addressed the problem in the Rocky Flats parking lot where the winds are sometimes so strong (over 100 mph) that cars need protection "from high velocity wind action assaulting vehicles with abrasive particles..." (Part II, p. ii)

We need studies done on site at Rocky Flats under conditions of very high velocity gusty winds and twisters or dust devils in order to find out what is the actual situation regarding resuspension of plutonium from contaminated soil and how much of it is getting into the air breathed by residents

of the area. When the winds are strong enough to sand-blast the paint and pit the windshields of cars at Rocky Flats, I suspect we have enough plutonium in the air to be dangerous to those who breathe it.

The present air monitoring system could easily miss detection of brief gusts of contaminated dust, especially when the plume happened not to be intercepted by one of the monitors. In view of the fact that plutonium dust is already blowing loose in the uncontrolled environment, the problem of control cannot now be solved by observing data from a few widely spaced monitors which average over 24 hours or more. Proper standards for soil contamination are clearly needed.

Ref. 1 Written testimony submitted by Prof. Lester Fraley of Colorado State University to the Wirth-Lamm Task Force on Rocky Flats, 21 Jan. 1975.

Ref. 2 Wind Tunnel Site Analysis of Dow Chemical Facilities at Rocky Flats Reports CER 71-72 RNM-FC-45 and CER 72-73 RNM-JAP-TGH-16 dated May 1972 and March 1973.

The next speaker is Miss Susan Carpenter of the American Friends Service Committee.

Miss Carpenter, you may proceed.

Miss Carpenter: Members of the Panel, Ladies and Gentlemen:

On behalf of the Colorado American Friends Service, I bring testimony today in favor of very rigorous standards for plutonium and all transuranium elements.

COLORADO

AMERICAN FRIENDS SERVICE COMMITTEE
TESTIMONY BEFORE THE
ENVIRONMENTAL PROTECTION AGENCY
January 10, 1975

Of all the changes introduced by humans into the household of nature, large scale nuclear fission is undoubtedly the most dangerous and profound. As a result, ionizing radiation has become the most serious agent of pollution of the environment and the greatest threat to human survival on earth.

The effects of alpha, beta, and gamma rays on living tissue are well known. The genetic hazard is clear. The inability to reduce the radioactivity in elements once they have been created presents an unparalleled set of problems.

Plutonium 239, the longest lived waste product, will have to be stored safely away for 240,000 years. In order to prevent leakage or theft for use in atom bombs, it must be kept absolutely protected from geological disturbances, civil strife, or enemy attack. The AEC readily admits that the problem of radioactive disposal is far from being solved.

Contrary to common sense, the burden of proof today lies with the ecologists; unless they can produce evidence of marked injury to people, the change will proceed. Common sense, on the other hand, would suggest that the burden of proof should lie with the person who wants to introduce a change; he should have to demonstrate that there cannot be any damaging consequences. It must be remembered that it may be many years before some kinds of damage become evident.

The decision to build nuclear power plants rather than conventional power plants is being based on economic considerations--will it efficiently produce the amount of energy we need to keep pace with our public demands? The fact that the nuclear fission represents an incredible, incomparable, and unique hazard for human life is seldom mentioned and seldom appears to enter into any calculation.

Scientists purport to define the maximum permissible concentration (MPC) of a given radioactive substance that the human body can be allowed to accumulate. But it is known that any accumulation produces biological damage. "Since we don't know that these effects can be completely recovered from," observes the U.S. Naval Radiological Laboratory, "we have to fall back on an arbitrary decision about how much we will put up with; i.e., what is 'acceptable' or 'permissible' is not a scientific finding, but an administrative decision."

In 1969, two scientists at the AEC's Livermore Radiation Laboratory called for a ten-fold reduction in the amount of radiation considered safe for the public. These scientists, John Gofman and Arthur Tamplin, asserted that if current limits were maintained, about 32,000 additional deaths from cancer could be expected annually.

In addition to the above dangers, the most massive wastes are the nuclear reactors themselves after they have become unserviceable. There is a lot of discussion on the trivial economic question of whether they will last for twenty, twenty-five, or thirty years. No one discusses the humanly vital point that they cannot be dismantled and cannot be shifted but have to be left standing where they are, probably for centuries, perhaps for thousands of years, an active menace to all life, silently leaking readioactivity into air, water and soil.

The main worry is about the future, and the international context.

FACT: On May 18th of this year, India exploded a 14-kiloton nuclear bomb, using perhaps as little as 14 pounds of priceless plutonium Indian scientists had secretly been removing from a small "research" reactor built for the Indians by the Canadians in the 1950's. (Washington Post, June 23, 1974)

FACT: "In building a nuclear weapon, the acquisition of the material is the most difficult part." Without nuclear reactors, acquisition

270

of materials for a nuclear weapon requires "a massive technology far beyond the capacity of most nations." With nuclear reactors, however, the necessary material (plutonium) becomes readily available. (The Proposed U.S.-Supported Egyptian and Israeli Nuclear Programs, by leading reactor and nuclear weapons experts of MIT, June 25, 1974.)

FACT: Every nuclear reactor in the world starts making plutonium the moment its uranium fuel fissions and begins to make heat. This means that whoever wants to make a bomb need only extract plutonium from the irradiated wastes of an atomic power plant (which is not a technically difficult process). A plutonium bomb is the cheapest and easiest to make. It can be built from half as muchmetal as a uranium bomb. And it can be made by using impure plutonium. (Washington Post, June 23, 1974.)

FACT: "A simple implosion nuclear weapon requires from 4 to 8 kilograms of plutonium, depending on the weapon design. A medium sized reactor produces in excess of 200 kilograms of plutonium per year. Accordingly, a few months operation of the reactor would produce enough material for a number of (nuclear) weapons." (MIT Nuclear Scient ist, as above.)

The economic prosperity of the world seems to be linked with nuclear energy. At the moment, nuclear energy provides only one per cent of the total electricity generated in the world. By the year 2000, if present plans go ahead, this will have increased to well over fifty per cent and the equivalent of two new 500 MWE reactors will be opened every day.

If this is really going to happen, there will be a continuous traffic of radioactive substances from the "hot" chemical plants to the nuclear stations and back again; from the stations to waste-processing plants; and

from there to disposal sites. A serious accident, whether during transport or production, can cause a major catastrophe; and the radiation levels throughout the world will rise relentlessly from generation to generation. Unless all living scientists are in error, there will be an equally relentless, though no doubt somewhat delayed, increase in the number of harmful mutations.

Rocky Flats Plutonium trigger plant dramatizes the case against plutonium and nuclear facilities.

Rocky Flats was built in the early 50's. The plant was built without citizen participation or education at a cost of 50 million dollars. Rocky Flats products, plutonium triggers, are sent across the countryside to assenbly installations in Burlington, Iowa, and Amarillo, Texas.

Rocky Flats' life in Colorado has been incident-filled. There have been over two hundred industrial accidents and a major industrial fire in 1969 which caused over 50 million dollars worth of damage. . . the worst accident in AEC history.

More than 20 million dollars worth of plutonium burned in the fire roughly enough to build 77 atom bombs like the one that incinerated Nagasaki. Most of the smoke was controlled in the special filtration system; however, Denver may not be so lucky next time. The "safest" plant in the AEC network produced the worst accident in the AEC's history.

Over 325 people have experienced radioactive contamination according to Roger Rapoport writing in the Los Angeles Times.

Within the past two years, tritium has leaked into Broomfield's water supply. Plutonium found in cattle grazing near Rocky Flats exceeded plutonium levels found in cattle grazing at bomb test sights in Nevada.

The unfortunate experiences of the Dow Chemical Company in operating this plant speak for themselves. Each incident in turn: the plutonium

fire, the finding of plutonium in the dust surrounding the plant, the release of tritium into the water, etc., have increased the public's concern and involvement. The denials, followed by admissions of mistakes and lack of proper precautions by Dow Chemical and the AEC, have progressively undermined our confidence.

The policies and people that bring Denver, Colorado, the Rocky Flats plant and the pursuant dangers have not been responsive to the concerns for the health, safety and continued quality of life for Coloradans. In this conflict taking place with Rocky Flats, the AEC, and concerned citizens, it appears to date that public safety is sadly the loser.

Radioactive pollution is an evil of an incomparably greater dimension than anything humankind has known before. What is the point of insisting on clean air, if the air is laden with radioactive particles? And even if the air could be protected, what is the point of it if soil and water are being poisoned?

Even an economist might well ask: what is the point of economic progress, a so-called higher standard of living, when the earth, the only earth we have, is being contaminated by substances which may cause malformations in our children or grandchildren? Can we deal with matters of such a basic character by means of bland assurances or official admonitions that "in the absence of proof that this or that innovation is in any way deleterious, it would be the height of irresponsibility to raise public alarm"?

No degree of prosperity could justify the accumulation of large amounts of highly toxic substances which nobody knows how to make safe and which remain an incalculable danger to the whole creation of historical or even geological ages. To do such a thing is a transgression against life itself, a transgression infinitely more serious than any crime ever perpetrated by people. The idea that a civilization could sustain itself on

the basis of such a transgression is an ethical, spiritual, and metaphysical monstrosity. It means conducting the economic affairs as if people really did not matter at all. We call on today the EPA to establish the most rigorous standards for plutonium and all transuranium elements. We prefer an international panel of scientists to undertake the extremely difficult and complex task of dismantling the nuclear arsenals--without secrecy.

We strongly advocate the search for alternative power sources, such as solar power, to replace nuclear power.

The Colorado American Friends Service Committee comes with a plea for the future, as well as the present quality of life for the human family.

"The world's greatest need is an appetite for the future . . . All healthy societies are ready to sacrifice the existential moment for their children's future and for children after these. The sense of the future is behind all good policies. Unless we have it, we can give nothing either wise or decent to the world." C. P. Snow

* * * * * *

RESOURCES

E. F. Shumacher, Small Is Beautiful, Harper and Row Publishers, 1973

Franklin Tugwell, Search for Alternatives: Public Policy and the Study of the Future, Winthrop Publisher, 1973.

Washington Post, June 23, 1974

MIT Nuclear Scientists, report reprinted in part by Another Mother for Peace, 1974

Speech by Dr. Fred C. Ikle, Director of U.S. Arms Control and Disarmament Agency, September 7, 1974

Roger Rapoport, "Secrecy and Safety at Rocky Flats," Los Angeles Times, 1969

Colorado Area American Friends Service Committee
2801 E. Colfax Ave., #304
Denver, Colorado 80206
388-5896

Thank you.

Chairman Mills: Thank you, Miss Carpenter. Are there any questions or comments by the Panel? Dr. Morgan?

Dr. Morgan: Miss Carpenter, I would like to commend you as a citizen for taking an interest in this matter. I think many of us, perhaps most of us would agree that the burden of proof should not be with the ecologists, and perhaps we all agree that many of these decisions, most of them should be made by the entire society, the group in which we live. However, I think as a university professor and former associate with the AEC, I would like to admit that we in the field of education have done a very poor job in passing information on to the public. I would urge you to continue your studies and research and not rely too much on the Washington Post and some of these sources of information, and I hope we in turn can provide to you more facts, more data that you can rely upon.

Miss Carpenter: I think that would ber very helpful.

Chairman Mills: If there are no more questions, thank you very much.

Radiation Danger in Denver area?

AEC asked to assist with soil radiation guide

By TOM REES
Rocky Mountain News Writer

The Colorado Department of Health is asking the Atomic Energy Commission (AEC) and the Environmental Protection Agency (EPA) to help develop criteria covering plutonium in soils for use in state and local guidelines.

The guidelines would be used in fulfilling requirements of the state's new subdivision law. One provision of the law calls upon boards of county commissioners to require subdividers to submit to commissioners an evaluation of potential radiation hazards in areas proposed for future land use.

The problem is that there are no existing criteria for plutonium in soils regarding exposure to the public.

Plutonium is a man-made fissionable isotope, the use and possession of which is regulated by the AEC. Criteria for the substance's existence in air and water exist, but none has ever been developed for its presence in soil.

Just exactly what health hazard is represented by plutonium remains unknown because current standards for the radioactive material are being debated by the scientific community. However, the National Cancer Institute considers plutonium one of the most potent cancer-producing substances known to man.

RADIATION HAZARDS CONTROVERSY

Stung by the controversy that arose over radiation hazards created by the use of uncontrolled uranium mill tailings for construction fill in the Grand Junction area, legislators this year passed the bill requiring county commissioners to evaluate potential radiation hazards in proposed subdivisions.

The problem of a lack of criteria arose when the Jefferson County Commissioners sought State Health Department assistance in interpreting and evaluating the new subdivision regulation.

The problem focuses on the possible future development of subdivisions near the Dow Chemical Co. Rocky Flats Plant 16 miles northwest of Denver, where land was contaminated several years ago by plutonium-contaminated oil which subsequently was spread. Dow, under contract with the AEC manufactures plutonium triggers for nuclear weapons.

The situation was raised at a quietly conducted meeting last Wednesday among health department, AEC and EPA officials. Dr. Edward Martell, Boulder nuclear chemist and Dr. H. Peter Metzger of Boulder, former president of the Colorado Committee for Environmental Information also were invited. Both men have called attention to off-site contamination from the plant. The outcome of the meeting wasn't as satisfying as the state officials hoped it would be.

The health department learned that the National Council on Radiation Protection is working on environmental contamination by radioactive materials, but it's unknown if the council is addressing itself to the problem of plutonium in soil.

The EPA has assigned some sort of priority to developing some general criteria for plutonium around nuclear facilities. The target date for producing the criteria is about two years hence.

Metzger asserts that the situation goes beyond the lack of criteria.

"What we learned during the Wednesday meeting duplicated the early days of the tailings problem in Grand Junction: By neglect the AEC caused the problem in the first place. It was left to organizations outside the AEC to discover the problem, whereupon the AEC assured the public that no problem existed. And, if one did, it wasn't an AEC responsibility.

'MASSIVE SCRAPING JOB'

"The difference today," Metzger said, "is that we haven't built thousands of homes over that radioactivity yet. If we do, and years from now it turns out that plutonium is as dangerous as some scientists say it is, we will be faced with another massive scraping job such as is about to take place in the uranium milling towns on our Western Slope."

Albert Hazle, assistant director of the health department's division of occupational and radiological health, said the new law, "puts the state in the position of rendering judgment on a situation for which there are no criteria to base a judgment.

"In the interim we'll have to be very conservative. We'll submit reports to the AEC and the EPA and ask them to help us make recommendations to county commissioners. We don't want to create another situation like Grand Junction," Hazle said.

The AEC is seeking to buy a wide buffer zone around the Rocky Flats facility to separate the plant from any other industry or housing by a mile of open space.

The Army Corps of Engineers earlier this week announced that it will begin negotiations soon to purchase approximately 4,070 acres around the plant. Funds for the purchase were made possible by a congressional appropriation of $6 million.

The AEC noted that the "greenbelt" also would "provide an additional margin of safety in the event of a plant accident which although extremely unlikely, can't be statistically ruled out."

(Reprinted by permission)
10—Rocky Mountain News
Sat., Oct. 28, 1972, Denver, Colo.

Secrecy and Safety at Rocky Flats

Where does security end and obfuscation begin in the handling of plutonium? By ROGER RAPOPORT

How much of the plant's safety is substantive and how much is empty reassurance has become a matter of bitter debate in recent years.

The road from Denver northwest to Boulder, Colorado, is an enchanting, 20-mile drive, uncluttered by gas stations, hamburger stands or motels. At night, when traffic is light and fierce winds howl out of the 8,000-foot Flatirons, it can be a scary place to run out of gas or blow a tire. But more often than not, an angel of mercy will show up behind the wheel of a pickup truck, armed with a can of gas, the know-how to fix flats and plenty of Western hospitality.

The men in the pickups seem anxious to be good, unobtrusive neighbors to the 1.1 million people of metropolitan Denver. And in this way they have something in common with the people who run a plant at Rocky Flats nearby. But some of the reasons are different.

The Rocky Flats plant is operated by the Dow Chemical Company for the Atomic Energy Commission under a cost-plus contract. It employes 3,200 persons and its specialty is the fabrication and processing of plutonium, a radioactive grayish metal (worth $43 a gram) created as a by-product of nuclear reaction and the key ingredient in most atomic bombs. The plant also repairs and replaces defective bomb and warhead components which are sent back to it when spot checks of nuclear stockpiles turn up duds.

All this dangerous work so close to a metropolitan area has made the plant's management, certain union leaders and the AEC sensitive about the issue of safety, both for the general area and for the workers at the plant. How much of the safety is substantive and how much is empty reassurance has become a matter of bitter debate in recent years.

Plutonium is doubly hazardous to work with. Minute quantities of it inhaled or imbedded in the skin can be lethal. It has a radioactive half-life of 24,400 years (something that makes it imperative that any of it that gets away not be left to lie about). Its radiation, of course, can cause permanent damage to living cells leading to leukemia and other forms of cancer. It also oxidizes quickly, making it a serious fire threat.

From its side of the fence, Dow and the AEC emphasize super-safety precautions, and boast that the plant "ranks first in AEC facilities for safety and holds the fourth best all-time mark in American industry—2,122 consecutive days (24,295,542 man-hours) without a disabling injury."

Rocky Flats officials tell about the elaborate safety precautions taken in the final assembly area (buildings 776 and 777). All workers in the area were heavily shielded and the entire plutonium assembly line with its milling machines, furnaces and presses was enclosed in glove boxes (ventilated, shielded enclosures) connected by conveyors. Moreover, to guard against the accidental release of plutonium into the atmosphere, the entire production area was sealed off inside a self-contained unit with a special internal filtration system. An elaborate network of automatic heat and radiation sensors plus roving teams of safety monitors guarded against accidents.

But at 2:29 p.m. on Sunday, May 11, this fail-safe system fell through. A fire broke out in the final assembly area. Despite the efforts of the Rocky Flats fire department, the blaze spread through both buildings 776 and 777. Smoke billowed so thickly that some of the firemen (wearing air tanks to protect against radiation danger) had to crawl along exit lines painted on the floor to make their way out.

By 5:30 p.m., when the blaze was brought under control, it had caused more than $50 million worth of damage. The worst accident in AEC history, the fire put the final assembly area out of commission and forced a halt in American nuclear missile production for part of the year.

Potentially, the disaster was the biggest step the United States has ever taken toward nuclear disarmament. More than $20 million worth of plutonium burned in the fire—roughly enough plutonium to build 77 atom bombs like the one that incinerated Nagasaki.

But rather than signal Geneva, Congress quickly shelled out $45 million in supplemental funds to clean up the mess, a figure equal to the entire fiscal 1969 Rocky Flats budget. Now 240 Rocky Flats regulars and 60 summertime college students are sifting through charred debris to recover the burned plutonium. Meanwhile hundreds of railroad cars will ship 330,000 cubic feet of radioactive wastes to AEC burial grounds in Idaho.

Anxious to understand how the AEC's safest plant could produce its worst disaster, I paid a visit to Rocky Flats recently. I learned that despite the vaunted precautions there have been over 200 small fires since the nuclear weapons facility opened in 1953. Recently, fires had been occurring about once a month in the buildings where the $50 million blaze took place. But on the Sunday afternoon the disaster started, only one ventilation system operator was in the building. Says Rocky Flats General Manager Dr. Lloyd M. Joshel: "I think we're going to have to review our monitoring procedures in this area."

All this has led local scientists to ask Rocky Flats officials if they shouldn't also review the possibility of moving their plant away from Denver. The Denver scientists are worried even though health surveys show that there was no release of plutonium from the plant site during the fire. Most of the smoke was trapped by the special filtration system.

Denver may not be so lucky next time.

Even the clean-up of the May 11 fire is causing more trouble. On July 30 two plastic bags surrounding a can containing some of the plutonium recovered from the $50 million blaze caught fire. Two workmen in the area were contaminated.

Their names are only the latest addition to the roster of more than 325 workers who have experienced radioactive contamination at the plant. Officially, AEC spokesmen say there have been a mere 21 disabling injuries and one fatality since the plant opened. But they refuse to disclose the number of workers who have received their maximum permissable dose of radiation and been transferred to cold (non-radioactive) sections of the plant. The local union is not allowed to see medical files of contaminated workers or make an independent investigation of plant accidents.

Perhaps the biggest question looming over Rocky Flats is the number of workers who have cancer or have died from it. Dow public relations man Mike Carroll says "It would not be discreet to discuss this. I've got the figures but I won't give them to you."

The May 11 fire was the biggest step the U.S. has taken toward nuclear disarmament. The plutonium that was burned was roughly enough to build 77 atom bombs like the one that incinerated Nagasaki.

One known cancer victim within the plant is 60 year-old Everett Holloway, an inspector with terminal leukemia: "I started checking into my medical records at the plant to see if I could establish some compensation. But I discovered that the company has lost some of my quarterly urine sample reports (which are taken to measure radioactive contamination). I was told that there was nothing the company could do for me until I become completely disabled. Supposedly they have switched me into a cold area but they're still machining a lot of radioactive material in my area and I don't know what effect it will have on my condition. I can't afford to quit because when a 60-year-old man like me comes asking for a job they look at you like you're poison."

Of course no one saw the plant as a liability when it came to Denver in 1953. Geographically, the rocky cow pasture 25 miles northwest of Denver was a smart choice because it was close by Colorado University in Boulder, skilled manpower in Denver and attractive recreational opportunities in the mountains. The plant soon grew into a crucial link in the AEC nuclear weapons complex

In all, the bomb work was divided between eight AEC facilities. Design

search and testing was done at New Mexico and California plants. Rocky Flats was responsible for plutonium components, the Kansas City plant made electro and electro-mechanical components, a Dayton, Ohio, plant made detonators and a plant in St. Petersburg, Fla., made neutron generators. These parts were assembled into nuclear weapons at plants in Burlington, Iowa, and Amarillo, Texas.

In the late 1950s, the plant mushroomed and radiation hazards grew with it. Between June 14, 1957, and October 28, 1958, there were 24 documented fires, explosions, plutonium spills, and contamination incidents at the plant. Testimony by Rocky Flats union leaders and government officials at AEC radiation hazard hearings in Washington during March, 1959, detailed many of the accidents; among them were serious fires in June and September of 1957.

Perhaps the biggest question looming over Rocky Flats is the number of workers who have cancer or have died from it. A Dow spokesman says it would not be discreet to discuss this.

Rocky Flats union leaders were particularly concerned about management's reluctance to bring in health physicists (who supervise worker health) after serious accidents took place. For example they testified that on October 28, 1957, a "chip fire in a production area occurred and as usual health physicists were not notified. No air samples were taken nor were any respirators worn to guard against inhaling dangerous plutonium. Health physicists learned of this operation after a worker involved in it coughed up black sputum at his home and became thus concerned with the method in which the incident had been handled by his supervisors."

The union leaders also pointed out that on September 4, 1958, supervisory personnel instructed workers to clean up a radioactive materials spill "using no respirators and without health physicists being informed of the situation." Subsequently, health physicists were notified, and recommended respirators and "area supervision gave in and allowed the workers to wear them on subsequent cleanup operations of the spill."

On October 3, 1958, another supervisor "stopped health physicists from allowing the men to know what the airborne contamination was in their production area on the grounds that it was his business only as to what the level was."

A variety of serious contamination incidents were also reportedly in supposedly cold areas. For example, on September 10, 1958, a "cafeteria survey showed 50 to 54 smears (taken to measure radiation) to be over allowable tolerance level." Ninety-seven of 99 smears in the locker room also showed contamination. Radioactivity was also found on drinking fountains, sinks, laundered caps, shoes, drums, flasks, carts, lifts and saws in cold areas.

As health hazards increased some workers were disappointed to see modification of some safety procedures. For example, prior to March, 1961, health physicists checked all employees out of hot areas with an alpha counter to make sure they were not carrying excessive radiation. But after March, 1961, workers were given more discretionary authority to monitor themselves out of hot areas.

Then and now, Rocky Flats officials felt that national defense precludes public discussion of these matters. But in the meantime they have been quietly documenting their problems in articles for the scientific community. For example, in 1964, Rocky Flats health physicists S. E. Hammond and E. A. Putzier had this to report in the sober international journal *Health Physics:*

"The Rocky Flats wound counter was developed in 1957 to measure the amount of plutonium contamination present in wounds incurred in process areas. Since that time more than 900 wounds have been monitored of which more than 300 have indicated some degree of plutonium contamination . . . The material is completely removed when possible. However, in cases where the plutonium is deeply imbedded or where physical impairment might result from complete excision, small amounts of plutonium may be left in the wound."

By 1965 union officials felt it was time to make a strong pitch for a new safety package in their contract negotiations with Dow. They asked for a joint "Radiation Safety Committee" with the company that would meet bi-monthly "to discuss problems arising from radiation safety complaints from any employees." They also proposed adding three union members to the company's Executive Safety Council and making radiation records of all employees available to "the union at least once each year in writing." All the proposals were rejected by management.

By 1967 it was becoming clear to *Health Physics* readers that the situation at Rocky Flats was getting worse. In an article titled "Evaluation of Lung Burden Following Acute Inhalation Exposure to Highly Insoluble PuO_2 (plutonium oxide)," J. R. Mann and R. A. Kirchner of the Rocky Flats staff reported that "On 15 October 1965, a fire in a plutonium fabrication plant resulted in a large-scale spread of plutonium oxide. The Rocky Flats body counter (a device that measures radioactivity in the body) was used to measure the plutonium in the lungs of all employees working in the area. Of approximately 400 employees counted, 25 were found to have enough plutonium in their lungs to deliver a dose of 15 rem/year. (In line with federal radiation standards Rocky Flats generally tries to keep worker exposure under 5 rem/year, although a complicated formula permits special exceptions.) On the average, 30 percent of the material initially deposited was cleared in 2 to 3 months. The remaining material is clearing very slowly with little or no measurable absorption into the bloodstream."

In another 1967 *Health Physics* article, C. R. Lagerquist, E. A. Putzier and C. W. Piltingsrud of the Rocky Flats staff described the gradual amputation of the thumb and second finger of a worker injured by the "explosive reaction between hot plutonium metal and carbon tetrachloride." They wrote that eleven months after the amputation "it was thought that there was a high concentration of plutonium in a small portion of the remaining thumb stump." But the operation was only a partial success and six months later "the remaining portion of thumb was removed."

Dissident members of Rocky Flats Local 15440 of the International Union of District 50 of the United Mine Workers finally got a little of the safety story out into the open in late 1967. At the time the coal-conscious international leadership of the United Mine Workers was conducting a vigorous campaign against a proposed nuclear power plant at Platteville, 30 miles north of Denver. Spearheading the campaign was the Ralph Nader of the atomic energy industry, a United Auto Workers official named Leo Goodman.

As Secretary of the Atomic Energy Technical Committee of the AFL-CIO, Goodman had served as a consultant to unions working in atomic energy and proved a nemesis to the AEC.

His files suggest about 6,000 Western states uranium miners are now dying of cancer. He also points out that there have been 1,400 known accidents in atomic plants and 200 known cases of cancer. Naturally these statistics are useful to the United Mine Workers in their fight to protect coal power and guard against the inherent dangers of nuclear power.

So in November, 1967, Goodman joined UMW leaders in a trip to Denver where they worked to block the proposed atomic power plant at Platteville.

After reading in a Denver paper that Goodman was in town, a group of Rocky Flats employees visited him at his motel room. They told the atomic hazards expert that safety was deteriorating rapidly in their plant, and reviewed case histories of workers who had contracted cancer and then been denied medical pensions. Reporters for the *United Mine Workers Journal* and *Cervi's Journal*, a muckraking Denver business weekly, were present and published accounts of the meeting. To the chagrin of Dow officials and leaders of Rocky Flats Local 15440 of District 50 of the UMW

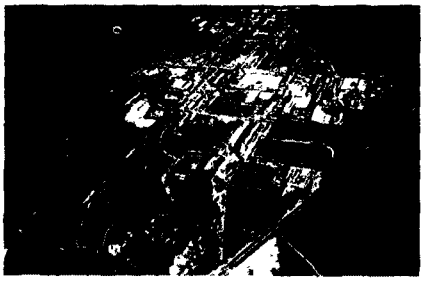
The risks of atomic power are so bad insurance companies will not sell policies for reactors. Only a special act of Congress provides $500 million worth of insurance for atomic power plants.

the stories pointed out that "Officials of District 50 of the UMW representing the Dow Chemical workers will not discuss the radiation dangers involved for workers at Rocky Flats. If they do, they face loss of their security clearance."

This story ignited a feud within the UMW. International Leaders of the UMW were already sore at District 50 (with a regional office in Denver) because it refused to join their fight against the proposed atomic plant at Platteville. After the stories on the meeting with Goodman were published, District 50 officials went out of their way to back the new atomic plant. In February, 1968, a delegation of Rocky Flats local 15440 leaders headed by President Jim Kelly traveled to Washington for a regional directors conference of District 50. Aided by their Denver regional director Sam Franklin, the Rocky Flats union leaders extolled the virtues of the safety program at their AEC plant. Using color slides provided by the Rocky Flats management they showed how "the Rocky Flats plant has achieved one of the world's best safety records . . . through a highly effective program of industrial safety." They pointed out that "The design of Rocky Flats facilities insures that each worker's exposure to radiation is kept to a minimum . . . The average work-related exposure of a Rocky Flats employee for an entire year is barely above the radiation received during a chest x-ray . . ." Gene DeCarlo, chairman of the union's radiation committee told how "all employees are particularly careful about cuts and scratches on their flesh as the radiation danger increases in an open flesh."

According to District 50's Denver Regional Director Sam Franklin, the assembled directors "were so impressed by the presentation that they subsequently passed a resolution calling for the expansion of District 50's

District 50 was accused of being willing 'to risk the lives of every citizen in the country in potential nuclear reactor accidents' for the sake of a few.



role in the atomic power industry."

Back at Rocky Flats, workers soon received news of the meeting in the February 26, 1968, edition of *District 50 News*. In the lead story it was reported that District 50 International President Elwood Moffett declared that "District 50's future is 'clearly interwoven' with the progress and development of the atomic energy industry." Further, the International Executive Board of District 50 promised to "continue to represent and safeguard our membership employed in every phase of that industry . . ."

The paper also carried the text of District 50's resolution endorsing atomic power plants " . . . contrary to the thinking of those who sporadically would remind us that progress in the field of nuclear energy represents a destructive force which could annihilate humanity . . . mounting scientific statistics amassed through the 2,000 man-years of experience in the Atomic Industry discount this pessimism."

Rep Chet Holifield, chairman of the Joint Committee on Atomic Energy, inserted the District 50 resolution into the Congressional Record. Beneath the Holifield story in the March 11, 1968, *News* issue was a Freudian slip of a filler that did not amuse the Rocky Flats workers: "1.4 million Americans now alive have been cured of cancer. Early detection and prompt treatment saved their lives. The American Cancer Society urges you to become familiar with cancer's seven warning signals and to fight the disease with a checkup and a check," it read.

The international leadership of the United Mine Workers was also not amused by District 50's endorsement of atomic power at the expense of coal. In March, 1968, the UMW International expelled District 50 charging that it was "willing to risk the lives of every citizen of this country in potential nuclear reactor accidents for the sake of a few members they have in atomic plants."

Since the break, District 50 has been getting along better with Dow and worse with the UMW. In March, 1968, just after District 50 endorsed atomic power, one of its biggest locals, 12075 in Midland, Mich. set a "chemical industry precedent" by winning an 80-cent-plus, three-year package from Dow. This paved the way for a 60 cent-an-hour direct wage hike plus a wage reopener in the third year for Rocky Flats Local 15440. The latter contract was ratified in June, 1968. But Local 15440 again lost its demand for the safety package originally proposed in 1965.

The UMW, through Washington atomic consultant Leo Goodman, subsequently charged that "Because the workers revealed the real hazards in the *UMW Journal* and *Cervi's Journal* of Denver (in November, 1967) . . . a sweetheart agreement was negotiated between District 50, Dow and the AEC (June, 1968) to foreclose any public discussion of the unsafe operating practices in the Rocky Flats plant . . . Thus, in order to cozy up to Dow Chemical, District 50 not only abandoned labor's traditional role in behalf of workers' safety in the plant but also collaborated with AEC-Dow Chemical in hiding from the people of the Denver community the great hazard which this plant brought to them."

Rocky Flats Local 15440 President Jim Kelly hotly denies these charges. The senior radiation monitor says that "If anyone told me to my face that we were playing sweetheart with management I'd knock him clear across the table. The real problem is that individual workers are afraid to turn their own plant health records (which they are eligible to see) over to the union. They think they'll lose their job. These guys raise a lot of hell in the locker room but they don't have the courage to get involved."

But on July 24 Kelly suddenly found that 200 of his chicken-hearted men had turned into wildcats. They walked off their jobs in building No. 44 when a plant official sent a union vice-president home because he refused to stop investigating an alleged work violation on company time. The grievance was the use of an inadequately trained radiation monitor on the cleanup of the May 11 fire. It is now in arbitration. The union vice-president and 154 of the wildcats received temporary layoffs and were docked on pay.

Both President Kelly and District 50 Denver Regional Director Sam Franklin are reluctant to talk loudly in public about their problems. They refuse to give out their records on the number of workers who have picked up their maximum permissible body burden of radiation and been transferred out of hot areas of the plant. Explains Franklin: "I'd appreciate it if you wouldn't bring up anything about this radiation business and men getting cancer because it will scare a lot of people."

But quietly, local 15440 is trying to arrange for some Washington-style publicity. Letters have been sent to Senator Edward Kennedy and to chairman Chet Holifield and vice chairman John Pastore asking for a meeting to discuss safety problems surrounding the fire on May 11 as well as discriminatory hiring practices. Chairman Holifield has already spoken

They refuse to give out their records on the number of workers who have picked up their maximum permissible body burden of radiation.

with the union leaders by phone and they say Sen. Kennedy's staff is trying to set up a meeting in Washington for mid-September.

But even should the meeting come off, the Q clearance may well save the day for the AEC. For the Q clearance is the real barrier to the truth about Rocky Flats. Ostensibly invoked to protect the national defense, it is really used by plant officials for self-defense. The Q clearance is the nation's highest security classification and explains why every Rocky Flats employee down to janitor is reluctant to discuss plant safety. For violating security can cost an employee his clearance, job, and pension as well as leave him open to federal prosecution. In the end, though, this silence may be shattered by disaster

The May 11 fire has led the Colorado Committee for Environmental Information, a group of scientists from colleges and industries in the area to voice "real concern for the health and safety of Colorado citizens because of possible accidents involving large quantities of radioactive chemicals at Rocky Flats, located in the rapidly growing metropolitan area between Denver and Boulder."

Rocky Flats officials are not oblivious to this fear themselves. The AEC's Mike Sunderlind, who has been with the plant since it opened, keeps a thick civil defense manual nearby at all time: "If some plutonium smoke went up we'd call all the police agencies, tell them which way the smoke was going and ask them to move everybody out of the path. Afterwards decontamination teams would have to scrape all the plutonium off everyone's roofs—it would take months. Then we'd have to bring in all the people and put them through our one body counter (designed to measure radiation). It would be one hell of a mess."

The AEC is particularly anxious to minimize fears about atomic power, and with good reason. At this writing, there are 15 American atomic power plants in operation, 31 being built and 42 in the planning stage. Several have had serious accidents and two good new books *The Careless Atom*, and *Perils of the Peaceful Atom*, document the hazards. One accident in Michigan endangered the lives of 133,000 people. After a 1957 accident at the Windscale Works breeder reactor in England, authorities had to seize all milk and crops within 400 square miles of the plant. And a 1957 AEC survey shows that a reactor built 30 miles from the nearest city could kill 3,400 people, injure 43,000 and cause $7 billion damage in a bad accident. The risks of atomic power are so bad that insurance companies will not sell policies for these reactors. Only a special act of Congress provides $500 million worth of insurance for atomic power plants and absolves them for liability over that amount.

Thus a panic in Denver over Rocky Flats could jeopardize the future of the entire atomic energy industry. For if the public figures out that nuclear war is not inevitable and nuclear accidents are, the AEC is in trouble. Of course the AEC does its best to discourage this kind of thinking. When I first started work on this story, the AEC made a special effort to dissuade me from visiting Rocky Flats. After I insisted on taking a look, I was accompanied by three p.r. men (one flew in 400 miles from Albuquerque; another was an FBI agent) who shadowed me into toilets and wouldn't let me within 100 yards of the firesite. George Dennis, the AEC man who came in from Albuquerque (his office governs Rocky Flats) pleaded with me "Not to give any of our secrets away to the Russians."

At a time when six nations have atom bombs and most high school physics students know the basics of atom bomb making, it seemed like he was really trying to invoke old-fashioned patriotism to keep AEC secrets from the Americans. After all, the AEC is spending a record $7,891,000 on Q clearance investigations of 17,300 personnel in fiscal 1970. Each investigation takes several months and one middle-aged Rocky Flats worker told me that "When they investigated me they went all the way back to my first grade teacher and she was 84."

Apparently the AEC is getting its money's worth. For security is a good way of keeping problems like leukemia, plutonium spills, and $50 million fires in the AEC family. Veteran Rocky Flats employees confess they still don't know what really happened on May 11: "Normally they have 8 to 10 guys patrolling those buildings for fires and radioactive contamination. Either they were playing around with something they don't want to admit to or they're guilty of the most incredible safety blunder I've ever heard of. If you had fires regularly in a building wouldn't you keep people on guard?"

In the end, the plant work force and the people of the Denver area are dependent on the AEC's good faith for their safety. Responding to public concern, Colorado Governor John Love arranged for a private briefing on the fire with Brig. Gen. Edward B. Giller, director of the AEC's military applications division. In an interview with *West*, Gov. Love indicated he found the AEC reassuring: "They seemed to be quite certain no radiation escaped from the plant site during the fire and will take precautions to make sure this kind of thing doesn't happen again. If you've got to have nuclear devices in the country I guess you might as well have the work done here as any place else."

But at a time when the United States has enough nuclear weaponry to wipe out the world several times over, one wonders what Rocky Flats is doing with enough plutonium to make at least 77 Nagasaki size atom bombs. While cleanup crews put the final production area back together Rocky Flats is moving ahead with a $75 million dollar expansion program. Some critics feel this is the wrong direction in the wake of the AEC's worst disaster. Says UMW atomic consultant Leo Goodman: "Now's our chance to get together with the Russians and ban nuclear weapons together. It will save us a lot of money and be a lot safer."

Security is a good way of keeping problems like leukemia, spills and fires in the family. The AEC will make 17,300 Q clearance investigations in 1970.

But this is only wishful thinking. Clearly the AEC will continue running the plant, paying the salaries, regulating security, determining health standards, monitoring radioactive leaks and investigating accidents. Questions about deteriorating safety conditions, accidents and worker health will remain unanswered. For Dow officials are beholden only to the AEC.

As criticism has grown there has been a predictable reaction inside the plant. Rocky Flats General Manager Dr. Lloyd M. Joshel inserted a brief message in his house organ *Dow Newsline* to remind employees that silence is golden: "We are facing a difficult situation as a result of the fire May 11. Certain uninformed people have questioned the value of our presence here and have attacked the integrity of both the AEC and Dow. It is hard not to make an angry rebuttal, but I hope each of you will help our efforts to solve this problem by not commenting on the situation either by letters or by discussions off the plant site."

Copyright (c) 1969 Roger Rapoport - first appeared in The Los Angeles Times.

Note:
Miss Carpenter also submitted an article titled "Project Gasbuggy and Catch-85" by Peter Metzger printed in The New York Times Magazine. It is not reprinted here because a copyright release was not obtained.

Also, an article by George Wald titled "Arise, Ye Prisoners" was submitted. It is reprinted after Dr. Cobb's testimony.

Chairman Mills: We have one other speaker before lunch. If we could get Dr. Eric Eisenbud from the Lutheran Hospital here in Denver.

Dr. Eisenbud: My name is Eric Eisenbud and I am an emergency room physician in the City of Denver.

In my mind the EPA's role in educating the American public about pressing environmental issues has perhaps been underutilized. For example, I would like to know the specific ways in which the citizens of Denver were informed about this very hearing. I suspect that if this hearing were publicized, EPA should not take the major credit.

I would like the EPA to consider the various types of accidental release of radioactivity in the environment. The subject of accidental release of plutonium oxide from Rocky Flats is adequately covered by other speakers here today. Other no less dangerous possibilities are nuclear power plant accidents, the so-called acts of God, and transportation accidents involving nuclear materials. This discussion, however, centers upon the situation of nuclear theft. Many of the ideas I present are thoroughly elucidated in Dr. Theodore Taylor's recently published book, Nuclear Theft, Risks and Safeguards.

Specific information about how to construct a nuclear bomb was officially declassified in 1954 under President Eisenhower's Atoms for Peace Program. The critical mass of plutonium oxide needed to construct a crude atomic bomb is approximately 10 kg. Similar amounts of uranium 233 and 235 should also be suitable for a bomb. According to Dr. Taylor:

> "Under conceivable circumstances, few persons, possibly even one person working alone, who

> possessed about 10 kg. of plutonium oxide and a substantial mass of chemical high explosive could, within several weeks, design and build a crude fission bomb...that...would probably explode with the power of at least 100 tons of chemical high explosive."

Furthermore, Taylor states that a nuclear explosion with a yield of only 10 tons in the center of a football stadium during a game could lethally irradiate 100,000 spectators.

Moreover, according to a special study completed last April by the AEC, "the potential harm to the public from the explosion of an illicitly made nuclear weapon is far greater than any plausible power plant accident..." (N.Y. Times, December 29, 1974). Indeed, the dispersal of a few grams of plutonium stolen from a nuclear fuel facility into the ventilation system of a large office building could kill most of its occupants.

Everyone is aware of the proliferation of world terrorist groups and activities in the past several years, and the possibilities of political blackmail through the use of crude atomic bombs are numerous. Let us briefly evaluate the risk of nuclear theft. It is essentially a function of the safeguards that exist in the nuclear industry today, and of the willingness of a person or group to steal nuclear material and to make nuclear threats. The New York Times reports about an unnamed Federal official who stated that

there have already been two instances when Government employees were discovered to have stolen enough nuclear material to build a nuclear bomb. Also, a highly placed official in the Atomic Energy Commission said one of its plants was unable to account for about 9,000 pounds of the highly enriched uranium it had produced since the plant began to operate. Finally, according to another AEC official, there have been several occasions in the last two years when Government agencies received plutonium bomb threats. (N.Y. Times December 29, 1974).

As for safeguards, praise is conspicuously lacking from all but the AEC itself. The Newsletter of the National Resource Defense Council (summer/fall 1974) states that a General Accounting Office report on November 7, 1973, documents that two of three licensed fuel plants it inspected had conditions "which significantly limited the license holders' capability for preventing, detecting, and responding to a possible diversion or diversion attempts of special nuclear fuels." The same plants were given a GOOD evaluation by the AEC. Somewhat earlier in 1973, the GAO had reported about security measures at nine nuclear power plants:

> "At several plants we visited, we noted unlighted protected area perimeters, unlocked outside doors, lack of intrusion alarms and unarmed watchmen." (N.Y. Times December 29, 1974)

Dr. Taylor went to compulsive lengths to evalute the various steps in the nuclear fuel cycle which are particularly vulnerable to theft, and found six areas where a single person could conceivably steal enough uranium or plutonium to make a crude nuclear bomb. He explains that there are several factors at the root of the inadequate safeguards:

1. The unwillingness of the AEC to seriously consider the possibility of a sophisticated armed attack on a nuclear facility or on nuclear materials in transit.

2. Lack of uniform and enforced regulations for the industry.

3. Lack of any critical feedback on the AEC from the public or from another governmental agency.

4. Both nonexistent public knowledge and superficial congressional knowledge of present deficiencies in safeguards.

5. Paucity of adequate monetary allocation for the areas of safeguards. Only $10-million dollars was expended in 1974 for the entire nuclear industry for safeguards.

An essential point is that if present safeguards are not significantly strengthened now, then the planned eightfold expansion of the nuclear industry and of existing plutonium stockpiles by 1990 will increase the risk of

nuclear theft exponentially.

An informed American public, not a handful of individuals from the Nuclear Energy Commission, should be given the right to make an educated decision about the risk of nuclear theft that they are willing to tolerate and about the type of safeguards that technology is capable of offering at this time.

I close with some questions for the EPA:

1. Does the EPA recognize that nuclear theft and its various forms of possible environmental contamination should be a major concern of the agency?

2. Is the EPA willing to undertake a more vigorous role than it has thus far in educating the American Public about this and other environmental threats?

3. Should not the AEC be directly accountable to the EPA with regard to such important matters as nuclear safeguards, particularly instances of transport of nuclear material between facilities?

Chairman Mills: Are you proposing these to the EPA in terms of receiving an answer?

Dr. Eisenbud: Yes.

Chairman Mills: In which case, we will respond to that. I will not attempt to clarify these issues at the moment.

Are there any questions by the Panel?

(No response.)

Chairman Mills: If not, we will stand in recess until 2:00

(Whereupon, at 1:00 p.m., a luncheon recess was taken.)

JAN 23 1975

Dr. Eric Eisenbud
Lutheran Hospital
8300 West 38th Avenue
Denver, Colorado 80212

Dear Dr. Eisenbud:

I am responding to the questions at the end of your testimony given at the recent Public Hearing in Denver, during which I informed you that I would do so.

Question 1: "Does the EPA recognize that nuclear theft and its various forms of possible environmental contamination should be a major concern of the agency?"

Response: Yes, EPA is concerned with the question of safeguard of nuclear materials. However, the primary responsibility for this activity resides, and in our opinion should remain, with the former Atomic Energy Commission and its successor agency, the Nuclear Regulatory Commission. For your information, I am enclosing a copy of EPA's comments on the draft "Generic Environmental Statement Mixed Oxide Fuels for Recycle Plutonium in Light Water Cooled Reactors," which conveys the Agency's opinion on this subject.

Question 2: "Is the EPA willing to undertake a more vigorous role than it has thus far in educating the American Public about this and other environmental threats?"

Response: My answer is No, because your question implies that EPA is not fulfilling its role concerning nuclear energy and its various ramifications. I believe the record of EPA attests to the fact that we are, in fact, fulfilling our responsibility already in a vigorous manner.

Question 3; "Should not the AEC be directly accountable to the EPA with regard to such important matters as nuclear safeguards, particularly instances of transport of nuclear material between facilities?"

Response: No. We have, in this Agency, spoken out on matters involving nuclear energy and will continue to do so. We are responsible for providing radiation protection guidance, for the promulgation of "generally applicable environmental standards," for technology assessment, including major reviews of environmental impact statements, and for such environmental monitoring as necessary to determine the "state of our environment." These responsibilities, however, do not and should not include direct responsibility for the safeguard program. EPA has responsibility for overseeing radiation protection on a national scale and does not need to be actively involved in the day-to-day regulation of nuclear facilities.

Sincerely yours,

W. A. Mills

William A. Mills, Ph.D.
Director
Criteria & Standards Division (AW-560)

Enclosure

cc: Paul Smith, Region VIII
A.J. Hazle, CDH

bcc: Dr. Augustine
Mr. Harward
Mr. Weaver
Dr. Burley

AFTERNOON SESSION

Chairman Mills: I would like to get started. I see that one of the Panel members has not arrived, Dr. First. He will be here shortly.

I think I should make a few opening comments for those who were not here this morning. The purpose of this hearing is to attain information relative to the setting of standards for plutonium and transuranium elements, and in that regard we hope that the information that we get is relevant to that particular question and would be within the scope of that. There are many issues having to do with nuclear power and activities which may or may not be involved with the establishment of plutonium standards, so I would ask those who have presentations this afternoon and this evening, as far as we need to go, to keep that in mind so we can move along.

There have been a few additional requests to give presentations, and I would say that those would follow the agenda that we had already established. That is, if one was willing to stay around until the last speaker on the agenda, then, we would try to accommodate those individuals.

We will move along. Our next speaker is Dr. Donald Geesaman from the University of Minnesota. Dr. Gessaman?

Dr. Geesaman: First, I am not a doctor, I am a professor, but not a doctor.

TESTIMONY CONCERNING THE ACCEPTABILITY OF EXISTING PUBLIC HEALTH GUIDANCE FOR PLUTONIUM

Donald P. Geesaman
School of Public Affairs
University of Minnesota
Minneapolis, Minnesota 55455

January 10, 1975

(Statement presented at the public hearing on plutonium standards held by the United States Environmental Protection Agency in Denver, Colorado on January 10, 1975. The material of that oral presentation is annotated and expanded here.)

Referencing is deliberately minimized in this testimony. The reader is referred to the attached Appendices, which are the basis for much of the testimony, and which have detailed referencing.

PERSONAL DESCRIPTION

My name is Donald P. Geesaman. I reside at 815 Heinel Drive, St. Paul, Minnesota. I am an Associate Professor in the School of Public Affairs of the University of Minnesota (Minneapolis). My principal research interest is the relationship between policy and technology with particular emphasis on nuclear technologies.

I am a citizen of the United States of America. I was born on February 12, 1933 in Fort Calhoun, Nebraska. I am a theoretical physicist by training. I was employed for 13 years at the Lawrence Radiation Laboratory (Livermore) of the University of California, where from 1960 to 1966 I was a member of the Theoretical Physics Division, and from 1967 to 1973 I was a member of the Biomedical Division. (The Lawrence Radiation Laboratory is a nuclear research laboratory operated under contract for The Atomic Energy Commission by the University of California.) While in the Biomedical Division at Lawrence Radiation Laboratory my work was primarily concerned with analysis of the hazards associated with nuclear technologies. In September of 1973 I joined the faculty of the School of Public Affairs at the University of Minnesota (Minneapolis).

SUMMARY

Plutonium is an effective radiological carcinogen in laboratory animals. Alpha-emitters, such as plutonium, are proven generic carcinogens in man.

The mechanisms underlying the origins of cancer are poorly known. Radiation-induced carcinogenesis is no exception.

Present standards for plutonium are based on the assumption of a uniform exposure by the material. For exposures by plutonium particulates, such an assumption is manifestly erroneous; and as a basis for making public health evaluations associated with particulate exposures, the assumption may be far from conservative. Human experience with plutonium exposures is insufficiently documented to provide meaningful support for existing standards.

Radiation exposures of tissue by plutonium particulates are notably inhomogeneous, diverse and complex. The concern is that amongst that considerable diversity, unrecognized resonant situations may exist with anomalously large carcinogenic responses which dominate the overall hazards associated with exposure. An animal experiment, such as Albert's, demonstrates the existence and hence possibility of such a resonance; others may exist. Scientifically respectable hypotheses can be developed around their existence; the disruptive particle hypothesis was so conceived.

If plutonium becomes a common element in commerce, the standards specifying its control acquire profound public health significance. Beneath the determination of those standards is the judgment of how scientific uncertainties relate to public health decisions. Considering the gravity of the decision and the imperfect knowledge on which this decision must be grounded, I would suggest that a proper basis for establishing plutonium standards is the most conservative hypothesis consistent with scientific experience. For this basis the hot particle hypothesis or the Martell hypothesis commend themselves for careful consideration.

STATEMENT

I consider it a privilege to testify here today. I have no fondness for giving testimony but I have paid my way here to appear because of what I consider a historical obligation to see through an issue which I helped to raise several years ago, and which I consider to be pertinent to your deliberations. I will be historical in my presentation. In that way the material and perspectives presented will be more meaningful to me. Most of what I have to say derives from concepts formed in the past at a time that I had formed no strong bias against nuclear power.

* * *

Shortly after joining the Biomedical Division of Lawrence Radiation Laboratory (Livermore), I was asked to assess the potential public health hazards associated with plutonium aerosols. Consequently, in February 1968 I published "An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue" (included as Appendix I). I quote some conclusions from the analysis in that report:

> "While no realistic evaluation of the total carcinogenic risk is accomplished, the results are such as to clarify the nature of the problem. In particular, if the loss of mitotic competence by a local cell population is sufficient to guarantee no origin of cancer within that population, then the carcinogenic risk from particulate sources does not scale to the total energy dissipated. To say what dose characteristics are significant to the risk would require an accurate knowledge of clearance, local shielding responses, and the mechanisms of cancer induction. In the absence of this detailed knowledge the suggested course is an experimental determination of the number of source particles per induced cancer."

and

"The particle problem is unique in that: (1) there is enormous variation in the dose level and dose characteristics to which different cell populations may be exposed, and (2) volumes involved are small so that disruptive doses are not necessarily organ fatal. Implicit in the problem is considerable diversity, and I would be concerned that somewhere in this diversity are unanticipated resonant situations where the risk is large compared with predictions made from linear dose effect relations.

"The risk does not scale with the total energy from a source, and with present knowledge it is precarious to try to describe in a detailed way the relationship between radiation level and carcinogenic tissue response. It would seem that the most reasonable and hopeful approach is to attempt an experimental determination of the number of cancers per source particle as a function of source strength at relatively low tissue burdens. With this, a meaningful estimate of risk would be readily accessible."

* * *

Subsequent to that report I reviewed experiments involving skin and lung carcinogenesis in mammals after intense localized doses of ionizing radiation. As a result of this analysis I published an addendum to the original report (included as Appendix II). There I reached the following conclusions:

"Summing up, intense radiation exposure of mammalian skin and lung tissue commonly results in cancers. Tissue injury and disturbance are a primary consequence of intense radiation insult, and are observed in association with carcinogenesis. Albert has exhibited a simple proportionality between skin carcinomas and atrophied hair follicles. No general description of precarcinogenic injury exists, but in a crude sense the available observations are compatible with the idea of an injury-mediated carcinogenesis. Cancer is a frequent instability of tissue. Since tissue is more than an aggregate of cells, and has a structural and functional unity of its own, it would not be surprising if some disrupted local integrity, a disturbed ordering, comprises a primary pathway of carcinogenesis. The induction of sarcomas with inert discs of Mylar, cellophane,

> Teflon and Millipore (Brues et al.) is indicative that such a mechanism exists. Presumably mitotic sterilization is an important factor in any carcinogenesis mediated by radiation-induced tissue injury. The functional relation of this factor to the carcinogenic response may be quite different from a linearity in the surviving mitotic fraction.
>
> "While regrettably unquantitative, the hypothesis of an injury-mediated carcinogenesis is suggestively descriptive. If the respiratory zone of the lung contains a structure analogous to the rat hair follicle, and if a radioactive particulate deposited in the respiratory zone has the capacity to disrupt one or more of these structures and create a precancerous lesion, then cancer risks of the order of 10^{-3} to 10^{-4} per particle can be expected for burdens much less than 10^{8} particles."

and

> "For occupational exposure the maximum permissible lung burden (MPLB) of Pu^{238} or Pu^{239} is 0.016μ Ci. Assuming a particle diameter of 0.3μ, this burden is equivalent to 3×10^{6} particles of $Pu^{239}O_2$ or 10^{4} particles of $Pu^{238}O_2$. If there is a possibility of tumorigenic risks of the order of 1/2000 per particle, this raises serious doubts as to the applicability of current MPLB to risk judgments involving particulates."

* * *

During the following year the analysis was extended, and discussion of the conclusions and their potential implications was given considerable internal distribution within Lawrence Radiation Laboratory (Livermore) and the Atomic Energy Commission. In November 1969, Arthur Tamplin and myself sent a letter (included as Appendix III) to John Totter, then Director of the Division of Biology and Medicine (AEC), with a copy to Glenn Seaborg, then Chairman of the Atomic Energy Commission. I quote from that letter:

> "This problem concerns the biological hazard attendant upon the inhalation of plutonium oxide particles. Our analysis of this problem suggests that these particles may represent a unique carcinogenic risk--that, when the lung exposure

occurs as a result of PuO_2 particles, the existing maximum permissible lung burden may be too high by orders of magnitude. If our suspicions are correct, the AEC could be confronted with a situation similar to the uranium miners in the plutonium industry. The enclosed report, UCRL-50387, ADDENDUM, is the basis for the above statements.

Our interest in this problem resulted from being requested to be members of the DBM Committee of Space Nuclear Systems Radiological Safety Matters. As you can see from the enclosed letters to Dr. Bruner, we disagreed with the Committee's conclusions beginning in August 1967. The more we studied the problem the more concerned we became as evidenced by the letter to Dr. Bruner of October 2, 1968. In this letter and the memo to Dr. Gofman we expressed our concern with respect to exposure of workmen in the very vital plutonium industry. We again expressed this concern at a briefing of the AEC Staff inn Germantown on October 25, 1968 (copy enclosed).

We are calling this problem to your attention at this time because it appears that it will soon become a subject of public debate. As a result of the fire at Rocky Flats, Dr. E.A. Martell has been conducting an environmental survey to determine the levels of Pu-239 in the Colorado area. As we understand it, he will probably be releasing his results in December. His results will show evidence of contamination from the Rocky Flats plant. Our impression is that he will at that time raise the question of permissible exposure.

It is important to note that there is no official guidance concerning exposure to these hot-particles. ICRP publication #9, page 4, paragraph 20 states, 'In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung.

Now, quite obviously, we do not feel that the Division of Biology and Medicine can adequately support the position taken by the Committee on Space Radiological Safety. Hopefully, the scientific community-at-large will be more receptive to their arguments but we doubt it."

* * *

In April of 1970 I was invited to the University of Colorado to debate with Chester Richmond (Los Alamos Scientific Laboratory) on the potential significance of the offsite contamination discovered around the Dow Chemical Rocky Flats Facility. I concluded my talk, "Plutonium and Public Health," (included in slightly modified form as Appendix IV) with this statement of perspective:

> "Finally I would like to describe the problem in a larger context. By the year 2000, plutonium-239 has been conjectured to be a major energy source. Commercial production is projected at 30 tons per year by 1980, in excess of 100 tons per year by 2000. Plutonium contamination is not an academic question. Unless fusion reactor feasibility is demonstrated in the near future, the commitment will be made to liquid metal fast breeder reactors fueld by plutonium. Since fusion reactors are presently speculative, the decision for liquid metal fast breeders should be anticipated and plutonium should be considered as a major pollutant of remarkable toxicity and persistence. Considering the enormous economic inertia involved in the commitment it is imperative that public health aspects be carefully and honestly defined prior to active promotion of the industry. To live sanely with plutonium one must appreciate the potential magnitude of the risk, and to be able to monitor against all significant hazards.
>
> "An indeterminate* amount of plutonium has gone offsite at a major facility 10 miles upwind from a metropolitan area. The loss was unnoticed. The origin* is somewhat speculative as is the ultimate deposition.
>
> "The health and safety of public and workers are protected by a set of standards for plutonium acknowledged to be meaningless.
>
> "Such things make a travesty of public health, and raise serious questions about a hurried acceptance of nuclear energy."

* * *

---

*The offsite contamination was, of course, ultimately fixed at several curies; the source of the contamination was concluded to be leaking barrels of plutonium-contaminated cutting oil which were located in outside storage.

In a July 8, 1971 letter (included as Appendix V) to Stanley Greenfield, then Assistant Director of the Environmental Protection Agency, I commented on the treatment of plutonium hazards in the Atomic Energy Commission's Draft Environmental Impact Statement on the Proposed Rocky Flats Plant Plutonium Recovery Facility:

> "More specifically, the exposition in paragraph 4 of Section 2.0 is an inadequate and unrepresentative description of the uncertanties in human risk attendant to exposure by plutonium aerosols. Human lung tissue has a well known carcinogenic potential under a number of situations, including radiation exposure; the Hanford beagle study demonstrates induction of lung cancer by plutonium aerosols. These are sufficient basis to establish plutonium induced lung cancer as a legitimate concern for humans. Judged in this context the negative results of the cited mouse study have little public health relevance. In addition, it requires pathological optimism to find reassurance in the results of the Hanford beagle experiment. Dogs were given aerosol burdens of ~1-10 microcuries of $Pu^{239}O_2$. At nine years post exposure the lung cancer response was virtually saturated and multicentric origin were noted in some dogs. A correlation observed between initial burden and time to cancer death was used to infer the limit burden for no life shortening that was mentioned in the draft statement. The exclusive interpretation of this crude correlation to mean a practical threshhold of burden is no more than a promotional indulgence. The observations do not necessarily imply that a practical threshhold exists below which no plutonium induced cancer will occur. Moreover, the range of exposures above the inferred limit burden may in fact, be interpreted as a region of saturated response, that is a burden regime in which cancer induction in a population approaches 100% during a normal life span. The point here is that the time to death may be related to the burden through population depletion, rather than through the latent period. In the former case, appreciable cancer incidence would be anticipated at lower burdens. To summarize a specific concern with the plutonium problem: 1) under a number of probably circumstances plutonium forms aerosols; 2) the physical character of these aerosols is such that on inhalation by humans they are preferentially deposited in the deep respiratory tissue; 3) because of slow clearance and because of the insolubility of the aerosol, particles deposited in this tissue may experience long residence times (hundreds of days);

4) an appreciable mass fraction of the aerosol is associated with particles sufficiently large that significant (≥ 1 alveolus) volumes of lung tissue will be exposed to intense radiation exposure (≥ 1000 rem) within a meaningful physiological time; 5) studies of the effects of intense local radiation (Albert, Hulse (skin), Maldague (kidney), deposition hotspots in bone seeking alpha emitters) suggest that despite the near mitotic sterilization of the involved tissue an enhanced carcinogenic potential may exist, in the sense that energy dissipated in a limited volume may be far more carcinogenic than if the same radiation were to dissipate its energy over a larger volume. The question is then do the larger particulates in a plutonium aerosol lead to associated alveolar exposures that have enhanced carcinogenic potential. If they do, then present standards can be in error by 2-3 orders of magnitude. Notice that the emphasis here is on the anomalous risk that may be associated with a single particle; and that if any threshold is relevant, it is not the dose threshold since local exposures are large, but rather a structural or volumetric threshold that must be exceeded by the physical extent of the exposure; and finally that this is a very special case of the low exposure problem, a case that is peculiar to plutonium as an insoluble aerosol-forming, long lived alpha-emitter.

"In relation to the preceding, the Hanford beagle study (~1-10 microcuries initial lung burden) showed cancers appearing in conjunction with radiation induced lesions. In addition, a dog having substantially less burden was prematurely sacrificed and no lesions or cancers were found. It would, however, be precarious to infer that absence of lesions implies no carcinogenic potential, or equivalently that radiation induced lesions are a necessary condition for high dose carcinogenesis. This point is illustrated by Albert's rat skin experiment, where carcinogenesis was optimal in a pre-ulcerative regime of less drastic radiation injury.

"It would be useful to have a formal documentation of past plutonium experience for humans, in order to judge the extent to which that experience can be used to quantify the hazards of plutonium. In the past 2 years the AEC has established a plutonium registry at Hanford. If any currently useful documentation is available from the registry, I am unaware of it.

"Dr. Langham at LASL has for some 25 years followed 12 humans with burdens in excess of a MPL. It is my impression, perhaps erroneous, that these burdens largely derive from exposures experienced in a waste recovery area where the plutonium aerosol was in fact

a dilute solution. If this is the case the relevance of this documentation to particulate exposure would be speculative.

"Independent of the biological questions, there are substantial and significant uncertainties associated with the resuspension of plutonium surface contamination. The subject receives essentially no comment in the draft statement. In the case of accidental release of plutonium with consequent contamination of an uncontrolled area, resuspension phenomena along with carcinogenic injury will determine the hazard to inhabitants of the area. Uncertainties in these two factors will be important in the public determination of an acceptable level of surface contamination, especially in the absence of official guidance for this latter quantity. The acceptable level of contamination will in turn determine the costs of cleanup of property and long term displacement of people."

* * *

Most recently I presented my views in a formal comment on the discussion of health effects of plutonium in "Particle Lung Dose Effects" of WASH-1535, Draft Environmental Impact Statement, Liquid Metal Fast Breeder Reactor Program, March 1974. What follows here closely approximates that comment.

The estimate of lung cancer incidence associated with the inhalation of plutonium (or other insoluble alpha-emitting transuranics) in particulate form is a critical factor, along with source terms and resuspension, in defining the probable impact of a plutonium based fuel-cycle. In the past, most administrative estimates of lung cancer incidence associated with the inhalation of plutonium particulates have been based upon a calculation of the average radiation dose delivered to the lung, and application of tumor incidence estimates for a uniformly irradiated lung. (See for instance, "Particle Lung Dose Effects" in WASH-1535, Draft Environmental Impact Statement, Liquid Metal Fast Breeder Reactor Program, March 1974.) In my

judgment this procedure is not a scientifically defensible basis for public health evaluations of plutonium hazards.

It is generally acknowledged the 'insoluble' particles of radioisotopes, when deposited in tissue, provide focal regions of high radiation dose rates. There is no presumption that the exposure by particulates of plutonium is uniform.

The structure and function of lung tissue is such that this tissue is peculiarly accessible and vulnerable to such particulate exposures. The deep respiratory tissue of the lung is made up of $\sim 10^8$ alveoli. Each aveolus is a complexly organized unit of tissue. If an insoluble alpha-emitting particulate is deposited in this tissue some 100 or less alveoli will be exposed during its residence. A crude measure of the nonuniformity or inhomogeneity of this exposure is that at most about one-millionth of the lung's alveoli are affected by a single static particulate.

The significance of the preceding is that in the actual lung exposure by an alpha-emitting particulate, the energy of the ionizing radiation is deposited in a very limited volume of tissue, and hence that the scale of the actual radiation dose to lung tissue is roughly a million times larger than the dose associated with an averaging of the equivalent radiation energy over the entire lung.

A multiplicative difference of a million in a significant physical quantity generally suggests a qualitative difference consequent to that quantitative difference. Suppose, for example, that the problem were to estimate the effects of rifle bullets on human organisms. Suppose that the bullets weighed 1/2 ounce and had a velocity of 1000 ft/sec. Note that the effect of the projectile depends on the energy, and note that a 6 ton vehicle

moving at 1 mile per hour has similar energy. There is experience with humans stopping slow moving vehicles by exerting strenuous counterforces. Using this experience the effect of rifle bullets on humans is inferred to be oxidation of the biological fuel necessary to do the work of stopping the vehicle. But this reasoning is manifest nonsense. Even though the energies involved are similar, human tissue distinguishes between a fast-moving rifle bullet and a truck weighing a million times more and moving at a one-thousandth the velocity. The former dissipates its energy in the gross disruption of local tissue, the latter leads to the ordered and non-injurious oxidation of biological fuel. The end results become very different as the physical characteristics of the situation change, and a new biological phenomenon intercedes. Obviously the way to estimate the effects of rifle bullets is either from past experience that is explicitly applicable, or alternatively, to calculate the effects considering the physical characteristics of the rifle bullet and knowledge of the biological and physical characteristics of the human organism.

This nonsense example has much the same logical structure as the usual administrative method of estimating the effects of hot particle or other highly inhomogeneous exposures. There, by introducing a fictitiously large mass of exposed tissue, the calculated dose becomes commensurately small. In passing from a real situation, in which a static radioactively hot particle irradiates 10 to 100 alveoli, to the fictional situation in which the ionizing radiation from the hot particle is averaged over 10^8 alveoli, the dose scale has fictitiously decreased by roughly a factor of a million.

One could argue here that energy averaging over statistically exposed volumes is also a physically meaningless radiological procedure because the

energy of the ionizing radiation is deposited in a narrow columnar region surrounding the path of the ionizing particle. The point is, however, that in certain exposure regimes biological effects do correlate with average ionizing energy to the exposed volume, and the merit of the procedure is thus established. It is sufficient in these cases to bear in mind that one is observing the statistical aggregation of discrete events.

Living tissue shows extensive intra-cellular and inter-cellular organization. Several regimes of biological response would be expected as physical (spatial, temporal, energetic) characteristics of tissue exposure are varied. Carcinogenic response to whole organ exposure by non-acute doses of radiation will fall in one of these regimes, and this will be a regime in which there is human experience. From the physical characteristics of plutonium aerosols, from the lung deposition experience with aerosols, and from the lung clearance experience with plutonium particulates, it can be inferred that at least one class of particles exist which subject lung tissue to an exposure associated with a different carcinogenic response regime. This is because another biological phenomenon has intervened.

For hot particle exposure that phenomenon is mitotic death of cells, i.e., loss of the cell's ability to divide. There is an extensive literature on the subject. Radiologically induced mitotic death is, in fact, the basis for treating malignant tissue with ionizing radiation, and is the cause of most acute symptoms consequent to radiation exposure. Even though the intercession of extensive mitotic death of cells must inevitably place certain particulate exposures in a different response regime from whole lung, non-acute exposures, a compelling argument might be made that the carcinogenic response in the former case is necessarily less than the carcinogenic response in the latter. This argument would appear to have merit since mitotic death

of cells, as well as reducing the general viability of the tissue, would also reduce the number of irradiated cells with carcinogenic potential. Usually implicit in this argument is a conceptualization of radiation carcinogenesis as originating with a single-cell, direct-injury process.

To confirm this argument, there is a respectable literature in which carcinogenesis is described as occurring after doses of radiation that are sufficiently local as to not be organism lethal, and that are sufficiently high for the fraction of mitotically competent cells to be greatly reduced, i.e., to 1% or less. Unfortunately, in at least some of these experiments, the most elegant of which is Albert's experiment on rat's skin, carcinogenesis is contrarily related to the fraction of mitotically competent cells, i.e., cancer induction in the regime where mitotic competence is greater than 1% is small compared with the cancer induction in the regime where mitotic competence is much less than 1%.

There are several points to be made here. Loss of mitotic competence and carcinogenesis are two indices of radiation effect in tissue. They cannot be independent since cancer cells are mitotically competent, hence the relationship between these indices can tell us something about modes of radiation carcinogenesis.

Mitotic competence, i.e., the fraction of mitotically competent cells, is not generally related in a linear way to carcinogenic response. Moreover, it is a major anomaly that an increased carcinogenic response is observed in dose regimes associated with greatly reduced mitotic competence. It is difficult to reconcile this result with any single-cell, direct-effect origin for radiation induced cancer in high dose regimes. (On this point see the results and discussion in "Tumor Induction in Rat Skin by 300-kv X-rays and 15 MeV Neutrons" in IAEA-SM-118/22, G.W. Barendson.)

Mitotic competence of a cell population decreases exponentially with increasing alpha-radiation dose and is a fairly general index of radiation effect in tissue. If radiation carcinogenesis universally decreased with mitotic competence, then estimates of carcinogenesis based on a fictitious averaging of a local inhomogeneous dose over a much larger volume would be necessarily conservative. Since radiation carcinogenesis can, and in fact, does increase to anomalously large values while the mitotic competence becomes vanishingly small, the fictitious averaging of dose over larger volumes is not necessarily conservative. Instead it would appear that situations exist in which an intense local dose of ionizing radiation can be a far more efficient carcinogen than a diffuse tissue exposure with the same type of ionizing radiation and the same total energy. The above then implies that averaging of dose over fictitiously large volumes may be far from conservative, especially if the averaging obscures much diversity and detail of the actual exposure.

It is obvious that as a local exposure becomes more intense, a stage must finally be reached where the carcinogenic efficiency of the exposure (on a per unit energy basis) is reduced. This is not pertinent to previous arguments. It suggests caution, moreover, in generalizing relative carcinogenic efficiencies from the comparative results of high dose inhomogeneous and homogeneous exposures. This caution applies to the discussion of the rat skin experiments of Passonneau et. al. and the hamster respiratory tissue experiments of Little et. al., in "A Radiobiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium" (WASH-1320), M. Barr, C. Richmond and D. Rosenholz.

What one wishes to know is the characteristics of the most carcinogenically efficient exposures and the amplitude of that carcinogenic

response. In the absence of an understanding of the mechanisms of carcinogenesi this is the knowledge most useful in defining the conservative limits of theoret risk associated with the diverse and complex tissue exposures by plutonium particulates. Albert's experiments were unique in providing that kind of refined description. For example, cancer induction was observed to be large only in a dose region where virtually all cells were mitotically sterilized, i.e., where only 1% to .0001% of the cells would be expected to have the ability to divide. Cancer induction was maximum for pre-ulcerative exposures, i.e., exposures where no gross lesions (total tissue disruption) were produced. Cancer induction was nearly proportional to the production rate of atrophied (disordered) hair follicles, and correlated with the dose to the minimally exposed germinal cell population of the hair follicle. Most importantly, with carefully chosen exposures, cancer production rates could be made as anomalously high as $\sim$ 1 cancer per 10^5 ergs which differs by orders of magnitude from cancer induction rates per unit energy associated with indiscriminant exposures. The observation of such a carcinogenic resonance (anomalously large response) for a specific tissue and a specific exposure regime is significant because it demonstrates the existence of such energetically efficient exposure situations. The amplitude of this response can then provide a reasonably conservative estimate of risk for the diverse and complex exposure of another tissue.

The Albert experiment illuminates the difficulties associated with describing radiation carcinogenesis and predicting the response, in the absence of an understanding of the underlying mechanisms. Even though a relatively simple tissue was involved, if the experiment had not been so carefully structured, much of the detail would probably have been lost, and with it the knowledge of this resonance in radiation induced skin cancer in rats. Detailed predictions in the anomalous regime would then have been erroneous.

Returning to the question of plutonium risks, a picocurie of Pu^{239} emits $\sim$ 10 ergs of ionizing radiation per year; a maximum permissible lung burden (occupational) emits $\sim 10^5$ ergs of ionizing radiation per year. Considering the wide variations in tissue irradiation following exposure to a plutonium aerosol, and considering the energy of the associated radiation exposure, when compared with the energy required per cancer in Albert's experiment, one is compelled to a concern that the wide diversity in plutonium particulate exposures will discover similar resonant responses, and that the amplitude of these responses and their extent in the total domain of exposures will be sufficient to dominate the overall carcinogenic risk. This concern is further exacerbated by inclusion of a compensating RBE factor of $\sim$ 10.

A comment should be introduced here on the concept of "waste radiation." Depending upon one's assumptions about the mechanisms of radiation carcinogenesis certain radiation induced biological effects may be considered unnecessary or undesirable for cancer induction and hence the radiation expended in producing those effects is wasted or without carcinogenic potential. Examples are cell sterilization, if one assumes that dead cells can not contribute to carcinogenic potential; or multiple sterilization of the same cell, if one assumes that while a sterile cell may increase carcinogenic potential, duplicate sterilization leads to no further increase. The most frequent example is the radiation wasted in exposures subsequent to induction of an autonomous cancerous lesion by a chronic exposure. This list is obviously not intended to be exhaustive. The point is that the hypothesis underlying the use of the concept should be differentiated to distinguish its meaning in a particular case. By invoking the notion of "wasted radiation," and by hypothesizing and proving certain exposure situations to be without carcinogenic potential, one could, in principle, quantitatively modify the previous concern,

by, for instance, showing that virtually all of the energy was without carcinogenic potential. Given the state of uncertainty surrounding both tissue function and radiation carcinogenesis, it seems doubtful that such an approach can make a significant contribution to hazard evaluation. More sensibly, if one knew the risk one could probably infer something about the appropriate conceptualization of wasted radiation and carcinogenesis.

The following excerpt taken from "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Report of the Advisory Committee on the Biological Effects of Ionizing Radiation, NAS/NRC, summarizes the state of knowledge concerning the causation of cancer (emphasis added):

> "Although the mechanisms of carcinogenesis, or of radiation carcinogenesis in particular, are not fully known, available information implies that most, if not all, types of cancer develop as a result of the combined effects of multiple factors. These causative factors may include: prezygotic (inherited) mutations of chromosomal aberrations, which can spread during development to many kinds of cells; somatic cell mutations or chromosomal abberations, which can be acquired at any time after conception; changes resulting from the action of viruses; and changes in systemic growth factors (e.g., depressed immune competence, hormonal imbalance) and in local tissue regulation (disorganization, damage), such as may result from diseases other than cancer or from advancing age.
>
> "Although point mutations, chromosomal abberations, and other changes at the cellular and molecular level may require only small doses, tissue disorganization and gross disturbances in physiology are unlikely without larger doses.
>
> "Of the many types of changes which radiation can cause in cells or tissues, none is considered to be unique for radiation. Many, if not all, such changes can presumably result from a variety of other agents."

This summary view on carcinogenesis does not conflict with the ideas leading to the conclusion reached earlier, that fictitious dose averaging to larger tissue masses need not be conservative. The possibility of various modes

of carcinogenesis, including tissue disruption, is acknowledged. In particular, the number of causative factors proposed is a measure of the considerable range of hypotheses available to describe experience.

Disease profiles are highly species specific. Cancer is no exception. Gross characteristics are obviously highly species specific also. A rat and a mouse are distinct and yet morphologically are very similar. The gross tissue differences are articulated out through subtly different informational coherences amongst cell populations, - the collective behaviour being phased ultimately, by a biochemical dialogue between cell neighborhoods whose functional potential is genetically moderated. Not to belabor this point unnecessarily, - cancer profiles are species specific; gross characteristics and, of course, genetic material are also species specific. In high dose carcinogenesis collective detuning of tissue by tissue disruption seems as acceptable an origin for the tissue instabilities of cancer as does an isolated single cell event involving the cell's genetic material. This is not to say that tissue disruption is a necessary condition for carcinogenesis, or even a sufficient one without some specific qualifications.

* * *

Return now to the problem of risk estimates associated with radioactive particulates in human lungs. Most of what has been said earlier in this comment has been general, and has been aimed at showing that there was no inherent conservatism in the tissue averaging method of estimating cancer risks, and that moreover the method could be far from conservative. The conclusion could as well be applied to lymphatic tissue or to bronchial tissue.

Having this background, notice that human lung tissue has a well known carcinogenic potential under a number of situations, including exposure to

ionizing radiations; and that in the Hanford dog study induction of lung cancer was observed after exposure to plutonium aerosols. These are a sufficient basis to establish plutonium induced lung cancer as a legitimate concern for humans.

The following is a review of the official guidance for estimating the carcinogenic effects from exposure to radioactive particulates:

> "(210) The NCRP has arbitrarily used 10% of the volume of the organ as the significant volume for irradiation of the gonads. There are some cases in which choice of a significant volume or area is virtually meaningless. For example, if a single particle of radioactive material fixed in either lung or lymph node may be carcinogenic, the averaging of dose either over the lung, or one cubic centimeter may have little to do with the case. Use of significant volumes or areas must be looked on as one of the round off devices which in special cases must give way to detailed study."
>
> NCRP Report #39
> Basic Radiation Protection Criteria
> January 15, 1971.

> "(20) In the case of non-homogeneous distribution of absorbed dose in the lung, an estimate of the Dose Equivalent to the whole lung, determined merely by the product of Q F and the mean absorbed dose, may be greatly in error, but our full understanding of this problem must await further experimental evidence. In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung."
>
> ICRP Publication 9
> Recommendations of the
> International Committee
> on Radiological Protection
> (adopted September 17, 1965).

> "41. On the basis of general considerations and of some experimental data, and clinical experience the Task Group were of the opinion that, for late effects, the same radiation energy absorption might well be less effective when distributed as a series of "hot spots" than when uniformly distributed. Thus, with particulate radioactive sources within a tissue, a mean tissue dose would probably introduce a factor of safety."
>
> ICRP Publication 14
> Radiation Sensitivity and
> Spatial Distribution of Dose
> (Publication 14 appears as a
> report of two Task Groups,
> and not as the official
> recommendations of the ICRP.)

The recommendations of the National Council on Radiation Protection and Measurement set forth in Report #39, and the recommendations of the International Commission on Radiological Protection set forth in ICRP Publication #9, are specific in offering no explicit guidance. Any implicit guidance intended in these recommendations would seem to bear most directly on the validity of existing standards when applied to highly inhomogeneous exposures.

The third citation taken from ICRP Publication #14 is a report of an ICRP Task Group and is not intended to provide dispositive official guidance. The discussion there is useful commentary, but is conditional and inconclusive without some quantitative definition. Certainly alpha-emitting particulates as they pass to sufficiently high activities must become energetically inefficient carcinogens. That, however, is not in itself an interesting issue.

With regard to the previously cited method of risk estimation based on dose averaging, supporting reference is often made to the Hanford beagle experience. The following statement taken from WASH-1585 is typical of such arguments:

"The average dose approach leads to estimates comparable to those of Gavankar following Thompson et al based on linear non-threshold extrapolation of observations on beagle dogs administered $^{239}PuO_2$ aerosols."

The observations on beagle dogs deserves separate consideration.

It requires unnatural optimism to extract reassurance from the results of the now completed Hanford beagle experiment. Dogs were given initial $Pu^{239}0_2$ burdens in the microcurie range. By nine years post-exposure the lung cancer response was virtually saturated and multicentric origins were noted in some dogs. Those receiving larger lung burdens greater than 10 microcuries died of pulmonary insufficiency within 4-1/2 years. Twenty-one dogs survived for more than 4-1/2 years, and only one of these did not exhibit lung cancer at death. A relationship observed between initial lung burden and time to death with cancer has been often used to infer a threshold burden below which no life shortening of dogs would be expected. These results are usually exhibited on a log-log graph which obscures virtually all differential detail. Most importantly, recognize the nature of the experiment, i.e., the lung burdens were large, the results were saturated, and the number of animals was small. The crude relationship observed between initial lung burden and time of death with lung cancer does not necessarily imply that a threshold burden exists for beagles. Quite to the contrary, the range of exposures above the inferred threshold burden may be interpreted as a region of saturated carcinogenic response, that is a burden regime in which lung cancer induction in a beagle population approaches 100% during a normal life span. The point is that the observed time to death is more likely related to the burden, through a population depletion effect, rather than through a burden dependent latent period. In the former interpretation appreciable cancer would be anticipated at lower burdens. This is again consistent with the extensive observations in "Toxicity of Radium-226 in Mice" (IAEA-SM-118/11)

M. Finkel, et. al., of radioisotope-induced bone tumors in mice, which support their interpretation that "latent period is constant and that the apparent relationship between increasing dose and decreasing time to death with tumor is due to the effects of dose-level on survival and on tumor expectancy."

The significance of the Bair beagle experiment is that it demonstrates carcinogenic potential in bronchiolar-alveolar tissue of beagle dogs after their having been exposed to microcurie quantities of plutonium. Cancers were observed in conjunction with fibrotic lesion.

* * *

The domain of this comment is broadened here in order to summarize a specific concern with plutonium, and certain other active alpha-emitters, such as U-233. Under a number of circumstances plutonium forms aerosols. The physical character of these aerosols is such that on inhalation by humans they are preferentially deposited in deep respiratory tissue. Because of slow clearance and because of their insoluble character, particles may experience long residence times in tissue. An appreciable mass fraction of the aerosol is usually associated with particles sufficiently large that small but physiologically significant volumes of tissue will be exposed to intense (i.e., doses that if given whole body would be organism lethal) radiation doses within a meaningful physiological time. Studies of the effects of intense local radiation to skin indicate that despite the near mitotic sterilization of the involved tissue, an enhanced carcinogenic response may occur, in the sense that energy dissipated in a limited volume may be far more carcinogenic than if the same type of radiation were to dissipate its energy over a much larger tissue mass. The question is then: do particulates of certain classes of plutonium lead to exposures that have enhanced carcinogenic potential? If they do, then present standards can be in error

by orders of magnitude.

Notice that the emphasis here is on the anomalous hazard associated with a single particle; and that if any threshold is relevant, it is not a dose threshold since local exposures are large, but rather a possible volumetric threshold that must be exceeded by the physical extent of the exposure. Plutonium, as an insoluble aerosol-forming, long-lived alpha-emitter, constitutes a very special case of the low exposure problem.

* * *

A plutonium industry has existed for more than two decades. By this time there must be a significant history of human exposure. Considering the early recognition of plutonium's toxicity, and its obvious potential for much expanded commercial use, the occupationally exposed population must or should have been closely followed. A plutonium registry has existed since 1968. An acceptable way to make limiting estimates of cancer risks would be to argue conservatively from past human experience. Considering the extent of past experience, the open literature contains relatively little detailed information on the history of humans following plutonium exposure. While I am no epidemiologist, it is clear that the existing literature is an inadequate base for rigorous argument in support of existing standards. Statements affirming that there have been no recorded cases of human cancer as a result of plutonium exposure must obviously be qualified by supporting epidemiological analysis of human experience. In the limit, not to have seen an effect would be a logically sterile observation, if one had not looked.

In the absence of such necessary argument, one is left with an obligation, through public health traditions, to more conservative and defensible methods of evaluating the cancer risks of alpha-emitting particulates. For this reason I commend to your attention, "Petition to Amend Radiation Protection Standards as They Apply to Hot Particles." in the Matter of RADIATION PROTECTION STANDARDS AS THEY APPLY TO HOT PARTICLES brought before the Environmental Protection Agency and the Atomic Energy Commission by the Natural Resources Defense Council, Inc., on February 14, 1974, and the supporting report of Arthur Tamplin and Thomas Cochran.

The hypothesis developed there is scientifically respectable and represents a state-of-the-art, conservative basis for public health judgments. I believe that a responsible joining of the public health and scientific issues would be accomplished by having any reduction in the conservative guidelines proposed there be argued from compelling refutation of the hypothesis, or from epidemiological studies of human experience.

WASH-1320, "A Radiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium, September 1974," I take to include a reasonable review of the scientific experience bearing on those two points. I do not find the material presented there a compelling refutation to the hot particle hypothesis, as a possible mode of carcinogenesis. By myopic and exclusive attention to the disjoint scientific experience that is available, WASH-1320 has obscured the sea of uncertainties in which these fragments of information are immersed. Moreover, I was disheartened that its discussion of human experience gave no new definition to that evidently limited body of knowledge. The aerosol characteristics associated with the early Los Alamos exposures were conjectured there, without any general discussion of possible

aerosol characteristics. Consequently, the relationship of the subsequent analysis to the validity of the hot particle hypothesis becomes similarly speculative, particularly when one remembers that many of the subjects were believed to have had a recovery area exposure to some form of plutonium solute.

To my mind the most significant observations in WASH-1320 were those associated with the recently completed Los Alamos experiment on Syrian hamsters. It appears anomalous that virtually no lesions of any sort were observed in conjunction with the plutonium microspheres. Certainly the cells contiguous to these particles were sufficiently irradiated to be mitotically sterile, and their apparent continued function and structural integrity for the lifetime of the animal raises the question of what are the appropriate time scales for the cells in lung tissue, and the question of how such necessarily sterile tissue would react to an overt stress such as a virus infection. In point, the Los Alamos hamster experiment confirms the opinion that the response of lung tissue to particulate radiation is poorly understood, especially when considered in conjunction with Little's experiments with Po^{210} showing a high incidence of bronchiolar-alveolar cancer in the same species. It is my recollection that the cancers of this type observed by Little and by Bair (beagles) were generally located in the peripheral region of the lung. Not knowing the distribution of the Los Alamos microspheres throughout the capillary matrix of the lung, I can not say whether these observations are of any possible assistance in reconciling the experiments. Another concern is that the imaginative technique of exposure used in the Los Alamos experiment may, in fact, have produced a particulate exposure that was too static. (Note: see amendment to this paragraph in attachment following questions.)

Finally, I would like to commend to your attention Dr. Martell's research on the potential health effects of ambient alpha-emitters (see his

testimony before this Panel). It would be presumptuous of me to comment on that work more than to say his hypothesis concerns a different particle size, different target tissues, different mechanisms of carcinogenesis, and hence it is disjoint from the hot particle hypothesis even though its implications to plutonium guidelines may not differ substantially.

* * *

The preceding discussion has no pretensions of being a comprehensive discussion of the health hazards associated with plutonium. What it does purport to do, is examine some of the significant uncertainties that bear on evaluation of those hazards, and to suggest a framework in which such considerations can be conservatively incorporated into public health considerations.

Despite much scientific effort the mechanisms underlying carcinogenesis are not understood, and radiation-induced carcinogenesis is no exception. Radiation exposure from plutonium particulates is highly inhomogeneous and diverse. The carcinogenic potential from such exposures is poorly known for humans.

Present standards for plutonium exposure are based on the assumption of a uniform exposure by this material. For exposure by particulates such an assumption is manifestly erroneous; and as a basis for making public health decisions regarding the hazards associated with particulate exposures, the assumption may be far from conservative. Human experience with plutonium appears to be insufficiently documented to provide conclusive epidemiological support for existing standards.

Plutonium is being considered as a major energy source for the near future. If it becomes a common element in commerce, the guidelines specifying

its control acquire profound public health significance. Beneath the determination on those standards is the judgment of how scientific uncertainties relate to public health decisions. Considering the gravity and irreversibility of this decision I would suggest that a legitimate basis for establishing standards would be the most conservative hypothesis consistent with scientific experience. For this basis the hot particle hypothesis or the Martell hypothesis commend themselves for careful consideration.

* * *

Donald P. Geesaman
Associate Professor
School of Public Affairs
University of Minnesota
Minneapolis, Minnesota

APPENDICES

I. An Analysis of the Carcinogenic Risk From An Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue

II. An Analysis of the Carcinogenic Risk From An Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue - Addendum

III. Letter - A. Tamplin/D. Geesaman to J. Totter

IV. Plutonium and Public Health

V. Letter - D. Geesaman to S. Greenfield

TID-4500, UC-48
Biology and Medicine

Lawrence Radiation Laboratory
UNIVERSITY OF CALIFORNIA
LIVERMORE

Bio-Medical Division

UCRL-50387

AN ANALYSIS OF THE CARCINOGENIC RISK FROM AN INSOLUBLE ALPHA-EMITTING AEROSOL DEPOSITED IN DEEP RESPIRATORY TISSUE

Donald P. Geesaman

February 9, 1968

Contents

ABSTRACT	1
INTRODUCTION	1
PULMONARY DEPOSITION	2
PULMONARY CLEARANCE	4
DEEP RESPIRATORY ZONE GEOMETRY	5
TISSUE EXPOSURE	7
SUBMICROSCOPIC STRUCTURE	9
RADIATION RESPONSE OF TISSUE	10
IMPLICATIONS	13
REFERENCES	14
APPENDIX I	15
APPENDIX II	16

AN ANALYSIS OF THE CARCINOGENIC RISK FROM AN INSOLUBLE ALPHA-EMITTING AEROSOL DEPOSITED IN DEEP RESPIRATORY TISSUE

Abstract

This paper is concerned with evaluating the carcinogenic risk from an insoluble alpha-emitting aerosol deposited in deep respiratory tissue Pulmonary deposition and clearance are described; and relevant times, lengths and geometries are noted in order to construct a simple model of deep respiratory tissue. $Pu^{238}O_2$ and $Pu^{239}O_2$ are taken as representative aerosols in making quantitative estimates of tissue exposure and response. While no realistic evaluation of the total carcinogenic risk is accomplished, the results are such as to clarify the nature of the problem. In particular, if the loss of mitotic competence by a local cell population is sufficient to guarantee no origin of cancer within that population, then the carcinogenic risk from particulate sources does not scale to the total energy dissipated. To say what dose characteristics are significant to the risk would require an accurate knowledge of clearance, local shielding responses, and the mechanisms of cancer induction. In the absence of this detailed knowledge the suggested course is an experimental determination of the number of source particles per induced cancer.

Introduction

The possibility exists that significant quantities of insoluble radioactive aerosols will be accidently released into the atmosphere. Inhalation of these aerosols by a population will involve some carcinogenic risk. This work arose out of an attempt to understand and evaluate that risk.

A general appraisal of the problem is closely related to several mechanisms and phenomena. In order to achieve a desirable level of completeness, gross and microscopic structure and function of the lung are briefly described relative to the questions of pulmonary deposition and clearance.* Relevant characteristic times and lengths are noted and used in constructing a simple model of lung structure and function in the deep respiratory zone. The alpha-emitters, $Pu^{238}O_2$ and $Pu^{239}O_2$, are taken as representative aerosols** in making quantitative estimates of tissue exposure and response. While no realistic evaluation of the total carcinogenic

*The material for this description is principally derived from Ref. 1 and 2.

**References 3 and 4 deal specifically with the clearance of PuO_2 aerosols.

risk is accomplished, some results are obtained which clarify the nature of the problem and suggest the specific areas of interest in future study.

Pulmonary Deposition

Knowing the characteristics of an aerosol, i.e., the size, geometry, density and concentration, it is then possible to make a reliable estimate of the deposition in the respiratory airways. Figure 1 shows in schematic a human respiratory tree along with the associated lengths, diameters, velocities and branching numbers. For a given aerosol the principal mechanism of deposition will vary among different regions of the lung.

		Branching number	Length (cm)	Diameter (cm)	Velocity (cm/sec)
Conducting zone	Trachea	0	11	1.6	150
	Main bronchi	1	6.5	1	190
	Bronchi	2	1.5	0.9	200
	Terminal bronchioles	16	0.3	0.06	2
Deep respiratory zone	Respiratory bronchioles	17 ↓ 19	0.15	0.05	1.4
	Alveolar ducts	20 ↓ 23	0.08	0.04	0
	Alveoli	24	0.03	0.03	0

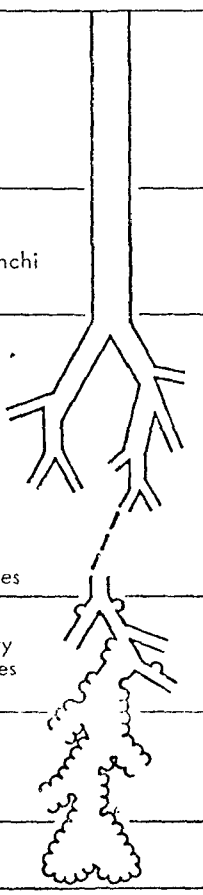


Fig. 1. The respiratory tree, schematic drawing and approximate descriptive values (compiled from Refs. 1 and 2).

In the upper respiratory tract, i.e., nose-pharnyx-trachea, inertial deposition is dominant. It occurs when an airway branches or changes direction, and the flowing air is unable to act on the particle with sufficient force to cause it to follow the flow pattern; consequently the particle persists in the original direction of motion until it strikes the wall of the airway and adheres. This mechanism is especially effective when aerosols are dense, flow speeds are large, and airways are tortuous. These conditions exist in the nasal chambers where the removal of large particles is accomplished.

In the lower respiratory airways gravitational settling accounts for most of the deposition. It is important when the residence time in an air duct is such that the distance a particle falls in that time is of the order of, or greater than, the vertical size of the duct. Because the total duct cross-section increases enormously in the deeper respiratory airways, the flow velocity becomes commensurately smaller, hence residence times are long and the deposition condition is satisfied in the deep respiratory zone (DRZ) for micron-sized particles. It is worth noting that when the tidal air finally reaches the alveoli its velocity is almost zero and it moves nonturbulently into the expanding alveolar space, simply following behind the stagnant air.

For submicronic particles, deposition by Brownian diffusion is significant. Since the diffusion amplitudes for the residence times involved are generally small compared to the duct dimensions of the vestibular airways, the mechanism is only important for submicronic particles entering the stagnant alveolar air spaces where residence times are large.

It is easy to identify these effects in Fig. 2, which shows the percentage deposition of a plutonium oxide aerosol as a function of size. Note the maximum around 0.75 μ in the deep respiratory zone branch. While the general structure of the deposition curves is typical, there will be some curve displacement and variation in shape for aerosols of different density and geometry.

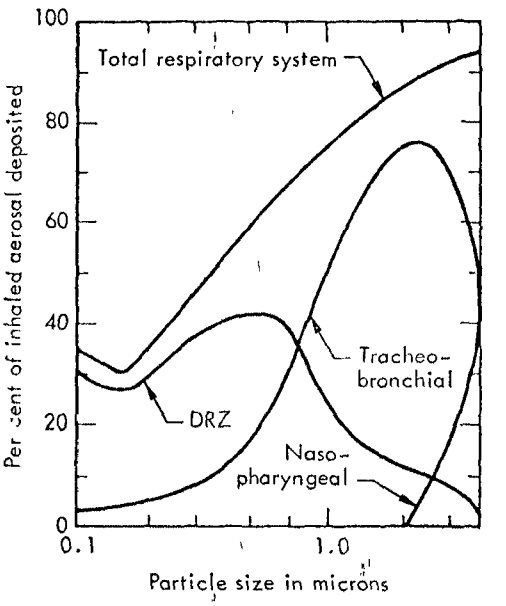


Fig. 2. Pulmonary deposition curves for a PuO_2 aerosol. (reproduced from HEALTH PHYSICS 13; 881, 1967 by permission of the Health Physics Society, after Fig. 6 of Mann and Kirchner (5).

Figure 2 should have been replaced by its improved counterpart in the Report of the ICRP Task Group on Lung Dynamics in Health Physics, 12:173 (1966).

Once a particle is deposited in the respiratory tract its fate depends principally on its locality. Airways from the terminal bronchioles upwards are ciliated, and a mucous coat is propelled up the tract with a velocity of the order of 1 cm/min, though the velocity in the smaller bronchi is somewhat reduced from this value. Particles residing on this mucous coat are usually removed to the mouth in a matter of an hour.

In the deep respiratory zone the ducts are not ciliated; there is, however, a thin mucoid coat on all air tissue surfaces and macrophages adhere to the alveolar walls. It is thought that particles deposited in this region are ingested by macrophages and that most of these cells then detach from the alveolar wall and are removed in some poorly understood way to the mucous blanket of the terminal bronchiole. This transfer is not believed to be accomplished by actively directed macrophage motion, as no tropism has been demonstrated. Possibly the mucous movement in the terminal bronchiole induces, through viscosity, a slow flow in the mucous coat of the deep respiratory zone in much the way that a river would disturb a backwater. It is more likely, however, that the motion of the mucous-covered alveolar walls during breathing is such that it acts to pump surface debris out of the alveoli. Whatever the mechanism, there is observed a fairly rapid phase of clearance from the region. The half-life for this process is of the order of a few days, though this depends on the magnitude of the lung burden. For small burdens the rate of clearance seems to increase with the burden, at larger burdens the response is saturated and the clearance mechanism is less effective.

A much slower clearance is also observed from this region; it has a time scale of 100's of days.[3] Again the process is not well understood; it is assumed that some particles are rendered static in the deep respiratory zone of the lung, and a few of these are occasionally mobilized, at which time they may be susceptible to the usual clearance path. The mechanism of immobilization is conjectured to be macrophages that, for some unknown reason, do not detach after ingestion, and instead remain at the site, proliferating and developing a supporting structure of connective tissues. These anomalies, called plaques, tend to appear in regions that because of structure or injury are more rigid, for example, where an alveolus opens into a respiratory bronchiole. The plaques are rigid structures and hence tend to immobilize the surface still more, which is likely to further reduce the effectiveness of the clearance mechanism for that vicinity. The association of plaques with static regions in the alveolar wall tends to bear out the idea that the normal clearance of the deep respiratory zone is supported by the excursions of the alveolar wall. It does not, however, rule out the induced-flow explanation of clearance, and in fact the two mechanisms may complement each other. The later release of particles is taken to occur when macrophage death within the plaque allows the release of a fraction of the ingested particles.

Some particles find their way into the pulmonary lymph nodes. Though a few

may actually penetrate directly into the interstitium in regions where the capillary network is relatively diffuse, most of the lymph burden derives from the plaques which cause the adjacent alveolar walls to lose their capillaries and basement membranes, thus making it possible for a ruptured cell in the plaque to empty some of its contents directly into the interstitial space from where it finds its way to the lymph node. The time scale for this clearance is observed to be the same as slow pulmonary clearance to the outside, which is consistent with the explanation.

With this description of clearance, characteristic scales can be assigned to particles experiencing the various phases of clearance. These are given in Table I. Because of their potentially long residence times, radioactive particles in the deep respiratory zone constitute an unusual risk. This is the particular problem that I want to describe.

Table I. Characteristic scales of pulmonary clearance.

	Length	Time	Velocity
Upper respiratory clearance	~25 cm	~1/2 hr	~1 cm/min
Fast DRZ clearance (moderate burden)	~ 2 mm	~ 2 days	~1 mm/day
Slow DRZ clearance	0	~500 days	0

Deep Respiratory Zone Geometry

To obtain some notion of the bulk nature of a lung, refer to Table II showing the fractional composition by volume of typical human lung at three-fourths maximal inflation. Renormalized values compatible with half-maximal inflation are included in the table. Notice that the lung is about 80% air and that most of this is in the alveoli and their vestibular air spaces. This should give some appreciation of the porous and sponge-like character of an inflated lung. Ninety percent of the gross volume is made up of sac-like alveoli, about 10^8 in total, clustered about airways which have undergone from one to seven branchings between the terminal bronchiole and the alveoli. Many different clusterings occur, but all achieve the same effect; that is, close packed alveoli sharing the same thin walls, and ventilated by a set of vestibular airways with approximately one-half the alveolar volume. An alveolus is best represented geometrically as a truncated sphere; collectively they can be pictured as a honeycomb-like structure wrapped around a duct. The ducts are generally so branched or alveolated as to have no internal surface.

Table III gives some idea of the dimensions involved with the DRZ geometry. These will vary somewhat in other species because the alveolus size is an inverse function of the organism metabolic rate. For my purposes it was sufficient to regard the deep lung tissue as a cubical lattice characterized by the length of a side, d, and a wall thickness, r. These

Table II Fractional composition of a human lung at three-quarters and one-half maximum inflation.

Three-quarters maximum inflation*				
DRZ	Connective and conductive structures		0.1	0.90
	Air in alveolar ducts and respiratory bronchioles		0.29	
	Air in alveoli		0.54	
	Blood barrier	Epithelial 0.009 Interstitial 0.012 Endothelial 0.009	0.03	
	Capillaries		0.03	
	Pre- and post-capillary		0.01	
One-half maximum inflation**				
DRZ	Connective and conductive structures		0.14	0.86
	Air in alveolar ducts and respiratory bronchioles		0.27	
	Air in alveoli		0.49	
	Blood barrier	Epithelial 0.012 Interstitial 0.016 Endothelial 0.012	0.04	
	Capillaries		0.042	
	Pre- and post-capillary		0.014	

*This portion of the table is taken from Ref. 2.

**Renormalization of the data for three-quarters maximum inflation.

Table III. Characteristic sizes (in microns) in the DRZ.

Alveoli	200 - 300
Alveolar duct	200
Respiratory bronchiole	500 × 1500
Alveolar septum	3 - 10

values can be chosen in a way that is compatible with DRZ densities, since this is the crucial parameter for determining the range of ionizing radiation. When this is done for the average lung data (see Appendix I) the results are $d = 200\,\mu$, $r = 8\,\mu$ at one-half maximum inflation; and $d = 230\,\mu$, $r = 6\,\mu$ at three-fourths maximum inflation.

In the lattice model the wall is treated as being elastic and uniform in thickness; in fact it is corrugated on length scales of a few microns. This structure primarily derives from distensions associated with the capillary mesh in the walls. The length scales of the radiation problem are sufficiently large that the approximation of uniform walls should have no appreciable consequences.

To see what kinds of volumes are exposed by a radioactive source consider a 1-μ particle of $Pu^{238}O_2$ embedded in the lattice. From Fig. 2 this size is nearly optimal for deposition in the deep respiratory zone. Pu^{238} emits 5.5-MeV alpha particles and has a half-life of 89 years. A particle of this size is a 60-pCi source and has a total alpha flux of about 200,000 per day or 2.2 per sec. The range in tissue, R, of 5.5-MeV alpha is 41.5 μ; there is no appreciable attenuation because of the size of the particle.

Since the range in tissue is greater than a septal thickness, the geometric range of an alpha as a function of field angle works out quite simply to be as shown in Table IV. The reasons for this result are clear.

Table IV. Angular dependence of the geometrical range of an alpha source in a cubical lattice geometry (For a derivation see Appendix II.)

1) *Along* lattice axes (defined by source)	$D \cong \frac{Rd}{r}$
2) In lattice plane (defined by source)	$D \cong \frac{Rd}{2r}$
3) *In other directions*	$D \cong \frac{Rd}{3r}$

where r = septal thickness
R = range in tissue
d = cube dimension
D = geometric range

and it is assumed that

$R > r$.

The geometric range D must scale like Rd/r, and a factor of 1, 2, or 3 must occur in the denominator depending on whether the field direction intersects with 1, 2, or 3 sets of the orthogonal planes which generate the lattice.

Hence the exposed volume can be thought of as a sphere of radius Rd/3r, on which are superimposed discs of radius Rd/2r and thickness d lying in the three 2-axis planes, on which in turn are superimposed arms of length Rd/r and cross-section d^2 in the six axis directions. The volume exposed is just

$$V = d^3\left\{\frac{4\pi}{81}\left(\frac{R}{r}\right)^3 + \frac{5\pi}{12}\left(\frac{R}{r}\right)^2 + 3\left(\frac{R}{r}\right)\right\}$$

where the bracketed expression is the number of alveoli in the volume, and the 3 terms are the sphere, disc and arm terms respectively. For the lattice model and a source with a solid tissue range of 41.5 μ, the geometric range is of the order of 1000 μ (Table V), and the number of alveoli exposed is of the order of 100 (Table VI). Figure 3 shows a cross-section view of an exposed volume in which the included alveoli are all appreciably exposed. The example exhibits an asymmetry of the order of d that can exist because of the location of the source within the alveolus.

The alpha flux around the source is described by a $1/4\pi x^2$ geometrical attenuation where x is the distance between source and field point. This leads to large dose rate gradients in the neighborhood of a source. The fluxes computed for a test source in a lattice (Table VII) give some idea of the intensities to which the tissue in the various regions is exposed. Notice that 6 orders of magnitude are covered over the exposed volume.

Bear in mind that this lattice model should not be taken too literally, but rather as a representative example of an

Table V. Geometric ranges (in microns) of a 5.5-MeV alpha source in a cubical lattice.

	$\frac{Rd}{3r}$ (sphere)	$\frac{Rd}{2r}$ (disc)	$\frac{Rd}{r}$ (arm)
1/2 maximum inflation $\left(\frac{R}{r} = 5\right)$	335	500	1000
3/4 maximum inflation $\left(\frac{R}{r} = 7\right)$	535	805	1610

Table VI. Number of alveoli exposed by a 5.5-MeV alpha source in a cubical lattice model of the DRZ.

	$\left(0, \frac{Rd}{3r}\right)$	$\left(\frac{Rd}{3r}, \frac{Rd}{2r}\right)$	$\left(\frac{Rd}{2r}, \frac{Rd}{r}\right)$	Total
1/2 maximum inflation $\left(\frac{R}{r} = 5\right)$	20	33	15	68
3/4 maximum inflation $\left(\frac{R}{r} = 7\right)$	53	64	21	138

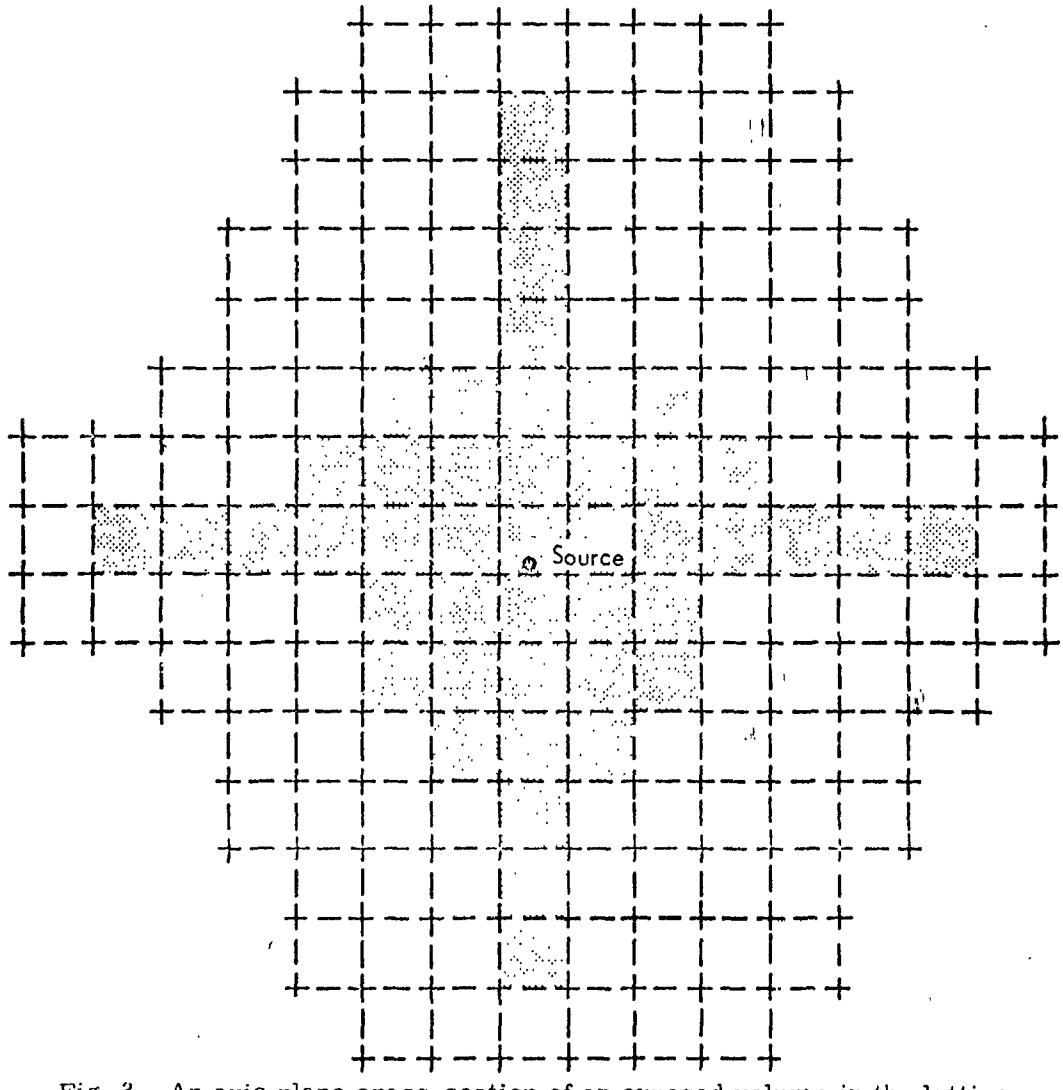


Fig. 3. An axis plane cross-section of an exposed volume in the lattice model; R/r = 7 (three-fourths maximal inflation).

Table VII. Alpha flux in number/μ^2/day.

	Distance from source				
	1 μ	10 μ	$\frac{Rd}{3r}$	$\frac{Rd}{2r}$	$\frac{Rd}{r}$
1/2 inflation	1.6×10^4	1.6×10^2	$14. \times 10^{-2}$	6.4×10^{-2}	1.6×10^{-2}
3/4 inflation	1.6×10^4	1.6×10^2	5.6×10^{-2}	2.5×10^{-2}	0.62×10^{-2}

exposed volume in a specific lattice geometry. It would not be representative in a region where masses of solid tissue occur whose characteristic size is of the order of 40 μ or more. Such masses are not usually encountered in the deep respiratory zone. From the model one can infer an effective absorption length of Rd/3r though many excursions can occur to 1-1/2 times and rarely to even 3 times that distance.

The effect of passing to a more realistic model with airways and wall corrugations would be to increase alveolar septal thickness by possibly as much as 30%. This would reduce the effective absorption length proportionally, but the presence of airways and wall corrugations would increase the length of excursions, and for active sources such as 1-μ $Pu^{238}O_2$, the distant alveoli exposed are probably the most significant. In any event, the simple lattice model gives order-of-magnitude geometric numbers, which is all that is required with the present state of the art.

Submicroscopic Structure

In order to talk about the response of the exposed cell populations it is necessary to say something about the tissue organization in the interalveolar septum. All air interfaces are covered by a single epithelial layer, all blood interfaces by a single endothelial layer. Each has its own basement membrane, these membranes usually adjoin each other, and the two tissues with their basement membrane comprise the thin ($< 1 \mu$) blood barrier of the respiratory zone. The capillaries occur in an approximately hexagonal mesh[2] (see Fig. 4) that occupies most of the interalveolar septum. One can imagine that the nuclei of the epithelial and endothelial cells tend to congregate in the openings of the capillary mesh, while their thin cytoplasmic extrusions protect the adjacent capillary lumen. Interspersed in the interstitial space are the septal cells, and the connective tissue fibers which give the alveoli their structural properties, especially elasticity. Again they can be expected to concentrate in the openings of the mesh.

Some simple geometrical considerations make it reasonable to associate three endothelial cells and two epithelial cells with each opening in the capillary mesh. The three endothelial cells are sufficient to cover three capillary segments and by associating three segments with each opening the entire mesh can be generated. If one conjectures that an endothelial cell covers several segments then one is

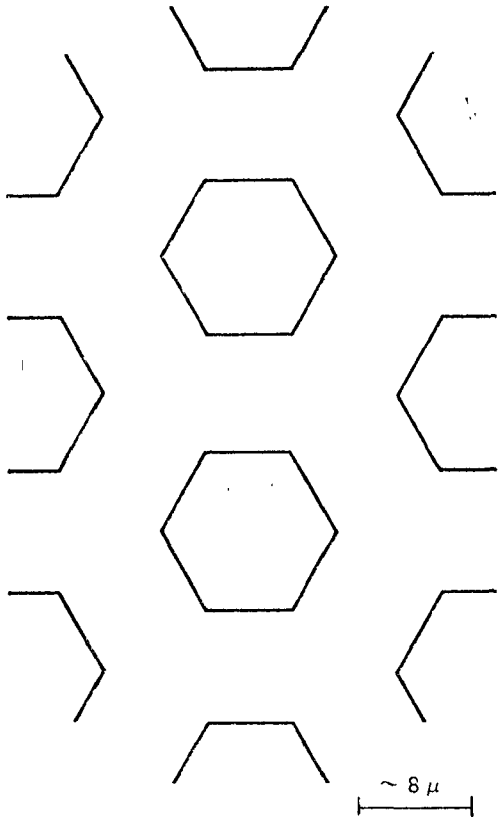


Fig. 4. The hexagonal array of the capillary mesh.

quickly led to very complicated three-dimensional geometries for the cell. The two epithelial cells are sufficient to cover the two sides of the hexagon. This assignment is consistent with the volume available in the center of the mesh. Again, the model should not be taken too literally, but rather as an order-of-magnitude estimate of cell population densitites that is not incompatible with electron micrographs of the alveolar septum.[1,2,6,7] There are ~3600 capillary segments in the walls of one alveolus.[2] Since each capillary segment is shared by two hexagons there are only three capillary segments countable with each hexagon, which implies that there are 1200 distinct, but not disjoint, hexagons on the surface. Each of these has of the order of three endothelial cells and two epithelial cells; hence the entire wall has ~3600 endothelial and ~2400 epithelial cells. Because this septum is shared, it follows that for an interior alveolus there are only 1800 endothelial and 1200 epithelial cells per alveolus. The number of epithelial or endothelial cells in a volume exposed by a $Pu^{238}O_2$ particle would be of the order of 10^5. (At one-half maximum inflation ~120,000 endothelial, ~80,000 epithelial; and at three-fourths maximum inflation ~250,000 endothelial, ~165,000 epithelial.) Septal cells have been ignored; presumably they are less numerous.

Radiation Response of Tissue

Knowing something about the lung geometry and the cell populations it is possible to make some comments about the radiation response. The carcinogenic implications of a nonuniform radiation environment will depend on the response of cell populations to the local radiation field. Since this radiation varies over many orders of magnitude it would not be surprising if several regimes of biological response were traversed. To try to relate radiation level and population response in a detailed way seems highly speculative. A more tractable aspect of the total problem is the loss of potentially cancerous cells by radiation injury. Barendson[8,9] has observed the effect of ionizing radiations in the arrest of clone

development from kidney T_1 cells. For alpha radiation he found the cell injury to be irreversible with a cross-section of the order of that of the cell nucleus. The latter result is consistent with Bloom's observations[10] with proton microbeams, where a large dose to the cytoplasm did not prevent mitosis while a small dose to the nucleus disrupted the separation of chromosomes. On this basis the cross-section for mitotic arrest by alpha radiation on lung tissue is taken by analogy from Barendson's observations with the added assumption that in all cases of interest the number density of chromosomes in the nuclear volume[11] is roughly equal to that in the kidney cell nuclei. Presumably the loss of mitotic capacity is sufficient to guarantee that cells are not potentially cancerous, which is not to say, however, that the disorder associated with their ultimate death may not have some implication of enhanced cancer risk by creating a region of trauma as a chemical irritant might do.

The radiation is random in direction, so a Poisson distribution applies. At a given radiation flux the number of mitotically fertile cells will decrease exponentially with a half-life of one over the flux through the effective nuclear cross-section. The tissue repair mechanisms of the organism must function on a similar or shorter time scale if the local cell population is not to be totally disrupted by the cumulative radiation dose. There are some clues to the history of lung cells after radiation. Phillips[12] gave 2000 R of X rays to rat lungs and then followed the tissue response for one year. He observed no widespread damage for up to three months, at which time some endothelial tissue sloughed and the affected region filled with plasma cells and mast cells. By six months the injured capillaries were largely reopened or replaced by collagenous deposits. In this period no manifestation of injury was noticed in epithelial cells. It is worth mentioning that usually the shape of the alveoli was undisturbed, which is probably accountable to the radiation indifference of the fibrous supporting structure.

These observations afford some idea of how long a cell persists after radiation insult. During this vulnerable time a cell population presents a static profile to radiation, and loss of mitotic capability should be cumulative. From Phillips' work it appears that for endothelial tissue this time is of the order of 100 days and for epithelial tissue a year or more. Note that these times may be in fact a decreasing function of dose[13] since it is possible that loss of mitotic capacity may derive from several injuries, each having a different time scale for manifestation. Two thousand R of X rays is, however, a sufficiently large dose that it should give representative numbers.

The epithelial time is probably of greater interest since the $Pu^{239}O_2$ induced pulmonary cancers in dogs appear to be largely epithelial in origin.[4] If consideration is limited to this tissue, Barendson's and Bloom's studies suggest that in regions where there is an alpha flux of more than 1 per year per cell nucleus cross section the population will lose of the order of one-half of its potential cancer cells. If there are more than 10 counts per tissue response time per cell nucleus cross section, the population is almost wholly depleted of potential

cancer cells. This roughly defines the radiation regimes of interest for a static source. In the example of a 1-μ $Pu^{238}O_2$ source embedded in a lattice lung at three-fourths inflation, the flux at the furthest perimeter is of the order of 90/year/$(5\ \mu)^2$, where $(5\ \mu)^2$ is taken to be a representative cross-section for an epithelial nucleus. If the response time of epithelial populations is one year or more then an alpha source of such intensity should sterilize all populations within the exposed volume. At the same time the carcinogenic risk associated with intracellular damage should disappear as the tissue loses its capacity for regeneration.

It would be useful to have an approximate idea of the source sizes for which the associated radiation is not population-lethal throughout the entire exposed volume. Ignoring the attenuation of the radiation by the tissue matrix, let x_{ep} be defined as the geometric distance beyond which the flux is less than 1/year/$(5\ \mu)^2$, i.e., the distance inside of which 63% or more of the epithelial cells in a local population are rendered mitotically impotent before repair begins. This quantity can be related to the source strength and hence to a source size, s, which is taken here to be a sphere diameter. For $Pu^{238}O_2$, $x_{ep} \cong 10^4\ s^{3/2}$ where s is in μ Similarly, for endothelial populations, $x_{en} \cong \frac{10^4}{2}\ s^{3/2}$. Since in the lattice model of the human lung the geometric range is limited by the attenuation in tissue to less than 1500 μ it is clear that unless the source size, s, is smaller than or of the order of 0.25 μ the yearly flux will be lethal for all ephithelial populations in the exposed volumes. The source size condition will only be slightly less stringent for endothelial populations $s < 0.35\ \mu$.

Pu^{239} emits alphas of similar energy, and has a half-life that is approximately 300 times longer. The previous considerations for $Pu^{238}O_2$ apply with the exception that for equal source-strengths the source diameter of $Pu^{239}O_2$ will scale about 7 times larger. Hence the source size condition will be modified to $s \leq 1.75\ \mu$.

Implicit in the preceding was the assumption that the source was static in the lattice for a time greater than the tissue repair time. If instead the source is supposed to be removed in a time characteristic of fast DRZ clearance, then the exposure time of an alveolus is of the order of one to a few days depending on its initial separation and its position relative to the clearance path. Comparing this with the static case it is evident that source intensity must scale about 100 times larger to produce similar damage; or equivalently particles whose diameters are $\leq 1\ \mu$ will not be population-lethal throughout the whole exposed volume. With a moving source the exposed volume will be somewhat more extensive, but since the distance traversed before reaching a ciliated airway is only slightly greater than the geometric range, it is doubtful if the exposed volume would increase by an order of magnitude.

Implications

Finally, does this really tell us anything about the carcinogenic implications of $Pu^{238}O_2$ and $Pu^{239}O_2$ inhalation. Consider a particle larger than 0.25 μ that is immobilized in the deep lung tissues. From the geometric model of the DRZ it is possible to make an approximate estimate of the exposed volume. If one can accept the inferred tissue-response times (admittedly tenuous), and the model for cell injury by alpha radiation, then it follows that in the absence of local shielding all of the epithelial populations within the exposed volume should be rendered mitotically impotent by the resident particle. This is assumed to be a sufficient condition for no cancer induction within the exposed volume. With sources smaller than 0.25 μ the risk should increase.

Next, consider the effect of possible local responses. With a source as active as $Pu^{238}O_2$ it may be that a macrophage would die shortly after ingesting a particle, and if that is the case then plaque formation would be prevented. Possibly the source would have such a disruptive influence on adjacent tissue that the harboring alveolus would become static and fill with debris. Local edema or a shell of denatured protein is conceivable. Almost surely something of this sort happens and to a considerable degree lessens the source range. The peripheral volume will be subjected to transient radiation dose in the time before this local response occurs. For all but the very smallest particles, only this transient radiation dose would be of carcinogenic significance, the rest of the emitted radiation being so confined in volume as to have a lethal effect.

Similarly the particles that are cleared quickly may produce a transient radiation does that is disrupting but nonlethal over part of the exposed volume. The relative importance of two comparable particles, one static and one cleared, is contingent on the time scale of the dose they inflict. This is poorly known in both cases.

If the preceding reasoning is correct, $Pu^{238}O_2$ and $Pu^{239}O_2$ particles deposited in the deep respiratory zone of the lung do not constitute a carcinogenic risk commensurate with the total energy dissipated. The part of that energy that is potentially carcinogenic is dependent on the intensity of the source and on the time scales of clearance and local shielding.

While it is unrealistic to scale the carcinogenic damage to the total energy from a static source, I doubt if the effects of radiation are so well known that we can fix the risk from the nonstatic phases of the problem. The particle problem is somewhat unique in that: (1) there is enormous variation in the dose level and dose characteristics to which different cell populations may be exposed, and (2) volumes involved are small so that disruptive doses are not necessarily organ fatal. Implicit in the problem is considerable diversity, and I would be concerned that somewhere in this diversity are unanticipated resonant situations where the risk is large compared with predictions made from linear dose effect relations.

The risk does not scale with the total energy from a source, and with present knowledge it is precarious to try to

describe in a detailed way the relationship between radiation level and carcinogenic tissue response. It would seem that the most reasonable and hopeful approach is to attempt an experimental determination of the number of cancers per source particle as a function of source strength at relatively low tissue burdens. With this, a meaningful estimate of risk would be readily accessible.

References

1. Hatch, T. F. and P. Gross. Pulmonary Deposition and Retention of Inhaled Aerosols. New York and London, Academic Press, 1964.
2. Weibel, E. Morphometrics of the lung. In Handbook of Physiology. Section 3, Respiration, Volume 1, W. O. Fenn and N. Rahn, eds. Washington, D. C., American Physiology Society, 1964, pp. 285-307.
3. Morrow, P. E., F. R Gibb, H. Davies, J. Mitola, D. Wood, N. Wraight, and H. S. Campbell. The retention and fate of inhaled plutonium dioxide in dogs. Health Phys. 13: 113-133, 1967.
4. Bair, W. J., J. F. Park, and W. J. Clarke. Long-term study of inhaled plutonium in dogs. Battelle Memorial Institute (Richland), AFWL-TW-65-214, 1966.
5. Mann, J. R. and R A. Kirchner. Evaluation of lung burden following acute inhalation exposure to highly insoluble PuO_2. Health Phys. 13: 877-882, 1967.
6. Porter, K. R. and M. A. Bonneville. An Introduction to the Fine Structure of Cells and Tissues. Philadelphia, Lea and Ferbiger, 1964.
7. Rhodin, J A. G. An Atlas of Ultrastructure. Philadelphia and London, W. B. Saunders Company, 1963, pp. 86-93.
8. Barendsen, G. W. Dose-survival curves of human cells in tissue culture irradiated with alpha-, beta-, 20-kV x- and 200-kV x-radiation. Nature 193: 1153-1155, 1962.
9. Barendsen, G. W., H. M. D. Walter, J. F. Fowler, and D. K. Bewley. Effects of different ionizing radiations on human cells in tissue culture. Radiation Res. 18: 106-119, 1963.
10. Bloom, W. Cellular responses. Rev. Modern Phys. 31: 21-29, 1959.
11. Sparrow, A. H , L. A. Schairer, and R. C. Sparrow. Relationship between nuclear volumes, chromosome numbers, and relative radiosensitivities. Science 141: 163-166, 1963.
12. Phillips, T. L An ultrastructural study of the development of radiation injury in the lung. U. S. Naval Radiological Defense Laboratory, USNRDL-TR-973, 1966.
13. Jennings, F. L. and R. A. Turner. Radiosensitivity of epithelium and endothelium in the lungs (abstract). Radiation Res. 22: 201, 1964.

Appendix I

Derivation of Parameter Values for the Cubical Lattice Model of the DRZ

From Tables II and III one can infer DRZ densities of approximately 0.12 g/cm^3 and 0.08 g/cm^3 for one-half and three-fourths maximum inflation, respectively. The model should reproduce these densities.

Consider a cubical lattice of side length d and finite wall thickness r, where d is measured between midplanes of the walls, and it is assumed that $d \gg r$. If all gross lattice dimensions are large compared with d, then surface corrections may be ignored and the gross lattice density is

$$\cong 1.05 \text{ g/cm}^3 \times 6\, d^2\, \frac{r}{2} \times \frac{1}{d^3} = 1.05 \text{ g/cm}^3 \times \frac{3r}{d} ,$$

where the wall density is taken as 1.05 g/cm^3 and the density of the remaining volume is taken as zero.

At three-fourths maximum inflation of an average adult lung Weibel[2] gives an alveolar radius of 140 μ for an assumed spherical geometry. This implies a radius of 122 μ at half maximum inflation. To choose a compatible cube dimension it seems appropriate to require that the associated volumes be equal, in which case d = 1.62 × (radius). These values of d together with the density relations will fix the parameter values at d = 197 $\mu \cong 200\ \mu$, r = 7.7 $\mu \cong 8\ \mu$ for half maximum inflation, and d = 226 $\mu \cong 230\ \mu$, r = 5.8 $\mu \cong 6\ \mu$ for three-fourths maximum inflation, which are in reasonable agreement with descriptions of the alveolus.

Appendix II

Derivation of the Approximate Volume Exposed by a Point Source in a Cubical Lattice

Let
- $d \equiv$ cube dimension
- $r \equiv$ thickness of a cube wall (septum)
- $\bar{D} \equiv$ geometric range of a source
- $R \equiv$ range in tissue of source
- $i, j, k \equiv$ indices of the 3 Cartesian axes centered at the source
- $\theta_i \equiv$ angle that the direction of $\bar{D}$ makes with ith axis
- $m_i \equiv$ number of septal planes traversed that are perpendicular to the ith axis.

Assume that $R > r$. It is approximately true that

$$(a) \quad \frac{m_i}{\cos\theta_i} \simeq \frac{m_j}{\cos\theta_j} \simeq \frac{m_k}{\cos\theta_k} \simeq \frac{D}{d} .$$

These relations break down when one or two of the $\cos\theta$'s become small in the sense that $\cos\theta \lesssim \frac{r}{R}$. Consider the various possibilities:

Case 1. $\cos\theta_j$, $\cos\theta_k$ are small, in which case $\bar{D}$ very nearly lies along the ith axis. Then (a) reduces to

$$m_i \simeq \frac{D}{d}$$

and since $R \simeq m_i r$, it follows that

$$D \simeq \frac{R}{r} d .$$

Case 2. $\cos\theta_k$ is small, in which case $\bar{D}$ is confined to the plane of the ith and jth axis. Then (a) reduces to

$$\frac{m_i}{\cos\theta_i} \simeq \frac{m_j}{\cos\theta_j} \simeq \frac{D}{d}$$

and since $R \simeq \frac{m_i}{\cos\theta_i} r + \frac{m_j}{\cos\theta_j} r$, it follows that

$$D \simeq \frac{1}{2} \frac{R}{r} d .$$

Case 3. $\cos\theta_i$, $\cos\theta_j$, $\cos\theta_k$ are not small. Hence (a) holds and

$$R \cong \frac{m_i}{\cos\theta_i} r + \frac{m_j}{\cos\theta_j} r + \frac{m_k}{\cos\theta_k} r, \text{ hence}$$

$$D \cong \frac{1}{3} \frac{R}{r} d .$$

Distribution

LRL Internal Distribution

M. M. May

D. P. Geesaman 25

G. H. Higgins

H. A. Tewes

TID Berkeley

TID File 30

External Distribution

D. S. Barth
J. McBride
Southwestern Radiological Health Laboratory
Los Vegas Nev.

L. K. Bustad
University of California
School of Veterinary Medicine
Davis, Calif.

H. D. Bruner
P. F. Gustafson
H. L. Hollister
S. A. Lough
Division of Biology and Medicine
U. S Atomic Energy Commission
Washington D. C.

G. M. Dunning
Division of Operation Safety
U. S. Atomic Energy Commission
Washington, D. C.

J. S. Kelly
Division of Peaceful Nuclear Explosives
U. S. Atomic Energy Commission
Washington, D. C

R. S. Russell
Agricultural Research Council
Radiobiological Laboratory
Letcombe Regis, Wantage, Berkshire
England

G. M. Ward
Animal Science Department (Dairy)
Colorado State University
Fort Collins, Colo.

External Distribution (continued)

D. E. Bales
E. D. Harward
Radiological Health Laboratory
U. S. Public Health Service
Rockville, Md.

K. E. Cowser
T. F. Lomenick
G. M. Van Dyne
Oak Ridge National Laboratory
Oak Ridge, Tenn.

H. S. Jordan
Los Alamos Scientific Laboratory
Los Alamos, N. Mex.

R. O. McClellan
Director, Fission Product Inhalation Program
The Lovelace Foundation
Fission Products Inhalation Laboratories
Building 9200, Area Y
Sandia Base
Albuquerque, N. Mex.

E. C. Freiling
Head, Physical Chemistry Branch
U. S. Naval Radiological Defense Laboratory
San Francisco, Calif.

TID 4500 Distribution, UC-48, Biology and Medicine

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in USA. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65.

VE/la

APPENDIX II

TID-4500, UC-48
Biology and Medicine

Lawrence Radiation Laboratory
UNIVERSITY OF CALIFORNIA
LIVERMORE

Bio-Medical Division

UCRL-50387, ADDENDUM

AN ANALYSIS OF THE CARCINOGENIC RISK FROM AN INSOLUBLE ALPHA-EMITTING AEROSOL DEPOSITED IN DEEP RESPIRATORY TISSUE: ADDENDUM

Donald P. Geesaman

October 9, 1968

Contents

ABSTRACT 1
INTRODUCTION 1
RADIATION CARCINOGENESIS AFTER INTENSE LOCAL EXPOSURE 1
CONCLUSIONS 6
REFERENCES 8

AN ANALYSIS OF THE CARCINOGENIC RISK FROM AN INSOLUBLE ALPHA-EMITTING AEROSOL DEPOSITED IN DEEP RESPIRATORY TISSUE: ADDENDUM

Abstract

Several experiments are reviewed involving skin and lung carcinogenesis in mammals after intense localized doses of ionizing radiation. A high incidence of cancer occurs for the exposures described. The observations suggest that the carcinogenesis is primarily mediated by injury or disruption of local tissue. It is concluded that there is a substantial possibility of enhanced cancer risk associated with the deposition of intense α-emitting particulates in deep respiratory tissue. Within this description lung cancer risks as high as 10^{-3} to 10^{-4} per disruptive source particle are indicated. The possibility of this enhanced risk places the present standards for maximum permissible lung burdens in serious question when applied to particulates such as $Pu^{238}O_2$ and $Pu^{239}O_2$. It is again suggested that in the absence of a detailed knowledge of pulmonary carcinogenesis, the best course of action is an experimental determination of the risk per disruptive particle for particle burdens $<< 10^8$ particles.

Introduction

The original report (UCRL-50387)[1] discussed lung structure and function in relation to radiation insult from insoluble α-emitting aerosols. Carcinogenic risk was treated principally within the assumption that cancer could nor originate in a population of mitotically incompetent cells. No credible risk evaluation was accomplished. This addendum extends the consideration of radiation-induced carcinogenesis. Several high dose experiments are reviewed and analyzed relative to the evaluation of carcinogenic risk in high dose situations. Conclusions are drawn and related to the original report.

Radiation Carcinogenesis after Intense Local Exposure

The induction of neoplasms by ionizing radiation is observed in diverse mammalian tissues and species. There is no comprehensive theory describing these observations.

As was previously indicated, particulate sources have the potential of exposing adjacent tissue to intense doses of radiation without being organ- or organism-fatal. Experiments involving carcinogenesis induced by intense local exposure are therefore especially relevant in judging whether particulate sources constitute a unique risk.

Albert's study of radiation-induced carcinoma in rat skin[2-4] gives some quantitative description of a high dose carcinogenic situation. Since such descriptions are rare, and since Albert's results have implications to risk analysis in general, his experiment is outlined here.

A skin area of 24 cm^2 was exposed to electron radiation with various depths of maximum penetration. The dose response curves are reproduced in Fig. 1. In all cases the response scale at sufficiently high doses was large,* ~1 to 5 tumors per rat at 80 weeks after exposure. It was noted by Albert that when the dose was normalized to a skin depth of 0.27 mm, the three response curves became continuous (Fig. 2). Since this depth is near the base of the hair follicle which comprises the deepest reservoir of epithelial cells of the germinal layer, it was suggestive that this might be a critical region in the observed carcinogenesis. The suggestion gained significance from the

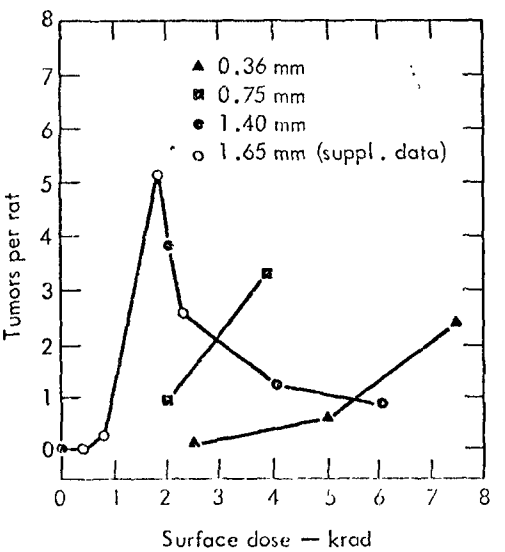


Fig. 1. Tumor incidence with respect to surface dose at 80 weeks for three penetration depths of electrons. (Reproduced with the permission of Academic Press, Inc., and Radiation Research after Fig. 5 of Albert, Burns and Heimbach.[2])

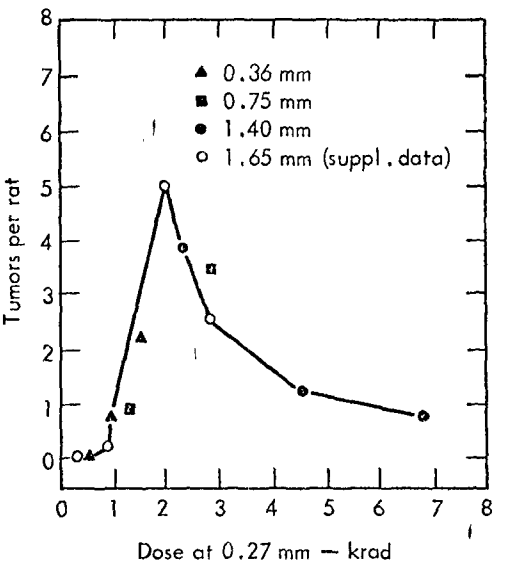


Fig. 2. Tumor incidence with respect to the dose at a depth of 0.27 mm in the skin at 80 weeks for three penetration depths of electrons. (Reproduced with the permission of Academic Press, Inc., and Radiation Research after Fig. 7 of Albert, Burns and Heimbach.[2])

*"Large" as used here describes tumorigenic responses which are greater than 1 tumor for 20 animals. For reference a whole body dose of 1000 R, and a cancer probability of 50 cancers per million per rad, implies a risk of 0.05 per animal.

observations that most of the tumors are similar to hair follicles, and that in the nonulcerogenic dose range the number of tumors per rat was in nearly constant ratio (1/2000 to 1/4000) with the number of atrophied hair follicles (Figs. 3 and 4). Thus the carcinogenesis in this experiment was remarkably correlated with the dose to and the specific damage of a particular skin structure. When exposures were made with stripe and sieve patterns of roughly 1 mm scale, geometrical effects were observed; most notably the cancer induction in the sieve geometry was suppressed at doses of 1700 R, but not at doses of 2300 R. The reduction, however, was again consistent with the reduction in damage as characterized by atrophied hair follicles.

For perspective it is valuable to relate these observations to cellular descriptions. Carcinogenesis in Albert's experiment is

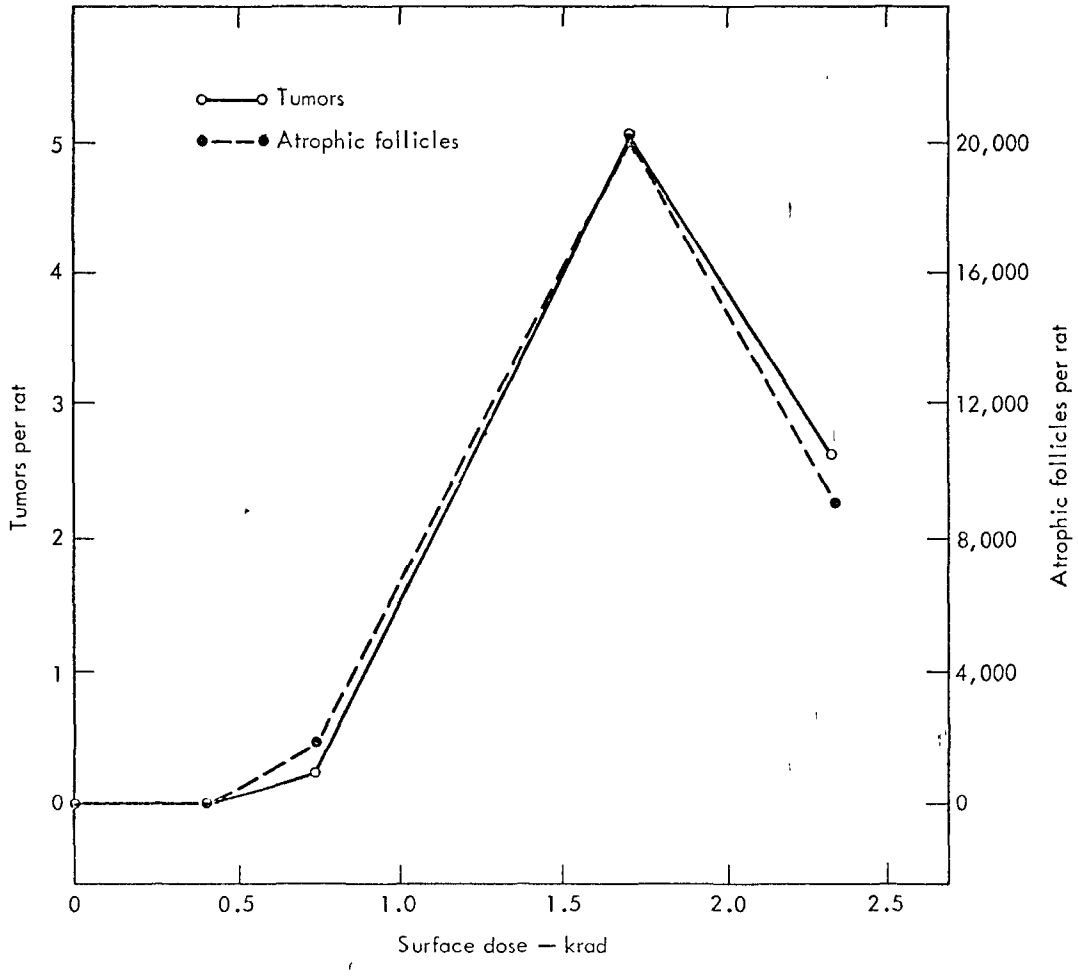


Fig. 3. Dose-incidence curves of skin tumors and atrophic hair follicles for 80 weeks after uniform surface irradiations of 24 cm^2 of skin with electrons that penetrated 1.65 mm. (Reproduced with the permission of Academic Press, Inc., and Radiation Research after Fig. 5 of Albert, Burns, and Heimbach.[4])

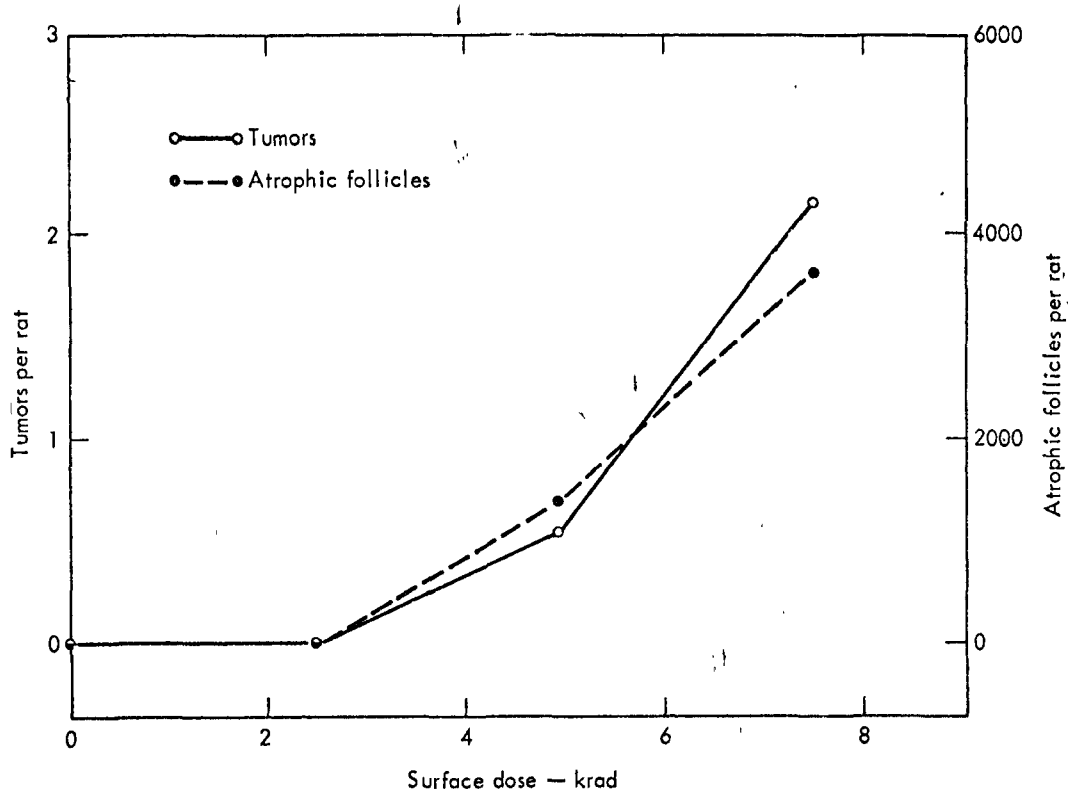


Fig. 4. Dose-incidence curves of skin tumors and atrophic follicles for 80 weeks after uniform surface irradiation of 24 cm^2 of skin with electrons that penetrated 0.36 mm. (Reproduced with the permission of Academic Press, Inc., and Radiation Research after Fig. 6 of Albert, Burns and Heimbach.[4])

maximum in the neighborhood of 2000 R. It is well documented *in vitro* and to a lesser extent *in vivo*[5] that the fraction of mitotically competent cells as measured by clonal formation decreases in a nearly exponential fashion with the dose. From these results a surviving mitotic fraction of approximately 10^{-5} would be expected in a population of germinal epithelial cells exposed to 2000 R. Even in this preulcerative dose regime the cell population suffers severe mitotic injury. It is significant that Albert's dose response curves show no simple relationship with the surviving fraction of mitotically competent epithelial cells. There is certainly no exponential decrease of the response in the neighborhood of D_{37},* and, in fact, the tumorigenesis is maximum in a dose region where the population of mitotically competent cells should be initially depleted by about 5 orders of magnitude.

To summarize this important experiment, a high incidence of cancer was observed after intense local doses of radiation, and the carcinogenesis was proportional to the damage or disordering of a particular skin structure.

Others have observed carcinomas and sarcomas in rats and mice after intense

*The dose which leaves 1/e of the cells mitotically competent.

Table I. Radiation-induced skin cancers observed in rabbits, sheep, and swine.

Animals	Surface dose	Exposed area	Cancer	Reference
2 rabbits[a]	16,000 R (P^{32} plaque)	20 cm^2	1 fibrosarcoma	8, 9
2 sheep[a]	16,000 R (P^{32} plaque)	20 cm^2	1 fibrosarcoma 1 karatocanthoma	8, 10
? swine	19,470 μCi-hr (Ru^{106} plaque)	?	1 squamous cell carcinoma	11

[a]Similar exposures at 2000 R and 8000 R with P^{32} plaques induced no observed cancers, nor did exposures of 2000 R, 8000 R, and 16,000 R with Sr^{90} plaques.

exposure of the skin to ionizing radiation (for a summary see Ref. 6). Cancer induction is generally a frequent event in these experiments. Even at elevated doses such as 12,000 R of 1-MeV electrons, Boag and Glucksmann[7] induced ~5 sarcomas per 100 cm^2 in rats.

A few results for rabbits, sheep and swine are collected in Table I. Despite the small number of animals involved, surface doses of 16,000 R from a P^{32} plaque induced several cancers, which is indicative that larger mammals are similarly susceptible to skin cancer after intense radiation insult. Again, these gross observations demonstrate that enhanced tumor incidence does occur after very high doses.

The skin experiments are remarkable in that a highly disruptive dose of radiation to a reparable mammalian tissue produced frequent carcinogenesis. There is no compelling reason to believe that respiratory tissue behaves similarly, but with the well documented carcinogenic potential of human lung tissue, and the disruptive capacity of radioactive particulates such as $Pu^{238}O_2$, it is reasonable to expect that a comparable development occurs for lung tissue. While a number of radioactive substances have been used to induce lung cancers in mice and rats (see Ref. 12), it is difficult to derive any characterization of carcinogenesis from these experiments. The work of Laskin et al.,[13,14] though not specifically involving deep respiratory tissue, does demonstrate a source-intensity response curve which is reproduced in Fig. 5. A Ru^{106}-Rh^{106} cylindrical source was implanted in the bronchi of rats, and cancers were observed to arise from the bronchial epithelium. The response curve indicates a substantial response (0.07)

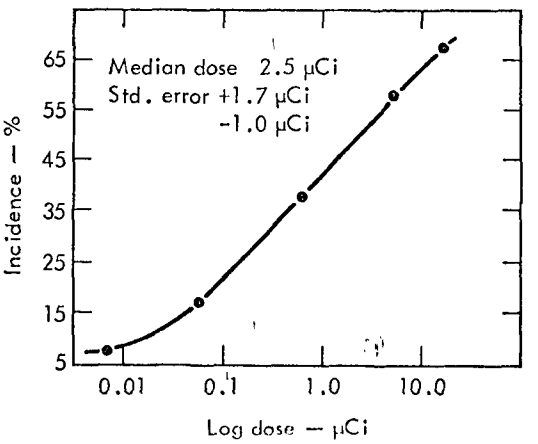


Fig. 5. Dose response relationship in μCi after exposure of the bronchial mucosa of rats to the β-radiation of Ru^{106}-Rh^{106} pellet implants. Squamous cell carcinoma in survivors beyond 143 days. (Reproduced with the permission of the Journal of the National Cancer Institute after Fig. 2 of Laskin et al.[13])

even at 0.008 μCi burden, and a slow, approximately logarithmic increase of tumor incidence over three orders of magnitude in the source intensity. Corresponding first-year doses to adjacent bronchial epithelium varied from 10^3 R to 10^6 R. Animals were followed until death, and it was observed that the tumor incidence generally increased with the dose accumulated at death. The lowest accumulated dose associated with a cancer was 1400 R. For an accumulated dose of the order of 10^6 R the incidence was ~2/3. Cember[12] fortified glass beads (0.3 μ diameter) with several microcuries of Sr^{90}-Y^{90}, and single beads were implanted in the lungs of rats. Tumors were observed in 7 of 23 animals. In a second experiment Cember exposed rat lungs to $Ce^{144}F_3$ particulates. For a burden range of 0.5 μCi to 50 μCi the observed tumor incidence fluctuated between 0.04 and 0.3.

All of these experiments involved intense exposures and a significant level of carcinogenesis. Severe damage and disruption of tissue were associated with the exposure. The nonuniformity of the exposures, the relatively long range of the β-emitters involved, the complex structure and function of the lung, and a general ignorance of the mechanisms of carcinogenesis, make more detailed interpretation largely speculative. There are few clues as to the critical tissue or dose parameters in the observed carcinogenesis.

The most relevant lung experiment is Bair's $Pu^{239}O_2$-inhalation study with beagles.[15,16] Exposure was to particulates of 0.25 μ or 0.5 μ median diameter; burdens were in the μCi range. In the period 2 to 7 years after exposure, 19 of 35 animals died and 13 of those 19 including the 9 most recent mortalities showed pulmonary neoplasia. Many of these cancers were multicentric in origin. The cancers again appeared in conjunction with severe lung injury. Since the natural incidence of the disease is small, it appears that at this level of exposure the induction of lung cancer is almost certain during the normal beagle life span. When the pathological response is this saturated, and the mechanism of induction is not understood, then it is doubtful that one can draw any inference about the response at smaller burdens. The smallest burden (at death) in a dog showing lung cancer was ~0.2 μCi. Presumably this would correspond to a particle burden of about 10^7 particles. Burdens which are smaller by orders of magnitude may still induce a substantial incidence of cancer.

Conclusions

Summing up, intense radiation exposure of mammalian skin and lung tissue commonly results in cancers. Tissue injury and disturbance are a primary consequence of intense radiation insult, and are observed in association with carcinogenesis. Albert has exhibited a simple proportionality between skin carcinomas and atrophied hair follicles. No general description of precarcinogenic injury exists, but in a crude sense the available observations are compatible with the idea of an injury-mediated carcinogenesis. Cancer is a frequent instability of tissue. Since tissue is more than an aggregate of cells, and has a

structural and functional unity of its own, it would not be surprising if some disrupted local integrity, a disturbed ordering, comprises a primary pathway of carcinogenesis. The induction of sarcomas with inert discs of Mylar, cellophane, Teflon and Millipore (Brues et al.[17]) is indicative that such a mechanism exists. Presumably mitotic sterilization is an important factor in any carcinogenesis mediated by radiation-induced tissue injury. The functional relation of this factor to the carcinogenic response may be quite different from a linearity in the surviving mitotic fraction.

While regrettably unquantitative, the hypothesis of an injury-mediated carcinogenesis is suggestively descriptive. If the respiratory zone of the lung contains a structure analogous to the rat hair follicle, and if a radioactive particulate deposited in the respiratory zone has the capacity to disrupt one or more of these structures and create a precancerous lesion, then cancer risks of the order of 10^{-3} to 10^{-4} per particle can be expected for burdens much less than 10^{8} particles.

Bair's work[15,16] does not contradict this. As well as showing a saturated response, his experiment involves particle burdens like 10^{8}, and since this number is comparable with the number of alveoli, it follows that there are many overlapping exposures. In this situation the particles do not necessarily produce isolated effects and the results can not be used to infer a risk per particle applicable at lesser burdens.

For occupational exposure the maximum permissible lung burden (MPLB) of Pu^{238} or Pu^{239} is 0.016 μCi.[18] Assuming a particle diameter of 0.3 μ, this burden is equivalent to 3×10^{6} particles of $Pu^{239}O_2$ or 10^{4} particles of $Pu^{238}O_2$. If there is a possibility of tumorigenic risks of the order of 1/2000 per particle, this raises serious doubts as to the applicability of current MPLB to risk judgments involving particulates. Aside from this question of enhanced risk from disruptive particulates, Bair's observation of a burden of ~0.2 μCi in a dog with lung cancer is precariously close to the presently prescribed MPLB. Experiments at lower particle burdens are crucial to defining the risk from insoluble α-emitting particulates.

References

1. Geesaman, D. P. An analysis of the carcinogenic risk from an insoluble alpha-emitting aerosol deposited in deep respiratory tissue. University of California Lawrence Radiation Laboratory (Livermore), UCRL-50387, 1968.
2. Albert, R. E., F. J. Burns, and R. D. Heimbach. The effect of penetration depth of electron radiation on skin tumor formation in the rat. Radiation Res. 30: 515-524, 1967.
3. Albert, R. E., F. J. Burns, and R. D. Heimbach. Skin damage and tumor formation from grid and sieve patterns of electron and beta radiation in the rat. Radiation Res. 30: 525-540, 1967.
4. Albert, R. E., F. J. Burns, and R. D. Heimbach. The association between chronic radiation damage of the hair follicles and tumor formation in the rat. Radiation Res. 30: 590-599, 1967.
5. Withers, H. R. The dose-survival relationship for irradiation of epithelial cells of mouse skin. Brit. J. Radiol. 40: 187-194, 1967.
6. Hulse, E. V. Tumours of the skin of mice and other delayed effects of external beta irradiation of mice using ^{90}Sr and ^{32}P. Brit. J. Cancer 16: 72-86, 1962.
7. Boag, J. W. and A. Glucksmann. Production of cancers in rats by the local application of β-rays and of chemical carcinogens. In Progress in Radiobiology, J. S. Mitchell, B. E. Holmes, and C. L. Smith, eds. Proceedings of the Fourth International Conference on Radiobiology held in Cambridge, 14-17 August, 1955. Edinburgh, Oliver and Boyd, pp. 476-479, 1956.
8. George, L. A. and L. K. Bustad. Gross effects of beta rays on the skin. Hanford Atomic Products Operation, Biology Research Annual Report for 1956, HW-47500, 135-141, 1957.
9. George, L. A. II, R. L. Pershing, S. Marks, and L. K. Bustad. Cutaneous fibrosarcoma in a rabbit following beta irradiation. Hanford Atomic Products Operation, Biology Research Annual Report for 1959, HW-65500, 68-69, 1960.
10. Ragan, H. A., W. J. Clarke, and L. K. Bustad. Late effects of skin irradiation. Battelle-Northwest Laboratory Annual Report for 1965 in the Biological Sciences, BNWL-280, 13-14, 1966.
11. Karagianes, M. T., E. B. Howard, and J. L. Palotay. Battelle-Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Volume I, Biological Sciences, BNWL-714, 1.10-1.11, 1968.
12. Cember, H. Radiogenic lung cancer. In Progress in Experimental Tumor Research, F. Homburger, ed. New York, Hafner Publishing Company, Inc. 4: 251-303, 1964.

13. Laskin, S., M. Kuschner, N. Nelson, B Altshuler, J. H. Harley, and M. Daniels. Carcinoma of the lung in rats exposed to the β-radiation of intrabronchial ruthenium^{106} pellets. 1. Dose response relationships. J. Natl. Cancer Inst. 31: 219-231, 1963.

14. Altshuler, B. Dosimetry from a Ru^{106}-coated platinum pellet. Radiation Res. 9: 626-632, 1958.

15. Bair, W. J., J. F. Park, and W. J. Clarke. Long-term study of inhaled plutonium in dogs. Battelle Memorial Institute (Richland), AFWL-TR-65-214, 1966 (AD-631 690).

16. Park, J. F., W. J. Clarke, and W. J. Bair. Chronic effects of inhaled $^{239}PuO_2$ in beagles. Battelle-Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Volume I, Biological Sciences, BNWL-714, 3.3-3.4, 1968.

17. Brues, A. M., H. Auerbach, G. M. DeRoche, and D. Grube. Mechanisms of carcinogenesis. Argonne National Laboratory, Biological and Medical Research Division Annual Report for 1967, ANL-7409, 151-155, 1967.

18. Mann, J. R. and A. R. Kirchner. Evaluation of lung burden following acute inhalation exposure to highly insoluble PuO_2. Health Phys. 13: 877-882, 1967.

Distribution

LRL Internal Distribution

Michael M. May	
R. E. Batzel	
G. H. Higgins	
A. R. Tamplin	25
H. A. Tewes	
D. Warner	70
D. P. Geesaman	25
TID Berkeley	
TID File	30

External Distribution

D. E. Abrahamson
University of Minnesota
Minneapolis, Minn.

D. E. Bales
E. D. Harward
U.S. Public Health Service
Rockville, Md.

D. S. Barth
J. McBride
Southwestern Radiological Health Laboratory
Las Vegas, Nev.

R. Brodine (Mrs.)
Scientist and Citizen
St. Louis, Mo.

L. K. Bustad
University of California
Davis, Calif.

K. E. Cowser
T. F. Lomenick
Oak Ridge National Laboratory
Oak Ridge, Tenn.

External Distribution (Continued)

G. M. Dunning
H. H. Hollister
J. S. Kelly
S. A. Lough
J. B. Storer
U. S. Atomic Energy Commission
Washington, D. C.

M. Eisenbud
New York University Medical Center
Tuxedo, N. Y.

E. C. Freiling
U. S. Naval Radiological Defense Laboratory
San Francisco, Calif.

P. F. Gustafson
Argonne National Laboratory
Argonne, Ill.

H. S. Jordan
Los Alamos Scientific Laboratory
Los Alamos, N. Mex.

B. Kahn
Public Health Service
Cincinnati, Ohio

R. O. McClellan
The Lovelace Foundation
Albuquerque, N. Mex.

E. W. Pfeiffer
University of Montana
Missoula, Mont.

R. S. Russell
Agricultural Research Council
Berkshire, England

G. M. Van Dyne
G. Ward
Colorado State University
Fort Collins, Colo.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission.

A Makes any warranty or representation expressed or implied with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights, or

B Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

TID-4500, UC-48, Biology and Medicine 221

Printed in USA. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65.

VE/lh

UNIVERSITY OF CALIFORNIA

Bio-Medical Division
LAWRENCE RADIATION LABORATORY
P.O. BOX 808
LIVERMORE, CALIFORNIA 94550

TELEPHONE (415) 447-1100
TELEX 34-6407 AEC LRL LVMR
TWX 910-386-8339 AEC LRL LVMR

November 26, 1969

Dr. John R. Totter, Director
Division of Biology and Medicine
U. S. Atomic Energy Commission
Washington, D. C.

Dear John:

We wish to continue our efforts for constructive discussions with you and your colleagues concerning the vital matters of Atomic Energy Development and the Public Health and Safety. We have repeatedly indicated our urgent desire to be constructive and to apprise you at the earliest possible time of problems of serious nature that might be in the horizon. My colleague, Don Geesaman and I, have one which we wish to bring to your urgent attention now and it is the subject of this letter.

This problem concerns the biological hazard attendant upon the inhalation of plutonium oxide particles. Our analysis of this problem suggests that these particles may represent a unique carcinogenic risk--that, when the lung exposure occurs as a result of PuO_2 particles, the existing maximum permissible lung burden may be too high by orders of magnitude. If our suspicions are correct, the AEC could be confronted with a situation similar to the uranium miners in the plutonium industry. The enclosed report, UCRL-50387, ADDENDUM, is the basis for the above statements.

Our interest in this problem resulted from being requested to be members of the DBM Committee of Space Nuclear Systems Radiological Safety Matters. As you can see from the enclosed letters to Dr. Bruner, we disagreed with the Committee's conclusions beginning in August 1967. The more we studied the problem the more concerned we became as evidenced by the letter to Dr. Bruner of October 2, 1968. In this letter and the memo to Dr. Gofman we expressed our concern with respect to exposure of workmen in the very vital plutonium industry. We again expressed this concern at a briefing of the AEC Staff in Germantown on October 25, 1968 (copy enclosed).

We are calling this problem to your attention at this time because it appears that it will soon become a subject of public debate. As a result of the fire at Rocky Flats, Dr. E. A. Martell has been conducting an environmental survey to determine the levels of Pu-239 in the Colorado area. As we understand it, he will probably be releasing his results in December. His results will show evidence of contamination from the Rocky Flats plant. Our impression is that he will at that time raise the question of permissible exposure.

It is important to note that there is no official guidance concerning exposure to these hot-particles. ICRP publication #9, page 4, paragraph 20 states, "In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung."

Dr. John Totter November 26, 1969

Now, quite obviously, we do not feel that the Division of Biology and Medicine can adequately support the position taken by the Committee on Space Radiological Safety. Hopefully, the scientific community-at-large will be more receptive to their arguments but we doubt it. At any rate, we felt that we should call this problem to your attention.

Sincerely yours,

Arthur R. Tamplin
Bio-Medical Division

Donald P. Geesaman
Bio-Medical Division

ART:ml

Encls. as stated

cc: Dr. Seaborg

"PLUTONIUM AND PUBLIC HEALTH"

(A talk given at the University of Colorado on April 19, 1970.)

(Printed with references added in Underground Uses of Nuclear Energy, Part 2, Hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works, United States Senate, August 5, 1970.)

(Printed with Author's Note added in Electric Power Consumption and Human Welfare, AAAS Committee on Environmental Alterations, August 11, 1974.)

(To be published in Energy and the Environmental Crunch, eds. Firebaugh, et. al., Oxford University Press,* 1975; and in Energy and Human Welfare, eds. Commoner, et. al., Macmillan Publishing Company, 1975.)

Donald P. Geesaman
School of Public Affairs
University of Minnesota
Minneapolis, Minnesota

* copyright

PLUTONIUM AND PUBLIC HEALTH

Donald P. Geesaman

Author's Note--June 1972.

On May 11, 1969 a major fire occurred at the large Rocky Flats plutonium facility located northwest of Denver, Colorado, and operated for the AEC by the Dow Chemical Company. For description of this fire see AEC press releases M-121, May 20, 1969, and M-257, November 18, 1969.

Consequent to this fire E.A. Martell and S.E. Poet conducted a pilot study on the plutonium contamination of surface soils in the Rocky Flats environs. Their results suggested an off site contamination that was orders of magnitude larger than that which would have been expected from the measured plutonium releases in the air effluent of the facility.

In a letter of January 13, 1970 to Glenn Seaborg, then chairman of the AEC, and in a press release of February 24, 1970 by the Colorado Committee on Environmental Information, Martell et al. called attention to this anomalous contamination and expressed concern over its uncertain origin and over its significance to public health. In response the AEC fixed the probable origin of the off site contamination as wind dispersal of plutonium leaking from rusted barrels of contaminated cutting oil, and denied that cause existed for concern over hazards to public health (see AEC press release N-22, February 18, 1970).

It was my conviction that the AEC response provided a distorted

and inadequate representation of the possible hazards associated with the observed off site contamination, and that the imminent large-scale commercial introduction of plutonium gave this situation a precedential significance much greater than the already considerable significance of the situation itself.

In April 1970 a representative of the AEC's Division of Biology and Medicine and myself were invited to present our views at the University of Colorado. "Plutonium and Public Health" derives from the preceding history and should be so interpreted. The presentation was to a lay audience and was made with that expectation. Adequate referencing was added to the written text prior to its inclusion in Underground Uses of Nuclear Energ Part 2, Hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works United States Senate, August 5, 1970.

As it stands the paper still represents a legitimate critique, and the recent emphasis on plutonium as a major energy source increases the relevance of the discussion. An updating would involve only incremental changes, and would generally supplement rather than disturb the substantiv arguments of the original paper. Hence while such an updating is desirable it is also of sufficient marginal value that it can be properly deferred at my discretion.

For those who are interested in reading the traditional AEC position on the subject I would suggest "Appendix 24 - Safety Considerations in the Operations of the Rocky Flats Plutonium Processing Plant", from AEC Authorizing Legislation Fiscal Year 1971 - Hearings before the Joint

Committee on Atomic Energy, Part 4, March 19, 1970.

Times have changed since May 1969. Then plutonium was regarded as a military substance and was accordingly given little public attention. Now it is much publicized as the energy source of the not too distant future. April 1970 was a time of transition, and I felt the strong presence of the earlier tradition, and the decision to speak was not an easy one for me. I have had no regrets.

D. P. G.

Plutonium and Public Health

For the sake of completeness let me give you some background on plutonium. It is an element that is virtually non-existent in the earth's natural crust. In the early 1940's it was first produced and isolated by Dr. Seaborg and colleagues; --Dr. Seaborg is presently Chairman of the Atomic Energy Commission. Plutonium has several isotopes, the most important being plutonium-239, which, because of its fissionable properties and its ease of production, is potentially the best of the three fission fuels. That is why it is of interest. Aside from its fissionable properties, plutonium-239 is a radioactive isotope of relatively long half-life (24,000 years), hence its radioactivity is undiminished within human time scales. When it decays, it emits a helium nucleus of substantial energy. Because of its physical characteristics, a helium nucleus interacts strongly with the material along its path; and as a consequence deposits its energy in a relatively short distance, --about four-hundredths of a millimeter in solid tissue. For comparison, a typical cell dimension is about 1/4 to

1/10 of that. A cell whose nucleus is intercepted by the path of such a particle suffers sufficient injury that its capacity for cell division is usually lost (Bar endson, A.W., 1962 and Bloom, W., 1959).

The cancer inducing potential of plutonium is well known. One millionth of a gram injected intradermally in mice has caused cancer (Lisco, H., et al., 1947); a similar amount injected into the blood system of dogs has induced a substantial incidence of bone cancer (Mays, C.W., et al., 1947), because of plutonium's tendency to seek bone tissue. Fortunately the body maintains a relatively effective barrier against the entry of plutonium into the blood system. Also, bedause of the short range of the emitted helium nuclei, the radiation from plutonium deposited on the surface of human skin does not usually reach any relevant tissue. Unfortunately the lung is more vulnerable.

Before I describe why this is, I'd like to say something about the characteristics of an aerosol. An aerosol is physically like cigarette smoke, or fog, or cement dust. Because of their small size, the particles comprising an aerosol remain suspended in air for long periods of time. If an aerosol is inhaled, then, depending on its physical characteristics, it may be deposited at different sites in the respiratory tree (Health Physics, 1966). Larger aerosol sizes are usually removed by turbulence in the nose particles deposited in the bronchial tree are cleared upward in hours by the ciliated mucus blanket that covers the structure. This clearance system does not penetrate into the deep respiratory structures, the alveoli, where the basic oxygen-carbon dioxide exchange of the lung takes place. Smaller

particles tend to be deposited here by gravitational settling, and if they are insoluble they may reside in the alveoli for a considerable time. The problem is that, under a number of conditions (Anderson, B.V., et al., 1967; Fraser, D.C., 1967; Kirchner, R.A., 1966; Mann, J.R., et al., 1967; Stewart, K., 1963; Wilson, R.H. et al., 1967) plutonium tends to form aerosols of a size that are preferentially deposited in deep lung tissue. Plutonium dioxide, which is a principal offender, is insoluble and may be immobilized in the lung for hundreds of days before being cleared to the throat or to the lymph nodes around the lungs (Health Physics, 1966).

An aerosol is comprised of particles of many different sizes, and their radioactivity may differ by factors of thousands or even more. I will simplify the argument and say that there is a class of these particles, the largest ones deposited in the deep lung tissue, that can be expected to have a different potential of cancer induction than the particles of the smaller class. This is because they are sufficiently radioactive to disrupt cell populations in the volume of cell tissue which they expose (Geesaman, D.P., 1968a). An example might be a particle that emits 5000 helium nuclei per day. It would subject between 1 and 20 alveoli to intense radiation, sufficient to inflict substantial cell death and tissue disruption. For reference, the alveoli are the basic structural units of the deep lung. They are shaped and bunched roughly like hollow grapes 0.3 millimeter in diameter. Their walls are thin, a few thousandths of a millimeter, and they are a highly structured tissue with many cell types. Intense exposure of local tissue by a radioactive particle is referred to as the hot

particle problem. The question is: does such a particle have an enhanced potential for cancer? No one knows. One can argue that cancer cannot evolve from dead cells, hence a depleted cell population must be less carcinogenic. This is believeable, and must be true on occasion. The facts are, though, that intense, local doses of radiation are extremely effective carcinogens, much more so than if the energy were averaged over a larger tissue mass (Geesaman, D.P., 1968b). Furthermore, this can take place at high doses of radiation where only one cell in ten thousand has retained its capacity to divide. The cancer susceptibility of lung tissue to radiation has been demonstrated in many species; one can say in general that the lung is more susceptible to inhomogeneous exposures from particles and implants than it is to diffuse uniform radiation. Some very careful skin experiments of Dr. Albert have indicated that tissue disruption is a very likely pathway of radioactive induction of cancer after intense exposure (Albert, R.E., et al., 1967a, 1967b, 1967c, 1969). The experiments show that the most severe tissue injury is not necessary, nor even optimal, for the induction of cancer. When these notions are applied to a hot particle in the lung, the possibility of one cancer from 10,000 disruptive particles is realistic. This is disturbing because an appreciable portion of the total radioactivity in a plutonium aerosol is usually in the large particle component.

Let me demonstrate what I mean. Suppose a man received a maximum permissible lung burden for plutonium, and suppose roughly 10% of the mass of the burden was associated with the most active class

of particles deposited (that is those emitting several thousand helium nuclei per day). This is reasonable. There would be something like a thousand of these particles and each would chronically expose 1 to 20 alveoli to intense radiation. If the risk of cancer is like 1 in 10,000 for one disruptive particle, then the total risk in this situation is one in ten, i.e., one man in ten would develop lung cancer.

Put another way, about 1 cubic centimeter of the lung is receiving high doses of radiation. It would not be surprising if intense exposure of such a localized volume led to a cancer one time in ten. The question is: if the individual volumes are separated from each other, is substantial protection afforded? No one knows. It is much easier to find two cancers using 50 exposures of 1 cubic centimeter each, than it is to find a couple of cancers in 50,000 single particle exposures. Certainly the length scales of injury are long enough that a disruptive carcinogenic pathway cannot be disregarded for isolated hot particles (Geesaman, D.P., 1968b).

One can look to the relevant experience for reassurance. In an experiment done at Hanford by Dr. Bair and his colleagues, beagle dogs were given $Pu^{239}O_2$ lung burdens of a few hundred thousandths of a gram (Bair, W.J., et al., 1966; Ross, D.M., 1967). At 9 years post exposure, or after roughly half of an adult beagle life span, 22 of 24 deaths involved lung cancer, usually of multiple origin. Five dogs remain alive. For comparison, these exposures are about 100 times larger than the present maximum permissible burdens in man.

There are two unsatisfactory aspects of this experiment. First,

because all of the dogs are developing cancer, it is impossible to infer what would happen at lower exposures; simple proportionality does, however, suggest that present human standards are too lax by at least a factor of ten. Second, because the radiation dose is large, with tissue injury almost killing the dogs; and because large numbers of particles are involved, often acting in conjunction; it is improbable that the risk from disruptive particle can be inferred. And after all, this is what we need to know, since almost all human exposures will involve hot particles acting independently, and if there is a risk from these particles, it will be additive throughout the population; --there will be no question of a threshold burden; and there will be a possibility that a man with an undetectable burden of a few particles will develop a cancer as a consequence. For the exposures of concern, 1000 people with 100 disruptive particles each will suffer as many total cancers as 10,000 people with 10 particles each, or as 100 people with 1000 particles each.

Human experience does not give us the answer either. Plutonium has been around for 25 years, and people have been exposed. In 1964 through 1966 contractors indicated an average total of 21 people per year with over 25% of a maximum permissible burden of plutonium (Ross, D.M., 1968) Three out of four of these exposures derived from inhalation. To be reasonably useful, the documentation of exposure must go back more than 15 years, because of the latent period for radiation induced cancer. In recent years documentation has improved greatly, but from early days there is pitifully little of relevance to the hot particle problem in the lung.

Since I have mentioned maximum permissible lung burdens, you are aware that there is official guidance. I would like to comment on it. The maximum permissible lung burden is established by equilibrating the exposure from the deposited radioactive aerosol with that of an acceptable uniform dose of x-rays. The International Commission on Radiological Protection indicates this may be greatly in error, and specifically states in its publication 9, "In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung." (ICRP, 1966). They are effectively saying that there is no guidance as to the risk for non-homogeneous exposure in the lung, hence the maximum permissible lung burden is meaningless for plutonium particles, as are the maximum permissible air concentrations which derive from it.

So there is a hot particle problem with plutonium in the lung, and the hot particle problem is not understood, and there is no guidance as to the risk. I don't think there is any controversy about that. Let me quote to you from Dr. K. Z. Morgan's testimony in January of this year before the Joint Committee on Atomic Energy, U.S. Congress (Morgan, K.Z., 1960). Dr. K.Z. Morgan is one of the United States' two members to the main Committee of the International Commission on Radiological Protection; he has been a member of the committee longer than anyone and he is director of Health Physics Division at Oak Ridge National Laboratory. I quote: "There are many things about radiation exposure we do not

understand, and there will continue to be uncertainties until health physics can provide a coherent theory of radiation damage. This is why some of the basic research studies of the USAEC are so important. D. P. Geesaman and Tamplin have pointed out recently the problems of plutonium-239 particles and the uncertainty of the risk to a man who carries such a particle of high specific activity in his lungs." At the same hearing, in response to the committee's inquiry about priorities in basic research on the biological effects of radiation, Dr. M. Eisenbud, then Director of the New York City Environmental Protection Administration, in part replied, "For some reason or other the particle problem has not come upon us in quite a little while, but it probably will one of these days. We are not much further along on the basic question of whether a given amount of energy delivered to a progressively smaller and smaller volume of tissue is better or worse for the recipient. This is another way of asking the question of how you calculate the dose when you inhale a single particle." (Eisenbud, M., 1970 He was correct; the problem has come up again.

In the context of his comment it is interesting to refer to the National Academy of Sciences, National Research Council report of 1961 on the Effects of Inhaled Radioactive Particles (U.S. NAS.NRC.1961). The first sentence reads, "The potential hazard due to airborne radioactiv particulates is probably the least understood of the hazards associated with atomic weapons tests, production of radioelements, and the expanding use of nuclear energy for power production." A decade later that statement is still valid. Finally let me quote Drs. Sanders, Thompson, and

Bair from a paper given by them last October (Sanders, C. L., 1970). Dr. Bair and his colleagues have done the most relevant plutonium oxide inhalation experiments. "Nonuniform irradiation of the lung from deposited radioactive particulates is clearly more carcinogenic than uniform exposure (on a total-lung dose basis), and alpha-irradiation is more carcinogenic than beta-irradiation. The doses required for a substantial tumor incidence, are very high, however, if measured in proximity to the particle; and, again, there are no data to establish the low-incidence end of a dose-effect curve. And there is no general theory, or data on which to base a theory, which would permit extrapolation of the high incidence portion of the curve into the low incidence region." I agree and I suggest that in such a circumstance it is appropriate to view the standards with extreme caution.

There is another hazardous aspect of the particulate problem in which substantial uncertainty exists. In case of an aerosol depositing on a surface, the material may be resuspended in the air. This process is crudely described by a quantity called a resuspension factor which is remarkable in that it seems generally known only to within a factor of billions (Kathren, R. L. 1968). Undoubtedly it can be pinpointed somewhat better than this for plutonium oxide, but the handiest way to dispatch the problem is to say there is some evidence that plutonium particles become attached to larger particles and are therefore no longer potential aerosols. Unfortunately there is also evidence that large particles generate aerodynamic turbulence, and are hence blown about more readily, and on

being redeposited tend to knock small particles free. In relation to this, I'd like to give you a little subjective feeling for the hazard. There is no official guidance on surface contamination by plutonium. Two years ago, in an effort to determine some indication of the opinions of knowledgeable persons with respect to environmental contamination by plutonium, a brief questionaire was administered to 38 selected LRL employees (Kathren, R.L., private communication). All were persons who were well acquainted with the hazards of plutonium. The group consisted of 16 Hazards Control personnel, primarily health physicists and senior radiation monitors. The remainder were professional personnel from Biomedical Division, Chemistry, and Military Applications, who had extensive experience with plutoniun I had nothing to do with the survey, nor was I one of the members who was queried. The conjectured situation was that their neighborhood had been contaminated by plutonium oxide to levels of 0.4 microcuries per square meter. For reference, this value is roughly ten times the highest concentration Dr. Martell found east of the Rocky Flast Dow Chemical facility (Martell, E.A., 1970), --and bear in mind that a factor of ten is a small difference relative to the large uncertainties associated with the hazards from plutonium contamination. Several questions were asked. One was, would you allow your children to play in it? 86% said No. Should these levels be decontaminated? 89% said Yes. And to what level should the area be cleaned? 50% said to background, zero, minimum, or by a reduction of at least a factor of 40. This has no profound scientific significance, but indicates that many people conversant of the hazard are not

blase about the levels of contamination encountered east of Rocky Flats.

Finally I would like to describe the problem in a larger context. By the year 2000, plutonium-239 has been conjectured to be a major energy source. Commercial production is projected at 30 tons per year by 1980, in excess of 100 tons per year by 2000. Plutonium contamination is not an academic question. Unless fusion reactor feasibility is demonstrated in the near future, the commitment will be made to liquid metal fast breeder reactors fueled by plutonium. Since fusion reactors are presently speculative, the decision for liquid metal fast breeders should be anticipated and plutonium should be considered as a major pollutant of remarkable toxicity and persistence. Considering the enormous economic inertia involved in the commitment it is imperative that public health aspects be carefully and honestly defined prior to active promotion of the industry. To live sanely with plutonium one must appreciate the potential magnitude of the risk, and be able to monitor against all significant hazards.

An indeterminate amount of plutonium has gone off site at a major facility 10 miles upwind from a metropolitan area. The loss was unnoticed. The origin is somewhat speculative as is the ultimate deposition.

The health and safety of public and workers are protected by a set of standards for plutonium acknowledged to be meaningless.

Such things make a travesty of public health, and raise serious questions about a hurried acceptance of nuclear energy.

References

Albert, R.E., F.J. Burns, and R.D. Heimbach, 1967. The effect of penetration depth of electron radiation on skin tumor formation in the rat. Radiation Res. 30: 515-524, 1967a.

_____. Skin damage and tumor formation from grid and sieve patterns of electron and beta radiation in the rat. Radiation Res. 30: 525-540, 1967b.

_____. The association between chronic radiation damage of the hair follicles and tumor formation in the rat. Radiation Res. 30: 590-599, 1967c.

_____, 1969. An evaluation by alpha-particle Bragg peak radiation of the critical depth in the rat skin for tumor induction. Radiation Res. 39: 332-344, 1969.

Anderson, B.V., and I.C. Nelson, 1967. Plutonium air concentrations and particle size relationship in Hanford facilities. BNWL-495, December 1967.

Bair, W.J., J.F. Park, and W.J. Clarke, 1966. Long-term study of inhaled plutonium in dogs. Battelle Memorial Institute Technical Report, AFWL-TR-65-214.

Barendson, G.W., 1962. Dose-survival curves of human cells in tissue culture irradiated with alpha-, beta-, 20-kV x- and 200-kV x-radiation. Nature 193: 1153-1155, 1962.

Bloom, W., 1959. Cellular responses. Rev. Modern Phys. 31: 21-29, 1959

Eisenbud, M. Panel discussion, 1970. In Environmental Effects of Produc Electrical Power, Phase 2. Testimony presented at Hearings before the Joint Committee on Atomic Energy, 91st Cong., 1970. Washington, D.C., U.S. Gov't. Print. Off. (To be published).

Fraser, D.C., 1967. Health physics problems associated with the production of experimental reactor fuels containing PuO_2. Health Phys. 13: 1133-1143, 1967.

Geesaman, D.P., 1968a. An analysis of the carcinogenic risk from an insoluble alpha-emitting aerosol deposited in deep respiratory tissue. University of California Radiation Laboratory, Livermore, UCRL-50387.

_____, 1968b. An analysis of the carcinogenic risk from an insoluble alpha-emitting aerosol deposited in deep respiratory tissue; Addendum, University of California Radiation Laboratory, Livermore, UCRL-50387, Addendum.

Health Phys., 1966. Task Group--Chairman, Paul E. Morrow, Deposition and retention models for internal dosimetry of the human respiratory tract, 12: 173-207.

ICRP, 1966. Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1965), ICRP Publication 9. Oxford, Pergamon Press. ICRP-PUBL-9, 1966.

Kathren, R.L., 1968. Towards interim acceptable surface contamination levels for environmental PuO_2.BNWL-SA-1510.

_____. Battelle Northwest (private communication).

Kirchner, R.A., 1966. A plutonium particle size study in production areas at Rocky Flats. Am. Ind. Hygiene Assoc. J. 27: 396-401, 1966.

Lisco, H., M.P. Finkel, and A.M. Brues, 1947. Carcinogenic properties of radioactive fission products and of plutonium. Radiology 49: 361-363.

Mann, J.R., and R.A. Kirchner. Evaluation of lung burden following acute inhalation exposure to highly insoluble PuO_2. Health Phys. 13: 877-882, 1967.

Martell, E.A., P.D. Goldan, J.J. Kraushaar, D.W. Shea, and R.H. Williams, 1970. Report on the Dow Rocky Flats fire: Implications of plutonium releases to the public health and safety. Colorado Committee for Environmental Information, Subcommittee on Rocky Flats, Boulder, Colorado, January 13, 1970. (Personal communication to Dr. Glenn T. Seaborg, Chairman, Atomic Energy Commission).

Mays, C.W., et al., 1969. Radiation-induced bone cancer in beagles. In Mays, et al., (eds.), Delayed Effects of Bone-Seeking Radionuclides. Salt Lake City, University of Utah Press.

Morgan, K.Z., Radiation standards for reactor siting. In Environmental Effects of Producing Electrical Power, Phase 2. Testimony presented at Hearings before the Joint Committee on Atomic Energy, 91st Cong., 1970. Washington, D.C., U.S. Gov't. Print. Off. (To be published).

Park, J.F., et al., 1970. Chronic effects of inhaled $^{239}PuO_2$ in beagles. BNWL-1050, Part 1: 3.3-3.5.

Ross, D.M. 1968. A statistical summary of United States Atomic Energy Commission contractors' internal exposure experience, 1957-1966. In Kornberg, H.A., and W.D. Norwood (eds.), Diagnosis and Treatment of Deposited Radionuclides. Proceedings of a Symposium held at Richland, Washington, 15-17 May 1967. N.Y., Excerpta Medica Foundation, 1968. pp. 427-434. (CONF-670521).

Sanders, C.L., R.C. Thompson, and W.J. Bair, 1970. Lung cancer: Dose response studies with radionuclides. In Inhalation Carcinogensis. Proceedings of a Biology Division, Oak Ridge National Laboratory, conference held in Gatlinburg, Tennessee, October 8-11, 1969. M.G. Hanna, Jr., P. Nettesheim, and J.R. Gilbert, (eds.) U.S. Atomic Energy Commission Symposium Series 18, 1970. pp. 285-303, (CONF-691001).

Stewart, K., 1963. The particulate material formed by the oxidation of plutonium. In Technology, Engineering and Safety, C. Nichols, (ed.) New York, The Macmillan Company 5: 535-579, 1963.

U.S. NAS-NRC-SUBCOMM, 1961. Effects of Inhaled Radioactive Particles. Report of the Subcommittee on Inhalation Hazards. Committee on Pathologic Effects of Atomic Radiation. National Academy of Sciences-National Research Council, Washington, D.C., Publication 848. NAS-NRC/PUB-848, 1961.

Wilson, R.H., and J.L. Terry, 1967. Biological studies associated with a field release of plutonium. In Inhaled Particles and Vapours II, C. Davies, (ed.) Oxford, Pergamon Press, 273-290, 1967.

UNIVERSITY OF CALIFORNIA

APPENDIX V

RENCE RADIATION LABORATORY
BOX 808
ERMORE, CALIFORNIA 94550

TELEPHONE (415) 447-1100
TELEX 34-6407 AEC LRL LVMR
TWX 910-386-8339 AEC LRL LVMR

July 8, 1971

Dr. Stanley N. Greenfield
Assistant Director
Environmental Protection Agency
5600 Fishers Lane
Rockville, Maryland 20852

Re: AEC's Draft Environmental Statement, Rocky Flats Plant
Plutonium Recovery Facility

Dear Doctor Greenfield:

By copy of his letter to you dated May 27, 1971, Dr. E. A. Martell invited my comment on the AEC's Draft Environmental Statement, Rocky Flats Plutonium Recovery Facility, April 1971. In response, I am submitting the following remarks for consideration in your review of that draft environmental statement.

A general comment: Plutonium is being projected as the primary energy source of the not-too-distant future. The gravity of this circumstance makes it appropriate that any environmental statement concerned with plutonium should give an informative representation of the associated hazards and uncertainties. The draft of April 1971 does not satisfy this criterion.

More specifically, the exposition in paragraph 4 of Section 2.0 is an inadequate and unrepresentative description of the uncertainties in human risk attendant to exposure by plutonium aerosols. Human lung tissue has a well known carcinogenic potential under a number of situations, including radiation exposure; the Hanford beagle study demonstrates induction of lung cancer by plutonium aerosols. These are sufficient basis to establish plutonium induced lung cancer as a legitimate concern for humans. Judged in this context the negative results of the cited mouse study have little public health relevance. In addition, it requires pathological optimism to find reassurance in the results of the Hanford beagle experiment. Dogs were given aerosol burdens of ~1-10 microcuries of $Pu^{239}O_2$. At nine years post exposure the lung cancer response was virtually saturated and multicentric origin were noted in some dogs. A correlation observed between initia burden and time to cancer death was used to infer the limit burden for no life shortening that was mentioned in the draft statement. The exclusive interpretation of this crude correlation to mean a practical threshhold of burden is no more than a promotional indulgence. The observations do not necessarily imply that a practical threshhold exists below which no plutonium induced cancer will occur. Moreover, the range of exposures above the inferred limit burden may in fact, be interpreted as a region of saturated response, that is a burden regime in which cancer induction in a population approaches 100% during a normal life span. The point here is that the time

382

to death may be related to the burden through population depletion, rather than through the latent period. In the former case, appreciable cancer incidence would be anticipated at lower burdens. To summarize a specivic concern with the plutonium problem: 1) under a number of probable circumstances plutonium forms aeorsols; 2) the physical character of these aerosols is such that on inhalation by humans they are preferentially deposited in the deep respiratory tissue; 3) becaus of slow clearance and because of the insolubility of the aerosol, parti deposited in this tissue may experience long residence times (hundreds of days); 4) an appreciable mass fraction of the aerosol is associated with particles sufficiently large that significant ($\geq$1 alveolus) volumes of lung tissue will be exposed to intense radiation exposure ($\geq$1000 rem) within a meaningful physiological time; 5) studies of the effects of intense local radiation (Albert, Hulse (skin), Maldague (kidney), deposition hotspots in bone seeking alpha emitters) suggest that despite the near mitotic sterilization of the involved tissue an enhanced carcinogenic potential may exist, in the sense that energy dissipated in a limited volume may be far more carcinogenic than if the same radiation were to dissipate its energy over a larger volume. The question is then do the larger particulates in a plutonium aerosol lead to associated alveolar exposures that have enhanced carcinogenic potential. If they do, then present standards can be in error by 2-3 orders of magnitude. Notice that the emphasis here is on the anomalous risk that may be associated with a single particle; and that if any threshold is relevant, it is not the dose threshold since local exposure are large, but rather a structural or volumetric threshold that must be exceeded by the physical extent of the exposure; and finally that this is a very special case of the low exposure problem, a case that is peculiar to plutonium as an insoluble aerosol-forming, long lived alpha-emitter.

In relation to the preceding, the Hanford beagle study ($\sim$1-10 microcuri initial lung burden) showed cancers appearing in conjunction with radiat induced lesions. In addition, a dog having substantially less burden was prematurely sacrificed and no lesions or cencers were found. It would, however, be precarious to infer that absence of lesions implies no carcinogenic potential, or equivalently that radiation induced lesions are a necessary condition for high dose carcinogenesis. This point is illustrated by Albert's rat skin experiment, where carcinogenes: was optimal in a pre-ulcerative regime of less drastic radiation injury.

(I enclosed UCRL-50387 and GT-121 as sources of supplementary discussion.

It would be useful to have a formal documentation of past plutonium experience for humans, in order to judge the extent to which that experie can be used to quantify the hazards of plutonium. In the past 2 years the AEC has established a plutonium registry at Hanford. If any currentl useful documentation is available from the registry, I am unaware of it.

Dr. Langham at LASL has for some 25 years followed 12 humans with burdens in excess of a MPL. It is my impression, perhaps erroneous, that these burdens largely derive from exposures experienced in a waste recovery area where the plutonium aerosol was in fact a dilute solution. If this is the case the relevance of this documentation to particulate exposure would be speculative.

Independent of the biological questions, there are substantial and significant uncertainties associated with the resuspension of plutonium surface contamination. The subject receives essentially no comment in the draft statement. In the case of accidental release of plutonium with consequent contamination of an uncontrolled area, resuspension phenomena along with carcinogenic injury will determine the hazard to inhabitants of the area. Uncertainties in these two factors will be important in the public determination of an acceptable level of surface contamination, especially in the absence of official guidance for this latter quantity. The acceptable level of contamination will in turn determine the costs of cleanup of property and long term displacement of people. I suggest that Dr. Martell is more competent than myself to discuss the physical basis of this topic.

By conjecturing essentially no releases and a substantial safety factor in present standards, the draft statement makes the facility appear unrealistically benign. I believe that it would be appropriate if the potential environmental impact were given realization by one or by both of the following examples.

1) By conjecturing an accident release, and using present knowledge of distribution, resuspension, deposition and lung cancer risks to estimate the magnitudes and uncertainties of the hazards to which contiguous Denver could be exposed. Something of this sort is done in "Theoretical Possibilities and Consequences of Major Accidents in U^{233} and Pu^{239} Fuel Fabrication and Radioisotope Processing Plants" ORNL-3441 (see attached excerpt); and the techniques of that study could be extended and refined for the specific case of the proposed Plutonium Recovery Facility. The study should be developed to the point of roughly estimating extent of human injury, scales of evacuation, costs of clean up and evacuation as a function of plutonium exposure standards and ground contamination criteria. Even though contamination from the May '69 fire at Rocky Flats was apparently contained, the magnitude of the fire was sufficient to demonstrate that a major release from such an occurrence was conceivable and hence should be considered.

2) By discussing the environmental implications, past and future, of the previous operating history of the Rocky Flats facility. In effect, this would mean considering the implications of the anomalous off site contamination discovered by Dr. Martell in 1969, since this total contamination was some orders of magnitude larger than the plutonium released in the plant's integrated air and water effluent. For this analysis, resuspensions would be related to an on site source of contamination. Uncertainties in associated human exposures and in the implications of these exposures would be described. Significance of future resuspension would also be defined. Such an evaluation would give a pragmatic measure of the level of environmental protection afforded by the facility in the past, as well as a sense of proportion for the hazard inherent in a plutonium handling facility.

I would appreciate hearing how the EPA chooses to deal with this environmental statement. If I can be of service to your organization, I will cooperate in any way that I can.

Sincerely yours,

Donald Geesaman

DG;dlp

cc: Dr. E. A. Martell NCAR Enc: UCRL-50387, GT-121, ORNL-3441 excerpt

Thank you for the opportunity to present this testimony.

Chairman Mills: Well I am sure you can appreciate the fact that there is a great deal of material and it is very difficult without a written speech to really delve into the depth of it.

Mr. Geesaman: As I say, I will have a written statement for you.

Chairman Mills: I have just a few questions for you, Professor Geesaman. In the addendum to the report that you referred to, you made reference to the fact that the risk for particles is more than $1x10^{-3}$, $1x10^{-4}$, is this correct? Correct me wherever I am wrong.

Mr. Geesaman: No, what I said was you could infer that it could be as large as. You see what I am tying it to is the finding of a resonance. That was the whole logic behind what I did in my approach. First I looked at the complexity of the situation, and said in that complexity do we have to worry about possibilities of what, in physical terms, you would call a resonance, an anomalous response, and then I looked at the Albert experiment and in there I found an anomalous response. I said as large as. I did not say --

Chairman Mills: Okay, then you go on to state that for less than 10^8 particles, is that correct?

Mr. Geesaman: Yes, because that scales to the number of alveoli, and I wanted to avoid the argument about aggregation, and because from a public health point of view what I

thought was of interest was burdens at that level where many people would have a few particles, or a chap might have a 10 or 100 picocurie burden typically.

Chairman Mills: From that, am I correct in understanding that Dr. Tamplin has used 10^3 - 10^4 as a cancer risk for particles?

Mr. Geesaman: Yes, I think that is accurate to say that. I think, in effect, he has tied it to that resonance of cancer production at the level of 10^4 to 10^5 ergs which is an unorthodox way of looking at it, but I do not think an inaccurate way of looking at it because it ties to the ultimate underlying physical quantity, the energy.

Chairman Mills: But, he did not go on and specify for a number of particles of less than 10^8, as I recall, which would have a different implication?

Mr. Geesaman: I cannot speak to that issue. I apologize for my ignorance.

Chairman Mills: Are there experiments that you know of that have been conducted in which you could test the theory that you propose, other than the Albert experiment?

Mr. Geesaman: No, I would say that the Richmond experiment was beautifully conceived, the one done by Richmond and Anderson at Los Alamos. The results are reassuring, if you can find security in not understanding things. I am bothered by that experiment because they do not see any lesions at

those levels of dosage. It is a well-conceived experiment. There are some very peculiar things about it. It is an experiment that is enormously reassuring for Syrian hamsters who have 10^3 microcuries -- no, 10^3 microspheres injected into such and such an artery and which then hang up in the capillary matrix of the lung. As I stated, I consider the results of that experiment to be very significant. I do not know what they mean, and you probably know much better than I what they mean, but to me they are anomalous because some of those particles are hot and the experimenters see nothing, and you know that that tissue is not normal tissue any longer, -- the contiguous tissue that is. It raises the whole question about what the nature of the appropriate time scale in the definition of a hot particle might be. It raises questions about whether the functional integrity of the lung is maintained, and are cells proliferating in there. I do not think they see any evidence of cell proliferation at all or cell death. It would appear that the tissue maintained a static profile under those exposure limits, which is a remarkable thing, and it raises a question that maybe hot particles have to be somewhat hotter.

Chairman Mills: Let me ask you the question from the standpoint of, did you see any possibility of testing your theory in the radium dial painters?

Mr. Gessaman: Dial --

Chairman Mills: Dial painters.

Mr. Geesaman: I am stone deaf in one ear.

Chairman Mills: Dial painters, that is the population of radium dial painters which is rather extensive and which aggregates --

Mr. Geesaman: I guess what I would say, and I cannot speak to that very explicitly, I looked at the hot-spot literature for bones many years ago, and then I could not draw a conclusion. But, I think there may be information in that literature. But, again, the length scale is different, -- the lung has this property, at least for the length scale for the range of an alpha particle, that it exhibits a density of like one-eighth. So, you have an extended region of exposure. It extends the range essentially a factor of 10 because the density is less.

Chairman Mills: Are there any other questions by the Panel? Dr. Morgan?

Dr. Morgan: Professor Geesaman, I would like to compliment you for a scholarly, thought-provoking presentation, review and interpretation of the literature. I do have a question about your use of the phrase "resonance incarcinogenesis." I usually associate resonance with frequency. Do you mean simply a mark at, say, 10^4 or 10^5 ergs, or are you relating it to the mitotic cycle?

Mr. Geesaman: I am sorry, this goes back to my history

in plasma physics. I consider a resonance to be a region, where the response function is large. It could be, as in the case I am thinking of, that it may depend upon more than just one or two parameters. But, it is a region where the carcinogenic response function is anomalously large. That is how I used the phrase.

Dr. Morgan: It is not related to the mitotic cycle on the --

Mr. Geesaman: There is no frequency associated with it.

Dr. Snyder: I note that you have, I take it, tried to analyze some of the experimental data. Now, admittedly one will not know the particle size distribution very accurately, but at least some approximate form of it might be known. Generally, they say it is log normally distributed. Have you tried to analyze the data, say, of Bair's experiments or others of that kind in terms of this concept to see whether you, in fact, do arrive at a number of carcinogents per particle, and does it hang together, you see? To me, it would seem likely that this would be related to the amount of activity in the particle.

Mr. Geesaman: Well, I would say, yes, it would be tied to the amount of activity, and the definition would depend essentially on some space time conditions that you specify. I have tried to do that. With the Bair experiment, the

number of particles are large enough that you immediately have to start talking about aggregates and how aggregates would affect the argument. How does the response scale with surface effect, and how would inhomogeneous and homogeneous exposures compare, where homogeneous means homogeneous distribution of particles, and you can go through all kinds of geometric arguments about that, but it is not very rewarding. It just shows that from this experiment, you cannot get a particle response coefficient.

More interesting -- I thought what you were asking related to the critical group of exposed people at Los Alamos that had been followed since 1945 and '46, (and I should say that I just got yesterday something from Dr. Richmond that discusses that again, and which I have not read carefully, and so my comments relate to what I have read before). What bothers me in the discussions there is the justification for the inclusion in the hot particle analysis of the 12 or 14 people who were exposed in a plutonium recovery area in which it does not seem to be clear what the nature of the exposure was, whether it was to the plutonyl nitrate to which the hydrogen peroxide was being added with the formation of fog, an actual solute fog, or whether there were low concentration plutonium solutions present that were also fogging when ammonia hydroxide were added. If one used the best guess size and activity

distribution of particles associated with each distinct exposure situation, I think it would give you much more significant information.

Dr. Snyder: Well, I would tend to agree, but I doubt if you are going to get very much information, epidemiological information out of the occupational exposures, see, because this kind of information will not be present. Generally when a person is exposed, we find, our laboratory, and I think in others, it is rarely or it is very difficult to really document carefully what particle size, what chemical form, and so on are really involved in the exposure. So, probably I would suppose the most precise information we can hope for in the immediate future would be from the experiments on animals using mono-disperse aerosols, and if you are aware it is only within the last couple of years that the laboratory has achieved something like this. So, consequently, we have to wait a while to see what will happen, whether these experiments can be interpreted in this. That is why I sort of wonder about your use of the word "meaningless." This was a "meaningless concept," you say, and yet it is the only concept that we have at present to fall back on. You see, until we have done this experimental work to deduce what the carcinogenic potential is per particle as a function of particle size, then we cannot very well say what the potential is for a real exposure. That is why I somewhat

feel you used a disreputable term in saying, "the concept of average dose to lung was meaningless."

Mr. Geesaman: Well --

Dr. Snyder: One uses it only because one has nothing else to fall back on, and I think people have been aware of many of these discrepancies and difficulties almost from the year one.

Mr. Geesaman: Well, I do not contradict that, and my use of the word "meaningless" is not to give umbrage, but to give perspective, because I think in a physical sense, it is meaningless. That is the construction I put on it, that it does not identify with reality, and that therefore what I would say, and this is a very conservative position, if you could find the maximum efficiency of cancer production on a per-energy basis, you can perhaps work away from a very conservative position by arguing from human epidemiological studies.

Now, it seems to me that there has been a plutonium industry since 1950 of significant size. I have no idea of how many people there are in that industry, but they must scale like a thousand or several thousand, and it would seem to me that epidemiological information is going to come in.

Dr. Snyder: As I mentioned, this epidemiological information will be rather imprecise. You will not have a precise knowledge of, even an approximate knowledge of how

many particles were inhaled, what the distribution and sizes were, and perhaps even the chemical form in many cases.

Chairman Mills: Any other questions?

Dr. Garner: I would like to add to what Mr. Geesaman said. I thought that was a very refreshing presentation. Like you, I have been very puzzled by some of the results out of Dr. Richmond's experiment. But, Tamplin and Cochran made much of the fact that Richmond had seen lesions. They make much of the fact that he had described lesions that he had said were similar to the lesions seen by Lushbaugh and Langham, and the guy who had the plutonium particle embedded in his skin, the ones that are often referred to as pre-cancerous lesions, but which were, I believe, described as similar to precancerous lesions; and Cochran and Tamplin, as I say, go a little further. In fact, they assume that they were precancerous lesions and deduced that later, I dare say, cancer would have appeared in Richmond's animals.

I feel a little more reassured than you do. I do not understand why no lesions were seen in lots of these animals, but lesions were seen in some animals. They were not cancerous lesions. They were not manifest as cancer, but some lesions were seen. It was not as if they were totally negative.

Mr. Geesaman: The negative result bothers me, that in conjunction with Dr. Little's experiment, where there was a fairly large carcinogenic response, these are what mystify

me. I did note something that might be relevant. I think both in Dr. Bair's experiments with the Beagles and in Dr. Little's experiment with the Syrian hamster, they talk about the cancer appearing at the periphery of the lung. Now, I do not know if that has any significance or not, and I do not know how it relates to the observations made by Dr. Richmond in his experiments. I do not know if those particles lie at the periphery of the lung. The way my mind works, is I look for anomalies. I feel if I can anticipate an anomaly, then I have a sense of understanding. So that experiment bothers me until in my mind's eye I can see some way of clarifying it. I am troubled by it.

Dr. First: In the proceedings that took place in Washington, the point was made that the particles that deposit in the lung do not stay fixed in one place for a long period of time, but, in fact, migrate under the physical action, physiological actions of the lung. My question is this: Would this modify your conclusions in any way with regard to the effect of a single particle if it were established that it moves quite rapidly in the context that we are considering, and how does this fit in with your analogy to the movement of trucks and bullets, a concept which I find a little puzzling, but I hope to get it straightened out when I read your manuscript?

Mr. Geesaman: I do get quite a little abuse on account

of that example. It is strictly an energy argument. But, as to the question of movement of particles in the lung, I just think back to that original little monograph that I wrote in which I tried to define the time scales and movement rates that must be involved in the various clearance modes. It seems to me that some of the material that goes into the deep respiratory tissue is cleared rather quickly. Now, I do not know what the mechanism for that clearance is. I do not know if the mechanisms for that clearance mode is really understood or not. But what I always presumed occurred, was that a particle was phagocytized by a macrophage, and then a tropism or the random movement of the macrophage cleared it to the ciliated portion of the trachial bronchial tree.

For the slow clearance mode, if the half-lives get to be like 500 days and the length scales are only like 300 microns or 8000 microns say at the greatest, the distance from an alveoli to the ciliated part of the trachial bronchial tree, when you start putting those times with those distances, the motion gets to be extremely slow, and what comes to my mind is that there must be some fixing mechanism such as the plaques, seen I think, in pneumoconiosis, there is a fixing mechanism where for some reason the phagocytes remain in place and a plaque forms, and ultimately the cell dies and lyses, and then you have the release of the particle

again, either externally where it may be cleared by the more rapid mode, or it is cleared into the septal region and goes into the lymph nodes. So, as I see it, there is probably a quasi-static mode. For the motion that occurs, if motion occurs, you have to redefine what hot particle means in terms of the nature of the exposure in a certain time against some cell population.

Dr. First: That is precisely my question, assuming that this information is correct, does this modify your analysis and conclusions? I did not ask the question as to whether or not you believe this, but what effect this would have on your analysis?

Mr. Geesaman: Only if the motion was very quick.

Dr. First: Supposing it is, what happens?

Mr. Geesaman: Then you may go to a more uniform distribution.

Dr. First: Does this then nullify the argument? Is this the key to the situation?

Mr. Geesaman: It is not the key certainly, because ultimately you have a great spectrum of particle activities available to you for consideration. If you look at the various isotopes of plutonium passing from plutonium-239 up to reactor plutonium, up to plutonium-238.

Dr. First: I think that is irrelevant.

Mr. Geesaman: It would seem to me that when you have

reactivity variations and size variations, that you probably are able to pick up many orders of magnitude in activity variation.

Dr. First: Irrelevant to my question, not the problem.

Mr. Geesaman: I would be happy to answer if my small mind is able to follow the intricacies of the question, I will do my best to understand it.

Chairman Mills: I feel I must cut this off. It is very informative, but we do have a long schedule. I apologize to you.

Responses to Comments and Questions of the Panel, Consequent to Testimony Given at the Public Hearing on Plutonium Standards Held by the United States Environmental Protection Agency in Denver, Colorado on January 10, 1975

Donald P. Geesaman
School of Public Affairs
University of Minnesota
Minneapolis, Minnesota

1) Response to Dr. Mill's question as to the significance of the qualifying condition "for particle burdens $<<10^8$ particles" in the estimate of possible risk per disruptive particle.

This qualifying condition was imposed to avoid discussion of regional aggregation of disruptive particles. If there are 10^8 alveoli and there are disruptive particle burdens $<<10^8$ particles, then there should be very few overlapping exposure fields. Moreover, this condition would include the exposures that were judged to be of principal public health interest. For a further remark on the question of regional aggregation, see my response to a question of Dr. Snyder.

2) Response to Dr. Morgan's question regarding my use of the word 'resonance.'

This usage is based on the following conceptualization. Carcinogenic response is taken as the dependent variable. The physical and biological variables describing the exposure situation define the field of independent variables. A subfield that describes an exposure situation of anomalously large carcinogenic response is referred to as a resonance. I think this usage is consistent with scientific practice.

3) In response to Dr. Snyder's objection to my description of the existing plutonium standards (when applied to particulate exposures) as 'meaningless.'

I stand by my description. Its intent was not to give offense, but to provide perspective.

Applying present plutonium standards to particulate exposures carries with it the assumption that is is proper to average focal exposures over fictitiously large volumes in order to infer carcinogenic response. Such averaging procedure presumes linearity and is patently erroneous when there are qualitative differences in response between the actual and the fictitious dose regime. Because of the activity levels of plutonium particulates, and because of the intercession of extensive mitotic death in the exposed cell populations, the response must be qualitatively different for the actual and the fictitious exposure. Hence in the context of particulate exposures the standards are scientifically meaningless. Moreover, since it can be observed that loss of mitotic competence in cell populations does not necessarily reduce, and may in fact greatly increase, carcinogenic potential, the technique of dose averaging when applied to particulates need not be conservative and is without meaning in a public health context.

I would agree that the technique has had administrative approval which does give it an abstract procedural meaningfulness similar in character to the emperor's new clothes.

As to my use of the word meaningless I do not feel that I went far beyond the position taken in paragraph 210 of NCRP #39 which states:

> "There are some cases in which choice of a significant volume or area is virtually meaningless. For example, if a particle of radioactive material fixed in either lung or lymph node may be carcinogenic, the averaging of dose either over the lung or one cubic centimeter may have little to do with the case."

4) In response to Dr. Snyder's enquiry, as to whether I had tried to interpret the results of the Hanford beagle experiment in terms of the disruptive particle hypothesis.

I have, but only to the point of seeing if the observations and the hypothesis could be made compatible. In the original Hanford beagle experiment, exposures were just sufficiently small that death did not occur from pulmonary insufficiency. Consequently there were large numbers of particles involved with much regional aggregation.

One can speculate on some limiting effects of particle aggregation. Assume that the carcinogenic potential scales like the surface area of the disrupted region. Consider N disruptive particles each capable of exposing a volume V with a surface S. In one case distribute the N particles so that their effects are isolated from each other. Then the carcinogenic potential is $\sim$ NS. In the other case distribute the N particles so that they completely expose a volume of order NV. Then the carcinogenic potential is $\sim (NV)^{2/3}$. The ratio of the two cases $\frac{\text{independent}}{\text{aggregated}} \sim N^{1/3}$. A similar calculation assuming the carcinogenic potential scales like the linear dimension of the disrupted region would have led to a ratio, $\frac{\text{carcinogenic potential-independent}}{\text{carcinogenic potential-aggregate}} \sim N^{2/3}$.

For large N, these simple hypothetical examples demonstrate that geometric effects might have a very significant effect in reducing the carcinogenic potential of aggregates. For an N of 10^6 particles the effect could be like a factor of 100 reduction for the surface case, and a factor of 10,000 reduction for the linear case.

To end I would say that beagles have shown a substantial incidence of bronchiolar-alveolar cancers after receiving burdens of plutonium in the microcurie range. The results of an extensive experimental program at lower burdens can not help but provide useful and much needed information.

5) Response to Dr. Gardner's comment on the differing degrees of encouragement he and I drew from the negative results of the Los Alamos experiment with Syrian hamsters.

In their Po-210 experiments with this species, Little et. al. demonstrated high incidence of bronchiolar-alveolar cancer. The Los Alamos experiment resulted not only in virtually no cancers, but, as I read the literature, in very little evidence of injury in the tissue adjacent to the hot particles. This is anomalous. It is also my impression from private conversation with Dr. Bair (and I hope that I do not misrepresent him here) that in their experience with attempts to induce pulmonary cancer in this species with various carcinogens, they have been relatively unsuccessful. I consider these results to be symptomatic of this general field of observation and enquiry. There are many observations, a few well conceived experiments, a great deal of hopeful talk, and no prevailing sense of understanding. I am troubled that this is a sandy footage on which to site a judgment. (Note: see amendment to this response in nest attachment.)

6) Response to Dr. Firth's question as to the applicability of the disruptive particle hypothesis, if, in fact, there is movement of the particulate burden.

First I would say that motion, per se, does not disqualify the disruptive particle hypothesis. It would still be applicable if the motion were sufficiently slow, or if a significant mass fraction of the particulate burden were periodically immobilized for significant times. A particle with just sufficient activity to be disruptive, if static for a period of a month, would become nondisruptive if it were in a state of sufficiently rapid motion. On the other hand, a particle that was so active as to be inefficiently disruptive if static for long periods would become more disruptive if it

were in a state of not too rapid motion.

The preceding comments are general. I am rather uncertain as to what you specifically have in mind, when you refer to evidence that the plutonium moves about in the lung. It is my understanding that after deposition of plutonium particulates in deep respiratory tissue, there is observed a fast and a slow clearance mode to the ciliated surfaces of the tracheal bronchial tree. Further there is a slow clearance to the pulmonary lymph nodes. Considering the slow mode of external clearance, the time scale is $\sim$ 500 days, the length scale between deposition site and ciliated surface is no greater than a few thousand microns. Movement of several microns a day is slow enough that it would not disqualify the hypothesis. The physical extent of the exposure would scale roughly $\frac{10^3\mu}{10^2\mu} \sim$ 10x larger. In the light of the existence of a rapid mode of clearance, however, it seems more likely that the slow clearance is related to a mechanism where the material is temporarily fixed by static or immobilized class of phayocytic cells, which on their demise, release the material making it again accessible to the rapid mode of clearance. As to the movement of particles which penetrate the septal spaces, I can make little comment. The length scales then become longer, but the long time scales for clearance to the lymph nodes, again suggest periods of fixation. In any event, I have not heard, nor been able to conceive of, a mechanism for the rapid wandering of particulates through the pulmonary tissue. That there is some gradual average directed motion is believable, that there is a rapid motion is difficult to reconcile with the long time scales for clearance.

February 11, 1975

AMENDMENT TO:

Testimony Concerning the Acceptability
of Existing Public Health
Guidance for Plutonium

AND TO:

Responses to Comments and
Questions of the Panel

Donald P. Geesaman
School of Public Affairs
University of Minnesota
Minneapolis, Minnesota

404

RE: Los Alamos Syrian Hamster Experiment

In para. 2, p. 24 of my written testimony, and in response #5 of my responses to comments and questions of the Panel, I commented on the nearly completed Los Alamos Syrian hamster experiment (2000 plutonium-loaded microspheres per animal, eight exposure levels, ∿ 70 animals per exposure level). There I stated:

> "virtually no lesions of any sort were observed in conjunction with the plutonium microspheres;"

and

> "The Los Alamos experiment resulted not only in virtually no cancers, but, as I read the literature, in very little evidence of injury in the tissue adjacent to the hot particles."

These statements were the basis for some of my subsequent discussion of this experiment. The statements were grounded specifically upon a recent summary of observed results taken from "A Radiobiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium" (WASH-1320), W. Bair, C. Richmond, and B. Wachholz (September 1974), which stated (emphasis added):

> "No aberrant clinical signs have been observed in any of the animals that have died or have been sacrificed to date. Blood samples have revealed no abnormalities even after long exposures and there have been no regional lymph node effects. Occasionally, small accumulations of macrophages are seen around spheres but the fibrous encapsulation previously described for the larger more radioactive (about 180 micron diameter) spheres (Richmond et. al., 1970, 1974) are not seen. Two rarely occurring tumors were observed among animals included in Table III-C. One hamster developed an angiosarcoma of the lung after 9.5 months exposure to 2000 microspheres each containing 0.42 picocurie alpha activity (level 2A). Another animal developed a lung sarcoma at the same exposure level after 12 months."
>
> (p. 19)

and

> "In a study of $^{239}PuO_2$ particles administered by intraperitoneal injection in rats, about 2% of the plutonium was found in the vasculature of the lung 300-500 days post-injection (Sanders, in press). The mean lung doses from these plutonium particles of > 0.3 μm diameter ranged from 10 to 600 rads for three treatment levels: 0.072, 0.360 and 2.900 μCi. Of 106 rats that survived longer than 200 days (life shortening occurred in the highest dose groups and was due to irradiation of the peritoneal cavity), one rat in the lowest dose group died with a bronchiolar-alveolar adenocarcinoma after 823 days. There was no other primary pulmonary neoplasia and little evidence of cellular reaction to the plutonium particles in the lung, even among those cells adjacent to the particles. Inflammation, fibrosis, and epithelial hyperplasia and metaplasia were not observed. In general these findings agree with the results from the current plutonium microsphere studies at Los Alamos (Richmond and Voelz, 1972, 1973; Richmond and Sullivan, 1974)."
>
> (p. 20)

While I had not seen the reference, (Richmond and Sullivan, 1974), I took the above description to be a proper representation of the experimental results.

In the past week it has come to my attention that the preceding description is at variance with the description given in the cited supporting reference, "Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division," C. Richmond and E. Sullivan (May 1974). I have subsequently seen that reference and I quote here some observations on the Syrian hamster experiment taken from the section on Biological Results (emphasis added):

> "Most of the animals placed on study early in the program have reached the end of their normal life span without developing significant pulmonary lesions. During the past few months, we have observed some histological changes in the lungs of very long-term animals (15-20 months). In these animals, an extension of bronchiolar epithelium

> into the aveolar ducts and alveoli has occurred. In some cases, the alveoli are lined with cuboidal or columnar epithelial cells (Fig.1). This lesion has been observed almost entirely in the higher activity levels (levels 4-6) and in animals given relatively small numbers of spheres (2000-6000). An interesting recent observation has been the identification of a similar lesion in animals from a lower activity group (level 3) which had been given larger numbers of spheres of approximately 60,000 (Fig. 2). This group of animals has been exposed only about 6 months. A consistent observation of this lesion after drastically different induction times could lead to speculation that the amount of tissue irradiated is an important element in timing of the tumorigenic response. There has been no increase in frank tumors observed within the past year; however, the epithelial changes described above could be considered as precursors of peripheral adenomas."
>
> (p. 7)

Omitting these observations from the later report (WASH-1320) resulted in a defective representation of the experimental results of that experiment.

In particular, considering the short life-span of the hamster, the appearance of these late, potentially pre-cancerous, lesions implies a severe qualification on the observation that virtually no ($\sim 10^{-6}$/particle) tumors have occurred in the fixed particle burden Syrian hamster experiment. Moreover, the inclusion of these observations makes the results of the experiment less of an anomaly, and makes them much more compatible with an interpretation based upon tissue disruptive processes and the hot particle hypothesis.

Chairman Mills:

The next speaker is Dr. Edward Martell from the National Center for Atmospheric Research.

Dr. Martell: Mr. Chairman, Members of the Panel, Ladies and Gentlemen:

I have presented written testimony to the Panel, which I will summarize in my oral presentation.

Before I do, I want to make a few informal remarks, and some clarification of some remarks made earlier today about air concentrations of Pu relative to the current standards and Pu soil concentrations compared to natural alpha activities. I should like to mention that air concentrations of Pu at the east fence of Rocky Flats which showed an average of about 1% of permissible air concentrations, and rarely exceeded 10% or more in periods of high wind conditions were, in fact, measurements made after the Pu sources were

covered. Now, there was a spill area of 3.3 acres. There also was a large apron of Pu contamination between the spill area and the east fence. The spill area was covered with a few inches of asphalt. The large apron was covered with a few inches of clean gravel. Only then Rocky Flats took Pu measurements at the east fence.

Well, all that this demonstrates is the efficacy of the cover in the two or three years subsequent to covering the sources. The AEC Health and Safety Lab made some additional measurements of Pu one mile further east of the fence and, lo and behold, the concentrations were more than an order of magnitude higher. There is a larger area of lower concentration in about one square mile area between the fence and the site of the measurements made further east. It is the re-entrainment of soils of relatively low Pu concentration -- but very high compared to Colorado interim soil standards -- that are involved. The air concentrations showed a remarkable increase with wind velocity. In fact, there are many orders of magnitude variation in soil dust concentration in Colorado surface air as a function of wind velocity. For ranges from a few miles per hour to, say, 60 miles per hour, we are dealing with four or five orders of magnitude increase. The problems of airborne contaminants are unique in areas of this kind. They are exceptional.

Now, earlier today we also heard that re-entrainment

factors vary all the way from 10^{-3} to 10^{-9}. I want to comment that we are really concerned with what people inhale, and that 10^{-3} is the re-entrainment factor that applies in areas where people are working, where vehicular traffic stirs up dusts, where farmers are plowing, and of other activities of this sort. The Pu concentration per gram of surface soil is not the point. If you look at the accumulation of particles of respirable size in deep respiratory systems, you find that there is a selective accumulation of insoluble particles of respirable size in the chronic exposure case. I have discussed this matter in some detail in the latter part of my written testimony.

So, let us look at what per gram of soil, the Colorado interim standard, really implies. The plutonium is mostly in the insoluble form and the resuspended plutonium is between 25 and 50 percent in respirable sized particles. I should point out that because plutonium oxide is friable, it continually degrades in size, so that any PuO_2 that is not small enough to be inhaled will become so, if you have patience.

Another aspect of this is that, because of its relatively high alpha specific activity, there is recoil detachment of Pu from soils. So, even though other small particles stick to surfaces of larger soil particles, there is always a large fraction of the alpha-emitter in the

detached form in the re-entrained airborne material. So, what we really want to look at is "What is the specific concentration of plutonium in respirable size particles that are insoluble and will accumulate in biological systems?" And what do we see? 2 DPM. The Colorado soil standard of two dpm Pu (approximately one picocurie) corresponds to between 10 and 100 picocuries of Pu per gram of insoluble soil particles that are of respirable size. Now, how much will someone accumulate in long-term exposure to such soil levels of Pu?

Now, we hear of all these complicated studies to determine the Pu and soil size distributions, the re-entrainment factors, the inhalation exposure patterns, inhalation retention fractions, etc. This approach involves such an accumulation of uncertainties and errors that no one can predict what somebody will accumulate in the long-term exposure case. But, there is a direct way to an approximate answer. For example, Lewis and Coughlin of the Veterans Hospital in Boston have demonstrated that the typical adult lung contains a certain amount of nitric acid insoluble particules that varies linearly with age. It (the lung burden) averages a half gram in a young adult, a gram in an adult in age 40 or so, and a gram and a half by the age of 60. Now, these are burdens of respirable particles. They are insoluble and they are persistent. And so a soil stand-

ard which gives you 10 picocuries to 100 picocuries per gram of insoluble particulate, is going to give the average 40-year-old 10 to 100 picocuries in his lung. Now, the actual situation is worse than that, because the lung residence times for insoluble particles has been demonstrated to be, for plutonium, of the order of two or two and a half years as the mean residence time. However, the residence time in the lymph nodes and lymph circulation system are longer. The residence time in the liver is longer, with values ranging from 10 to 40 years quoted in the literature.

So, in the chronic exposure case, you are going to build up higher concentrations everywhere else other than in the lung. Now, this is one of the reasons I wonder why we are preoccupied with the lung cancer threat from inhaled particles. If we are concerned with exposures from working 10 to 30 years, we should look for higher Pu concentrations in in other organs. If we are concerned with the general public exposures, we should be overwhelmingly concerned with the Pu risk in the organs which have the longest residence times, and which therefore accumulate the largest amounts and highest concentrations.

With these preliminary remarks, I would like to suggest that any comparison of plutonium oxide, largely in insoluble particles of respirable size, with the bulk radium in the top foot of soil is a very simple and naive approach to the problem, and one that just does not belong in a forum of this kind.

Basic Considerations in the Assessment of the Cancer Risks and Standards for Internal Alpha Emitters

Edward A. Martell
National Center for Atmospheric Research *
Box 3000
Boulder, Colorado 80303

January 10, 1975

(Statement presented at the public hearings on plutonium standards sponsored by the United States Environmental Protection Agency, Denver, Colorado, January 10, 1975.)

* The National Center for Atmospheric Research is sponsored by the National Science Foundation.

1. Introduction: The adequacy of the biomedical basis of standards for occupational and public exposure to plutonium and other internal alpha emitters has been widely discussed[1-5] and seriously questioned[6-8]. The serious uncertainties in the cancer risks attributable to internal alpha emitters must be resolved before we are irretrievably committed to a nuclear energy program. This is a matter of immediate concern in the western suburbs of Denver due to plutonium and americium contamination of surface soils in public areas around the Rocky Flats Plutonium Plant[9]. Many other places are similarly affected by transuranium element contamination and its attendant cancer risks.

Recent controversy regarding the adequacy of plutonium standards has focused on several aspects of the problem. For the cancer risks attributable to inhaled plutonium oxide particles, for example, it has been asked which organ--and how small a tissue volume of that organ--is "critical" (i.e., experiences the highest cancer risk). Further debate centers on whether the average alpha radiation dose to the critical organ or the tumor risk attributed to a given number of individual hot plutonium oxide particles provides the best guidance for the assessment of risks and standards for plutonium.

Geesaman[6] has discussed possible mechanisms of cancer induction by hot particles and concludes that the tumorigenic risk may be as high as 1/2000 per particle for submicron particles of plutonium oxide. A recent examination of hot particle risks by Tamplin and Cochran[8], based largely on the Geesaman study, led these authors to recommend that the occupational MPLB (maximum permissible lung burden) be reduced by a factor of 115,000, to a value of 0.14 pCi. A recent study[10] was carried out by Bair, Richmond, and Wachholz at the request of the U.S. Atomic Energy

Commission, with the specific objective of providing an updated review of the evidence bearing on the problem of uniform versus nonuniform alpha radiation dose distribution in the lung. The authors of this study take exception to the conclusions and recommendations of Geesaman, Tamplin, and Cochran[6,8] and conclude that

> "the nonuniform dose distribution of plutonium particles in the lung is not more hazardous and may be less hazardous than if the plutonium were uniformly distributed and that the mean dose lung model is a radiobiologically sound basis for establishment of plutonium standards."

Bair et al.[10] fail to take into account the full implications of some of the recent published results, in particular the observed higher tumor risks for $^{238}PuO_2$ than for $^{239}PuO_2$,[11] the apparently limited biological response of mammal lung cells from ^{238}Pu and ^{239}Pu incorporated into ceramic microspheres,[12,13] and the tobacco smoke radioactivity results[14]. The latter results imply that as little as a few picocuries of insoluble alpha-emitting particles in the lung may give rise to a significant risk of lung cancer and other serious health effects in the chronic exposure case.

On the basis of a brief review of the known effects of alpha interactions with cells (below) it will become evident that alpha radiation-induced cancer in mammals and man must be brought about by subjecting a large number of living cells to a limited number of alpha interactions. Thus, in principle, the highest risk would be associated with a uniform distribution of the alpha dose, in accordance with the conclusion of Bair et al. However, in fact, we are almost always concerned with a highly irregular tissue distribution of alpha-emitting particles. For hot particles, the tumor incidence must be due to the low-dose irradiation of a large number of cells by a very small fraction of the hot particle

burden. And for long-term exposures, unacceptably high tumor risks appear to be associated with picocurie burdens of internal alpha emitters. This serious possibility calls for a drastic downward revision of permissible exposure standards for inhaled plutonium. It also is possible that the health effects for inhaled alpha-emitting particles include greater incidence of atherosclerosis and other degenerative diseases of the cardiovascular system. The published evidence supporting these conclusions is briefly reviewed below.

2. Tumor Production: The interactions of various types of radiation with living cells and their mutagenic effects have been widely investigated, with results that have been reviewed and summarized by Lea,[15] Muller,[16] and others. When alphas interact with the chromosome or its genes in the nucleus of a cell, the dense ionization in the track of the alpha particles gives rise to closely spaced breaks which bring about a wide variety of irreversible chromosome structural changes, or mutations. X-ray and γ-ray interactions give rise to a diffuse distribution of ions, resulting in widely spaced invidivual breaks, most of which can undergo repair by recombining without structural change. Thus permanent structural changes for X-rays and γ-rays are proportional to the square of the dose, with greatly reduced incidence at low dose rates. By contrast, structural changes resulting from alpha interactions are directly proportional to the number of interactions and are independent of alpha interaction rates. Thus, with regard to the production of irreversible structural changes in cells the relative biological effectiveness of alpha radiation, compared to X-rays and γ-rays, increases markedly at lower dose rates and over longer periods of exposure.

For alpha interactions with cell nuclei, most of the structural changes are lethal and lead to the mitotic death of the cell at the next or subsequent cell division[17,18]. However, as Lea[15] and others have pointed out, some cell nuclei experience only minor structural changes (chromosome inversions, duplications, translocations, deletions, etc.) and remain viable. However, although only a very small fraction of alpha interactions give rise to viable mutated cells, these survive to proliferate, whereas cells that suffer lethal changes are eliminated from the cell population. Thus in the case of long-term exposure of tissue to internal alpha emitters at low dose rates there is a cumulative increase in the population of cells which have survived one or more chromosome structural changes. However it is equally obvious that a cell whose nucleus is subjected to repeated alpha interactions within the mean life of the cell has only a negligible chance of survival.

It is likely that a radiation-induced tumor begins with the formation of a single malignant cell characterized by a combination of two or more chromosome changes and/or gene mutations. The alpha radiation-induced bone tumor incidence in dogs is observed to be proportional to the square of the alpha dose[19] implying that a sequence of two or more low-probability events must be involved. This is consistent with the two-mutation and multiple-mutation theories of cancer[20,21] based on the age distribution of cancer in man. On the basis of these considerations, the production of a malignant cell involves a sequence of events, as follows: (1) production of a viable mutated cell; (2) clone growth from the mutated cell; (3) production of a second viable mutation in one or more of the clones; (4) growth of a clone of doubly-mutated cells; etc. Thus, for a two-mutation sequence, the tumor risk may be proportional to the function

$R^2t^3\tau_c^{-2}$, where R is the alpha dose rate, t is the time of exposure, and τ_c is the mean life of the normal cell and singly mutated cell. The term $(t/\tau_c)^2$ represents the number of cells in each clone which should be proportional to the square of the time of exposure[21] and the mitotic rate (i.e., the reciprocal of τ_c). Such a tumor risk relationship makes it quite apparent that a linear extrapolation to low dose rates is not conservative for alpha radiation-induced tumors, but rather, that there may be a marked inverse dose rate vs risk relationship. There is an increasing body of published experimental evidence that reflects such a trend.

Speiss and Mays[22] observed that for ^{224}Ra alpha radiation-induced bone sarcoma in man, the tumor incidence per rad approximately doubled for a fourfold increase in the spacing of ^{224}Ra injections and that the observed incidence of bone tumors per rad in children was nearly twice that for adults. Upton et al.[23] showed a significantly higher incidence of tumors in mice for a given neutron dose at more protracted periods of exposure. Moskalev and Buldakov[24] showed that fractionation of the administered ^{239}Pu dose over larger periods of time increased bone tumor induction. The higher tumor incidence per rad for the smaller lung burdens of crushed $^{238}PuO_2$ microspheres observed by Sanders[11] seems best explained by the limited alpha irradiation of large numbers of cells by numerous very small, mobile particles of low activity per particle (see below). Hamsters subjected to low alpha doses from ^{210}Po distributed quite homogeneously in the bronchiolar-alveolar region show a marked increase in the lung tumor incidence per rad at very low doses and dose rates[25]. And the incidence of bronchial cancer in uranium miners reflects a higher tumor risk per rad at the lower doses[26] for this low dose rate exposure group. The tobacco radioactivity results[14] indicate a significant tumor risk for the

cumulative alpha radiation dose from ^{210}Po in insoluble particles in the bronchi of smokers, involving much lower dose rates.

On the basis of the above considerations, it is evident that the tumor risk is optimized when a very large number of cells and their descendants are subjected to only a few widely spaced alpha interactions with the small target afforded by the cell chromosomes. This follows necessarily from the fact that most alpha interactions with cell chromosomes lead to the subsequent mitotic death of the cell, as Barendsen has shown[17,18]. The production of a malignant cell calls for a sequence of two or more low-probability events and thus cannot be speeded up by the application of massive alpha doses, but rather only by subjecting a much larger number of cells to a limited number of interactions. Additionally, assuming that the tumor risk to the tissue subjected to alpha irradiation is proportional to $R^2t^3(\tau_c^{-2})$, explained above, it is apparent that the alpha activity concentration, or the activity per particle which is equated to a given tumor risk, decreases with increasing time of exposure and also that a given risk can be attributed to smaller cumulative doses when the time of exposure t is appreciably longer than the mean life of the cell, τ_c. Brues[27] and Burch[28] both pointed out that the two-mutation theories of carcinogenesis[20,21] would imply an exceptionally high effectiveness of widely spaced radiation for tumor production. It is proposed that just such a dose-rate relationship serves to reconcile the observed significant tumor risk in cigarette smokers with the presence of a persistent lung burden of insoluble smoke particles involving a total of only a few picocuries of ^{210}Po[14].

3. <u>"Hot" PuO_2 Particle Risks</u>: If the above tentative conclusions are correct, then the same considerations must apply in the assessment of tumor risk for hot particles. In this connection, a preliminary consideration

of the influence of specific alpha activity and particle size of the hot alpha-emitting particles is in order.

Raabe et al.[29] report an apparent rate of dissolution of $^{238}PuO_2$ in lung fluid two orders of magnitude higher than that observed for $^{239}PuO_2$ particles. Such a dramatic difference in the chemical behavior of two isotopes of plutonium is seriously inconsistent with the negligible influence of isotope effects on the chemical kinetics of heavy elements. Thus it seems necessary to explain this apparent solubility difference on physical grounds. The specific activity of the $^{238}PuO_2$ particles (~80% of $^{238}PuO_2$ and ~20% of $^{239}PuO_2$) was about 220 times that of $^{239}PuO_2$. In addition the $^{238}PuO_2$ particles exhibited a very significantly lower density than the $^{239}PuO_2$ particles,[30] indicating a highly faulted structure and weakened intermolecular bonding for the $^{238}PuO_2$ particles. Fleischer[31] proposes that the apparently higher dissolution rate for $^{238}PuO_2$ may be explained by the alpha recoil nucleus ablation of the surface layers of the particles, with a fragmentation rate proportional to the specific alpha disintegration rate and with variable sizes of fragments ranging up to ~10^4 atoms. The poorer structural integrity of the $^{238}PuO_2$ particles may give rise to an increase in the size range of the ejected fragments. Such small fragments, ranging up to tens of angstroms in diameter or more, would pass readily through the 0.1 μm diameter pores of the membrane filters used in the dissolution experiments.[29] Also, such small ablation fragments may exhibit a much higher mobility in tissue than particles of 0.1 to 1.0 μm diameter, the size range of particles used in most animal inhalation experiments. This greater mobility for very small ablation fragments in tissue may explain the more rapid rate of translocation observed for $^{238}PuO_2$ from the lung to the liver

and bone.[32,33]

Another explanation for the apparently higher solubility of $^{238}PuO_2$ than $^{239}PuO_2$ is the possibility that the intense alpha radiolysis of the lung fluid at the surface of the particles leads to the production of chemically active free radicals which in turn react with PuO_2 molecules on the particle surface. This process also would proceed at a rate proportional to specific activity and to particle surface area. In this case the dissolved plutonium would diffuse away from the hot particles. However this dissolved plutonium undoubtedly would be slowly redistributed in the lung in the same fashion as that reported by Moskalev[34] for inhaled soluble compounds of plutonium, resulting in a highly nonuniform distribution with hot spots located predominantly in the subpleural region of the lungs. This gradual conversion of the soluble plutonium compounds to small colloidal size particles at focal points of activity may be the result of the self-chelating properties of tetravalent plutonium in solution.

In recent studies of rat inhalation of $^{238}PuO_2$, Sanders[11] has demonstrated a substantially increased risk per rad for small lung burdens of aged, "crushed" $^{238}PuO_2$ microspheres. In this case the inhaled particles are smaller particles with a proportionally larger surface area. The more rapid rate of translocation to other organs Sanders observed can be attributed variously to the higher mobility of the smaller particles, to the higher rate of surface ablation (or dissolution) for the increased surface area, or both. The higher tumor incidence can be attributed to the greater mobility and wider redistribution of the $^{238}PuO_2$ microspheres and their breakdown products, subjecting a much larger number of cells to a limited number of alpha interactions.

The correctness of the above interpretation is reinforced by the results of the Los Alamos ceramic sphere experiments reported by Richmond et al.[12,13] and further discussed by Bair et al.[10] In these experiments, 2000 zirconium oxide microspheres of 10 μm diameter, each sphere containing a specified amount of plutonium, were injected into the lungs of groups of experimental animals. The total plutonium per microsphere ranged from 0.07 to 1.6 pCi of ^{239}Pu and from 4.3 to 59.4 pCi of ^{238}Pu, with identical activity for each of the 2000 microspheres in each of eight animal exposure groups (70 animals per group). The local dose rate, averaged over the small tissue volume within 40 μm from the surface of the ceramic microspheres, was ~ 17,000 rads per year for the 0.07 pCi microspheres, or ~ 200,000 alpha disintegrations per year within each microgram of irradiated tissue. The dose rate was correspondingly higher around the microspheres of greater activity. Less than one milligram of tissue, only one millionth of the lung, is subjected to these massive radiation doses.

The limited biological response obtained in these experiments is consistent with expectations on the basis of Barendsen's results[17,18]; the small population of cells within the alpha range around the microspheres experiences so many alpha interactions that all cells receive chromosome structural changes that result in their mitotic death. The 10 μm diameter microspheres are immobile in tissue. Also, their specific alpha activity is so low compared to pure PuO_2 that their surface recoil ablation and dissolution rates are neglibibly low. Thus in these experiments there was no large population of cells subject to lower intensities of alpha interactions, as was the case for Sanders' crushed $^{238}PuO_2$ microsphere experiments.[11] Richmond and Voelz[12] observed only two lung tumors (at 9.5 months and 12 months in animals exposed to 2000 ceramic microspheres

of 0.42 pCi ^{239}Pu per microsphere) for a total of ~ 10^6 hot particles. It is suggested that these two tumors may be attributed to the action of energetic protons scattered by alpha interactions with hydrogen atoms in tissue. The expected yield is one scattered proton per 10^4 alphas. Such protons have energies of about 100 KeV and a range about four times that of the alpha particle. Thus these secondary protons irradiate 63 times as many lung cells at lower interaction rates. It is unlikely that the two tumors observed in these experiments can be attributed to X ray or γ-ray irradiation for reasons indicated by Warren and Gates.[35,36]

4. Critical Health Effects: It is widely recognized that inhaled insoluble alpha-emitting particles deposited in the lung are, in part, translocated via the phagocytic action of macrophages to the lymph nodes and to other sites in the reticuloendothelial system, and also via blood leucocytes to the liver, spleen, and bone marrow. Recent experiments with inhaled plutonium show that the pattern and rate of translocation of plutonium from the lung to other sites are highly dependent on particle size and specific activity, with more rapid transport of the smaller and more active particles. Thus, it is far from obvious whether the lung, lymph nodes, liver, bone, or other organs, or fractions thereof, should be taken as the critical organ or critical tissue site.

It has long been known that those tissues in which there is more active cell division suffer the earliest and most severe radiation damage effects and that this includes the blood-forming cells in lymphatic glands and in bone marrow.[16,37] Such effects include the destruction of rapidly multiplying cells that produce the blood platelets that assist in the control of blood clotting, or reduction in the population of leucocytes with a corresponding reduction in resistance to disease. These effects,

424

together with the accompanying chromosome structural changes, can give rise to the earlier incidence not only of cancers, but also of a whole range of diseases of the cardiovascular and renal systems[37,38].

Let us review, also, the mounting evidence suggesting that inhaled insoluble alpha-emitting particles may be the agent of atherosclerosis, giving rise to an increased risk of death by early coronaries and strokes. Ahterosclerosis is reported to be present in every instance of partial or complete arterial occlusion and every case of coronary thrombosis[39]. Recently Benditt has proposed[40] that the human atherosclerotic plque is a monoclonal proliferation of a mutated cell of the artery wall, and thus an arterial tumor. Elkeles[41-43] has observed anomalously high concentrations of alpha activity at the calcified plaque sites. In addition, atherosclerosis plaques normally occur in the main and abdominal aortas and the coronary arteries, but rarely in the pulmonary arteries[42-44]. This distribution suggests a respiratory origin for the mutagenic agent. Attempts to reproduce arterial lesions in animals by chemical, mechanical, and nutritional means have not produced plaques similar to those of atherosclerosis in man[40]. However atherosclerotic plques have been directly induced in human arteries by intensive irradiation with X rays and radium[45]. There is a high incidence of early coronaries among cigarette smokers, with a mortality rate for males who smoke two packs or more daily that is 2 to 2.5 times that of nonsmokers with a mean age of death some 10 to 16 years earlier.[46] For all these reasons, it is proposed that inhaled insoluble alpha-emitting smoke particles are very likely to be the mutagenic agent that gives rise to atherosclerosis in cigarette smokers. If this is the case, similar increased risk of early coronaries is to be expected for other groups of individuals who are occupationally or environmentally exposed to inhalation of insoluble alpha-

emitting particles of respirable size. Attention should be addressed to groups exposed to airborne industrial effluents that contain uranium oxide, thorium oxide, lead-210 and polonium-210; to airborne plutonium oxide from stack effluents, nuclear accidents, and plutonium spills; to high levels of fallout from atmospheric nuclear tests; etc.

The first and most obvious place to look for such effects is among past and present plutonium workers. Very significant increases in the incidence of early coronaries as well as lung cancer and cancer at other sites is observed among cigarette smokers[46] with insoluble alpha-emitting particle burdens of only a few picocuries of ^{210}Po in the lung[14] and similar total alpha activity per 100 grams of arterial wall tissue[41-43]. By comparison, plutonium workers exhibit plutonium organ burdens ranging from a few picocuries to a few nanocuries or more[47,48]. And although there has been no epidemiological study of the age-incidence of heart disease and cancer among plutonium workers, the limited published information bearing on this question is more disturbing than reassuring. Most often cited is the medical experience of 26 plutonium workers at Los Alamos[49,50], usually accompanied by a statement to the effect that none of the medical findings for this group can be attributed definitely to internally deposited plutonium. With equal justification one may state that most of the serious medical findings in this group can be attributed to plutonium. One member of the original group died in the early 1950s. Cause of death is not reported. Another died of a coronary at age 38. A third suffered a coronary occlusion but recovered and was well compensated. A fourth developed a hamartoma of the lung and his right lower lobe was surgically removed in May 1971. A fifth had a melanoma of the chest wall. A sixth had a partial gastrectomy for a bleeding ulcer. One subject suffered loss of teeth, apparently due to damage to the lamina dura of

the jaws (which show the earliest effects in beagles given toxid doses of plutonium). Another subject has gout. The full medical history of this group, now mostly in their fifties, has not yet completely unfolded. Only 12 of these 26 plutonium workers were exposed to plutonium inhalation. Which of the observed effects were experienced by the inhalation exposure group? Regardless of the distribution, the medical experience of this small group thus far provides no basis for complacency about the health consequences of plutonium exposure.

Hanford employees and others whose autopsy tissue samples exhibited plutonium levels in excess of 5 pCi/kg died mainly of coronary heart disease and other cardiovascular effects and to a lesser extent of cancer and pulmonary emphysema[47]. On the basis of the evidence reviewed above, it appears that atherosclerosis may be an alpha radiation induced cancer of the artery wall. Thus coronary heart disease and other diseases of the cardiovascular and renal system may be expected effects of inhaled plutonium and of other insoluble alpha emitting particles. An adequate assessment of the magnitude of such risks can only be obtained by a comprehensive medical follow-up of all past and present plutonium workers. Until the age distribution of these effects among plutonium workers is fully assessed, any claim by the proponents of nuclear energy that there is little risk associated with the MPLB (maximum permissible lung burden) of 16 nCi of plutonium, or small fractions thereof, is totally unjustified. The growing evidence suggests that as little as a few picocuries of alpha activity in the lung, in arterial tissue, and in other organs gives rise to a significant cancer risk.

5. Discussion: The published evidence, reviewed above, clearly indicates that a linear extrapolation to lower doses and dose rates is not conservative for internal alpha emitters. The initial effects of alpha inter-

actions with cell chromosomes are irreversible and thus will vary linearly with alpha dose rate. However the cumulative effects of internal alpha emitters give rise to an increase in the populations of mutated cells (cells with viable structural changes in their chromosomes) and the health consequences of such changes. Therefore the tumor incidence per alpha disintegration must increase with decreasing dose rate. For this reason, a given cancer risk is equated with smaller cumulative alpha doses and with much smaller internal alpha-emitter burdens as the period of exposure increases.

By contrast, the cellular effects of X rays and λ rays are largely reparable at low dose rates. This stems from the fact that the diffuse distribution of ion pairs produced by such radiation results in widely spaced single chromosome breaks that repair themselves readily. For these reasons, the relative biological effectiveness of alpha particles compared to X rays and λ rays increases continuously with decreasing dose rate. Thus alpha radiation acquires a greatly increased biological significance relative to soft radiation in the production of tumors and other health consequences of chromosomal structural changes.

There are several other lines of evidence that reinforce the theory that alpha interactions with cells play a unique role in human cancer production. The distribution of cancer in the bronchi, in the lymphatic system, in arterial tissue, and in the liver and bone involves sites at which insoluble alpha emitters are known to accumulate. Anomalously high concentrations of alpha activity have been observed at the bronchial cancer sites[51], at cancer sites adjoining lymph glands in other organs[52,53], in atherosclerosis plaques[41-43], at liver cancer sites in Thorotrast patients[54], at bone tumor sites in the radium dial

workers[55], etc. The difficulties of producing lung cancer by external radiation have been pointed out by Warren and Gates[35,36]. The abscence of cancers in muscular tissue, except at sites of Thorotrast injection or plutonium injection, also is relevant to this issue. All of these observations reinforce the idea that one or more of the chromosomal structural changes that characterize a malignant cell must be brought about by alpha interactions and not by low-intensity X rays or λ rays. In this connection, the determination of the nature of the structural differences between the healthy and the malignant cells of each organ could shed some light on this important question.

It is also observed that the relative significance of chemical agents, viruses, and radiation in the incidence of human cancer is not known. Details of the mechanisms of cancer induction by chemical agents and viruses are poorly understood. And the proposed chemical carcinogens in cigarette smoke and in polluted urban environments have not been demonstrated to be carcinogenic at the low concentrations involved. For these and other reasons discussed above, it is likely that radiation, and alpha radiation in particular, may be the principal agent of human cancer. In view of such a possibility, it is very disturbing to note that the U.S. National Cancer Institute, now spending about one-half billion dollars per year on cancer research, has completely neglected research in the field of radiation-induced cancer.

Published evidence[39-45] indicates that atherosclerosis is a tumor of the artery wall and that the alpha activity at the calcified plaque site is likely to be the mutagenic agent. If so, the major causes of death in the general population--coronary disease, other cancers, and strokes--may in large part be attributable to internal alpha emitters from natural and pollutant sources. If so, fallout plutonium and other

alpha-emitting contaminants must already be contributing to increased cancer incidence and life shortening in the general public. Cigarette smoking causes increased risk of early coronaries, lung cancer, cancer at other organ sites, and other health effects[46], with about 15 years' reduction in life expectancy for those who regularly smoke two packs of cigarettes or more per day (attributable to lung burdens of only about 5 pCi of ^{210}Po in excess of that of nonsmokers). Fallout levels from past atmospheric nuclear tests have given rise to plutonium organ burdens of ~0.5 pCi/kg of lung tissue and ~0.7 pCi/kg of liver tissue in the general public[56]. Although these levels are only about 10 percent of the ^{210}Po organ burdens of heavy smokers, the effects may be correspondingly greater because the total population is exposed and the inhalation exposure begins at birth.

If the health risks attributable to fallout plutonium exceed 10 percent of the risks of heavy smoking, then inhalation exposure at ~20 times fallout (the surface soil concentration of plutonium which corresponds to the interim soil standard adopted by the Colorado Board of Health in 1973) would give rise to organ burdens more than twice that of heavy smokers. Exposing children to such levels would thus be equivalent to having them smoke four packs of cigarettes per day, beginning at birth. This estimate assumes (as I believe to be the case) that the inhaled, insoluble radioactive smoke particles give rise to the serious health effects of smoking.

For the estimation of organ burdens which may result from the inhalation of soil contaminants, it is common practice to attempt to determine the average surface soil concentrations, the applicable resuspension factors, inhalation exposure patterns, particle size distributions, lung retention, lung clearance, translocation patterns and rates, etc. The

large cumulative errors and uncertainties in the prediction of the ultimate organ burdens from long-term exposure to contaminated surface soils and urban dusts by such a long sequence of complex processes serve to make this procedure an almost useless exercise. There is a more direct approach which should give more reliable estimates. Lewis et al.[57] show that the adult lung burden of nitric-acid-insoluble particles increases almost linearly with age, with about 1.5 grams per kilogram of lung tissue at age 60. It seems reasonable to assume that individuals chronically exposed to soil dust and urban dusts will acquire just such burdens of the insoluble constituents in the respirable size fraction of dust particles (i.e., particles less than ~5 μm diameter). It should be noted that PuO_2 particles are highly insoluble and friable. Experimental measurements in the Rocky Flats area also have shown that about one-third of the airborne plutonium which has been resuspended from soil surfaces by wind action resides in particles of respirable size. However, only a very small fraction of the bulk surface soil is made up of insoluble particles of respirable size. For this reason, wind resuspension of soils with one picocurie of plutonium per gram (the Colorado interim standard) will give rise to an estimated 10 to 100 pCi of plutonium per gram of insoluble airborne dust of respirable size. People exposed to such a soil level should be expected to acquire plutonium lung burdens of 5 to 50 pCi by age 20, or 15 to 150 pCi by age 60, with additional amounts distributed in the lymph nodes, liver, bone, and other organs. Thus it is far from clear that the Colorado interim soil standard is a safe and acceptable standard.

There are, of course, a number of considerations that make it inappropriate to equate the effects of a given burden of low specific activity, alpha-emitting cigarette smoke particles with the same amount

of alpha activity in hot particles. The Los Alamos experiments[12,13] showed that most of the alpha dose from "hot" particles of PuO_2 is wasted in the excessive irradiation of cells within the alpha range of the hot particle surface. Thus the high tumor risk for the hot $^{238}PuO_2$ particles in the Battelle experiment[11] can be variously attributed to (a) the mobility of the smaller particles, (b) the recoil ablation and/or dissolution rates, which increase with specific activity and with surface area of hot particles, and (c) the possible irradiation of larger numbers of cells with scattered protons (an effect that may be significant for very hot particles).

Thus, the insoluble alpha emitting smoke particle, uranium oxide, thorium oxide and other alpha-emitting particles of moderate to low specific activity may be expected to give rise to a higher tumor risk per alpha disintegration for a given cumulative dose. Similarly, ^{239}Pu in mixed fallout particles may be expected to produce more tumors per disintegration than is the case for pure $^{238}PuO_2$ and $^{239}PuO_2$. However, although larger burdens of hot particles will be required for a given tumor risk, such risks can be expected to increase with both alpha-specific activity and with particle surface area, and the effects should occur earlier for a given burden, especially when smaller particles of higher specific activity are involved.

The above considerations make it obvious that the present practice of averaging the alpha dose over the whole lung or some arbitrary fraction thereof[10-13] is a highly questionable and grossly misleading procedure at best.

It also should be noted that americium-241 is present in association with plutonium contamination in the Rocky Flats area and in nuclear test areas. In addition, curium isotopes as well as americium-241 will be

preeent in high concentration in the nuclear fuel mixture from fission and breeder reactors which use plutonium fuel. The chemical behavior of americium and curium in the environment will give rise to their substantial uptake in the biosphere and the food chain[58]. Thus the ingestion of americium and curium, their uptake from the gastrointestinal tract, and their accumulation in the liver and skeletal tissue of mammals[58] and man will give rise to additional serious health risks. Americium and curium ingestion will be relatively more serious than plutonium inhalation in some environments, particularly in vegetated areas of moderate to high rainfall, where soil resuspension processes are not very effective.

6. Recommendations: It is urged that the U.S. Environmental Protection Agency consider and act upon each of the following recommendations, which are called for in order to provide an improved basis for the assessment of health risks and standards for plutonium and other actinides and to provide a higher degree of protection from the effects of internal alpha emitters for occupational groups and the general public through adoption of conservative interim standards for plutonium exposure.

(1) Initiate a comprehensive interagency research program to assess the health risks of inhaled alpha-emitting particles, with special attention to both "hot" particles and insoluble particles of low activity per particle (Some pertinent studies have been proposed to the EPA[59].)

(2) Conduct a comprehensive epidemiological health study of all past and present plutonium workers and of all other groups which have been exposed to the inhalation of plutonium at levels significantly above fallout plutonium.

(3) Call upon the National Cancer Institute and the National Heart and Lung Institute to apply an appropriate fraction of their resources to assess the role of inhaled alpha-emitting particles on the incidence of

human cancer and heart disease.

(4) Adopt more conservative occupational standards for plutonium. A reduction of present air concentration and lung burden standards by a factor of between 100 and 1000 appears to be in order. Better protection should be provided for younger employees and groups exposed to possible inhalation of finely divided and higher-specific-activity plutonium.

(5) Reduce public exposure levels of plutonium and other alpha emitters to the practical minimum. In my view, this would limit public exposure to airborne dusts not exceeding 0.5 pCi of alpha activity (about one alpha disintegration per minute) per gram of nitric-acid-insoluble particulates of respirable size. This level would result in the accumulation of adult organ burdens about equal to that from fallout plutonium[56]. On this basis the Colorado interim standard may be at least 20 times too high.

(6) Call for a full disclosure of all past plutonium spills and accidental releases and conduct appropriate surveys and cleanup operations.

(7) Develop standards for americium and curium, with particular attention to their distribution in the food chain and their uptake from the gastrointestinal tract.

(8) Give immediate attention to current plans of the U.S. Department of Defense and the U.S. Atomic Energy Commission to resettle Eniwetok Atoll. The high levels of plutonium and americium on these islands and in the lagoon sediments are likely to give rise to tragic health effects on this small native population group.

References

1. Langham, W. H., "The problem of large-area plutonium contamination," U.S. Dept. of Health, Education and Welfare, Bureau of Radiological Health Seminar Paper No. 002, 1969.

2. Dean, P. N. and Langham, W. H., "Tumorigenicity of Small Highly Radioactive Particles," Health Physics 16, 79, 1969.

3. International Commission on Radiological Protection, "Radiosensitivity and Spatial Distribution of Dose, Reports Prepared by Two Task Groups of Committee 1 of the International Commission on Radiological Protection," ICRP Publication 14, Pergamon Press, Oxford, 1969.

4. International Commission on Radiological Protection, ICRP Publication 19, "The Metabolism of Compounds of Plutonium and Other Actinides," Pergamon Press, May 1972.

5. Bair, W. J. and R. C. Thompson, "Plutonium: biomedical research," Science 183, 715-722, 1974.

6. Geesaman, D. P., "An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue," USAEC Documents UCRL-50387 and UCRL-50387 Addendum.

7. Long, A. B., "Plutonium inhalation: the burden of negligible consequence," Nuclear News, 69-73, June 1971.

8. Tamplin, A. R. and T. B. Cochran, "Radiation standards for hot particles," National Resources Defense Council Report, February 14, 1974, Wash. D. C.

9. Poet, S. E. and E. A. Martell, "Plutonium-239 and americium-241 contamination in the Denver area," Health Physics, 23, 537-548, 1972.

10. Bair, W. J., C. R. Richmond and B. W. Wachholz, "A radiobiological assessment of the spatial distribution of radiation dose from inhaled plutonium," U.S.A.E.C. Report WASH-1320, September 1974.

11. Sanders, C. L., Jr., "Carcinogenicity of inhaled plutonium-238 in the rat," Radiation Research 56, 540-553, 1973.

12. Richmond, C. R. and Voelz, G. L., (eds.), Annual Report of the Biological and Medical Research Group (H-4) to the USAEC, Division of Biology and Medicine, Los Alamos Scientific Laboratory Report LA-4923-PR, 1972.

13. Richmond, C. R. and Voelz, G. L., (eds.), Annual Report of the Biological and Medical Research Group (H-4) of the LASL Health Division for 1972 to the USAEC, Division of Biomedical and Environmental Research, Los Alamos Scientific Laboratory Report LA-5227-PR.

14. Martell, E. A., "Radioactivity of tobacco trichomes and insoluble cigarette smoke particles," Nature 249, 215-217, 1974.

15. Lea, D. E., Actions of Radiations on Living Cells, Cambridge University Press and MacMillan Co., N.Y., 1947.

16. Muller, H. J., "Radiation damage to the genetic material," 93-165 in Science in Progress, 7th Series, Yale University Press, 1949-1950.

17. Barendsen, G. W., T. L. J. Beusker, A. J. Vergroesen and L. Budke, Effects of different ionizing radiations on human cells in tissue culture II. Biological Experiments, Radiation Research 13, 841-849, 1960.

18. Barendsen, G. W., "Impairment of the proliferative capacity of human cells in culture by α-particles with differing linear-energy transfer," Int. J. Rad. Biol. 8 (5), 453-466, 1964.

19. Mole, R. H., "Problems of low-level irradiation, pp 207-232 in Proceedings of Symposium on Internal Radiation, Heber, Utah, May 1969, Dougherty et al. eds., Pergamon Press, 1962.

20. Armitage, P. and R. Doll, "A two-stage theory of carcinogenesis in relation to the age distribution of human cancer," British Journal of Cancer 11, 161-169, 1957.

21. Fisher, J. C., "Multiple-mutation theory of carcinogenesis," Nature 181, 651-652, 1958.

22. Spiess, H. and C. W. Mays, "Bone cancers induced by ^{224}Ra(ThX) in children and adults," Health Physics 19, 713-729, 1970.

23. Upton, A. C., M. L. Randolph and J. W. Conklin, "Late effects of fast neutrons and gamma-rays in mice as influenced by the dose rate of radiation: induction of neoplasia," Radiation Research 41, 467-491, 1970.

24. Buldakov, L. A., E. R. Lyubchanskii, Yu. I. Moskalev and A. P. Nifatov, Atom Publications, Moscow, 1969; A. A. Horvath, trans., and R. G. Thomas, ed., pp 192-193, Lovelace Foundation Report LF-tr-41, June 1970, Albuquerque, New Mexico.

25. Little, J. B., A. R. Kennedy and R. R. McGandy, "Lung cancer in hamsters by low doses of alpha radiation from polonium-210," Science, 1975, (in press).

26. Radford, E. P., School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland personal communication.

27. Brues, A. M., "Critique of the linear theory of carcinogenesis," Science 128, 693-699, 1958.

28. Burch, P. R. J., "Radiation carcinogenesis: a new hypothesis," Nature 185, 125-134, 1960.

29. Raabe, O. G., G. M. Kanapilly and H. A. Boyd, "Studies of the in vitro solubility of respirable particles of ^{238}Pu and ^{239}Pu oxides and an accidentally released aerosol containing ^{239}Pu," pp 24-30 in Inhalation Toxicology Research Institute Annual Report 1972-1973, Lovelace Foundation, Albuquerque, New Mexico, LF-46, 1973.

30. Raabe, O. G., H. A. Boyd, G. M. Kanapilly, C. J. Wilkenson and G. J. Newton, "Development and use of a system for routine production of mono-disperse particles of $^{238}PuO_2$ and evaluation of gamma emitting labels," pp 1-9, Inhalation Toxicology Research Institute Annual Report 1972-1973, Lovelace Foundation, Albuquerque, New Mexico, LF-46, 1973.

31. Fleischer, R. L., "On the dissolution of respirable PuO_2 particles," submitted to Health Physics, August 1974.

32. Park, J. F., D. L. Cott, D. K. Craig, R. J. Olson and V. H. Smith, "Solubility changes of ^{238}Pu oxide in water suspension and effect on biological behavior after inhalation by Beagle dogs, Proc. Third International Congress, IRPA (in press).

33. Bair, W. J., J. E. Ballou, J. F. Park and C. L. Sanders, "Plutonium in soft tissues with emphasis on the respiratory tract," Chapter 11 in Handbook of Experimental Pharmacology XXXVI, Springer-Verlag, Berlin, Heidelberg, New York, 1973.

34. Moskalev, Y. I., "^{239}Pu: Problems of its biological effect," Health Physics 22, 723-729, 1972.

35. Warren, S., "Specific effects of irradiation on the lung," 303-307 in Internal Radiation, Proceedings of Symposium, Heber, Utah 8-11 May 1961, Pergamon Press, 1962.

36. Gates, O. and S. Warren, "The production of bronchial carcinoma in mice," Am. J. Path. 36, 653-671, 1960.

37. Muller, H. J., "The biological effects of radiation, with especial reference to mutation," Act. Sci. Ind. No. 725, 477-494, 1938.

38. Burch, P. R. J., "Radiation Biophysics," Chapter 11 in Principles of Radiation Protection, K. Z. Morgan and J. E. Turner, eds., John Wiley & Sons, Inc., 1967.

39. Horn, H. and L. E. Finkelstein, "Arteroscierosis of the coronary arteries and the mechanism of their occlusion," The American Heart Journal, 655-680, 1940.

40. Benditt, E. P. and J. M. Benditt, "Evidence for a monoclonal origin of human atherosclerotic plaques," Proc. Nat. Acad. Sci. U.S.A. 70(6) 1753-1756, June 1973.

41. Elkeles, A., "Radioactivity in calcified atherosclerosis," British Journal of Radiology 34, 602-605, 1961.

42. Elkeles, A., "Atherosclerosis and Radioactivity," Journal of the American Geriatrics Society 14(9), 895-901, 1966.

43. Elkeles, A., "Alpha-ray activity in coronary artery disease," J. Amer. Geriatrics Soc. 16(5), 576-583, 1968.

44. Mitchell, J. R. A. and C. J. Schwartz, Arterial Disease, Blackwell Sci. Publ., Oxford, 1965.

45. Sheehan, J. F., "Foam cell plaques in the intima of irradiated small arteries," Arch. Path. 379(5), 297-308, 1944.

46. The Health Consequences of Smoking, January 1973, seventh of a series of reports of the Public Health Service, U.S. Department of Health, Education and Welfare, (U.S. Government Printing Office, Washington, D.C. 20402, $1.85).

47. Nelson, I. C., K. R. Heid, P. A. Fuqua and T. D. Mahony, "Plutonium in Autopsy Tissue Samples," Health Physics 22:025, 1972.

48. Lagerquist, C. R., S. E. Hammond, D. L. Bokowski, and D. B. Hylton, "Distribution of plutonium and americium in occupationally exposed humans as found from autopsy samples,: Health Physics 25, 581-584, 1973.

49. Hempelmann, L. H., C. R. Richmond and G. L. Voelz, "A Twenty-Seven-Year Study of Selected Los Alamos Plutonium Workers," Los Alamos Scientific Laboratory report LA-5149-MS, 1973.

50. Hempelmann, L. H., W. H. Langham, C. R. Richmond and G. L. Voelz "Manhattan Project Plutonium Workers: A Twenty-Seven Year Follow-up Study of Selected Cases," Health Physics 25:461, 1973.

51. Little, J. B., E. P. Radford, H. L. McCombs and V. R. Hunt, "Distribution of polonium in pulmonary tissues of cigarette smokers," New Engl. J. Med. 273, 1343-1351, 1965.

52. Watson, S., "Only vertebrates with a lymphatic system are subject to malignant disease (Ullman)," Medical Journal of Australia 52, 993-994, 1965.

53. Oliver, R. and S. Watson, "The lymphatic system--a storehouse of long-stay deposits of inhaled radioactive particles," Health Physics 12, 720, 1966.

54. Proceedings, Conference on Distribution, Retention and Late Effects of Thorium Oxide, Ann. N. Y. Acad. Sci. 145, 523-858, 1967.

55. Gofman, J. W. and A. R. Tamplin, "The question of safe radiation thresholds for alpha emitting bone seekers in man," Health Physics 21, 47-51, 1971.

56. Moss, W. D. and E. E. Campbell, "Plutonium concentrations in tissues of a general population," Health Physics 22, 933, 1972; Los Alamos Sci. Lab. report, LA-4875, 1972.

57. Lewis, G. P. and L. Coughlin, "Lung 'soot' accumulation in man," Atmospheric Environment 7, 1249-1255, 1973.

58. Martell, E. A., "Actinides in the Environment and their Uptake by Man," NCAR Report of a study carried out for The Energy Policy Project, sponsored by the Ford Foundation, 1975.

59. Martell, E. A., "Evaluation of the cancer risks from insoluble particles of low specific alpha activity in man," proposal submitted to U.S. Environmental Protection Agency, October 1974.

Chairman Mills: Thank you, Dr. Martell.

Is it your understanding that the Transuranium Registry has more than 26 or 27 Los Alamos workers?

Dr. Martell: I find several things wrong with the Transuranium Registry. First of all, participation on the part of Rocky Flats wrokers has been -- the last time I checked -- something like six percent of current employees and very few in the past, I do not know anything about the size of the Los Alamos group.

Chairman Mills: I think we are talking about several hundred?

Dr. Martell: If we look at past plutonium workers, and if we do not have any preconceived notions about how much of a plutonium organ burden causes serious health effects, then we should look at all past plutonium workers, at Rocky Flats and elsewhere. I am sure that this involves between ten or twenty thousand people, if we can find them.

Chairman Mills: But, there are more than the Los Alamos in the Registry at the present time, is that your understanding?

Dr. Martell: You will have to get a report from the

Registry people. I only know that from Rocky Flats, where we have had the largest number of plutonium workers over the past 20 years, there is only a token and recent participation in the Transuranium Registry.

I was also going to comment that the cause of death was given in the case of Hanford plutonium workers whose autopsy samples were examined. You will see there they selected only those who exceeded 5 femtocuries per gram of tissue which is about 5 picocuries for a particular organ burden. Most of them died relatively early of coronaries.

It is suggested that we need good statistics on this. As I say, if it be demonstrated that the cancer agent in cigarette smoking is the insoluble alpha-emitting particle, then it only takes a few picocuries in a chronic exposure case to give you a significant risk. You will note that cigarette smokers have only 2 to 2.5 times the nonsmokers risk of an early coronary. But the male heavy cigarette smoker is dying 16 years earlier as the mean time of death from a coronary than the nonsmoking male. Thus, it is not just the relative risk because this is an important cause of death in the general population. In these cases, you have to look at the mean time of death. This is why we should have a comprehensive study of all past plutonium workers, for the benefit of future workers -- for the benefit of getting the most responsible standards we can for them and

for the public. I make some specific recommendations based on my judgments in this matter in the latter part of my written testimony. But I will not take the time to go through it here.

Chairman Mills: I think in your statement -- I just glanced at it -- you made the statement that the linear hypothesis is not conservative for the insoluble plutonium particle. Would you say the same for soluble plutonium?

Dr. Martell: I am glad you brought this up, because one of the things I meant to point out in connection with the difference between artificial alpha activity and natural, is the fact that all natural activity inhaled or ingested is in water soluble form and is soluble in body fluids. The main sources of radium in man come from drinking water and from radium taken up from the food chain. And the main sources of lead-210 and polonium-210 include surface contamination on plant foods and inhaled particles. In all of these cases, the alpha activity, except for plutonium activity, are in soluble form on the surface. So, all normal alpha intake in a natural clean environment is soluble. And all artificial alpha radioactivity that accumu-- lates in various organs, as I suggest here, are insoluble. Plutonium oxide characteristically is insoluble. Lead-210 that comes from coal-burning effluents may be associated with insoluble particulates. But in tobacco smoke, it is a

high specific activity particle that is exceedingly insoluble in body fluids and, for that matter, in strong acids. And so there is this characteristic difference and it makes a tremendous difference. People living in urban areas who are not cigarette smokers have only about 10 percent of lead-210 and polonium-210 in their lungs in the form of insoluble particles. But the specific alpha concentration of those particles is about 50 to 100 times as high per milligram as the 90 percent that is dispersed in soluble form. Now, we do not have good measurements for heavy smokers at various tissue sites yet. However Arthur Elkeles showed that, in the arterial wall the alpha activity in the insoluble form in plaques is about 5 to 100 times the natural level. So, I am just pointing out, there is this major difference. And therefore the pattern of cellular interaction is completely different for natural alpha activity in the body and for the particulate insoluble alpha activtiy in the body. It is not just a matter of comparing, in aerosols, the insoluble particulate alpha activity with other insoluble particulate. In the body we must separate these two alpha components. We see that the dissolved natural alpha activity tissue background is a major factor, and a major component in the nonsmoker, but even these people have focal points that may play a significant role in their health effects. I submit that as soon as we increase

the number and activity of the insoluble particle burdens, we may be shifting the whole pattern of diseases of old age -- the health effects of chromosome changes the cardiovascular diseases -- to earlier ages. This is what the cigarette smokers' experience is telling us. The whole pattern of health effects is rougly 15 years earlier for the two-pack-a-day cigarette smoker. Is the same effect taking place in the plutonium worker -- in the plutonium experience? I submit that the AEC has not conducted the comprehensive epidemiological study necessary to answer that question. And I think it bears answering.

Chairman Mills: Are there any other questions?

Dr. First: I think this was in your unwritten testimony, so I would like to ask you a question. Did I understand you to say that 50 percent of the airborne insoluble particles containing plutonium are a respirable fraction?

Dr. Martell: I should say 25 to 50 percent. This was based on -- it was higher for the the higher wind concentrations -- a limited number of measurements made by the AEC Health and Safety Lab with two different methods of measuring the size distribution of airborne particles. These are not my measurements. One expects that when a small particle is attached to a larger soil particle, it will stay put, but that does not seem to be the case. Either the physical action during the process involved in retrainment detaches

them, or a significant fraction may simply remain detached because plutonium oxide is so dense and so friable. You also have the alpha recoil process that could detach them. Thus, in the case of plutonium and any other high specific activity alpha-emitting particulate, you have a special, a perhaps somewhat unusual behavior.

Dr. First: Well, this means, I take it, that the air monitoring samples which are taking the entire sample are represented by somewhere between 50 and 75 percent of non-respirable particles; is that a correct deduction?

Dr. Martell: No, it is more than that. It is a very tiny fraction, something like one part in 60 to 300 of the bulk of the retrained soil that is in the form of insoluble particles of respirable size, particles less than 5 or 6 microns in diameter. A large fraction of the plutonium is in that interval, but very little of the bulk soil is in that fraction. In addition you have the further problem that we have to confine ourselves to the insoluble particulates if we want to see what fraction of the lung deposited material is going to persist and be accumulated there or be transolocated to other organs.

Dr. First: What I am trying to get at is that the air monitoring samples are total insoluble dust; is that correct?

Dr. Martell: That is total dust.

Dr. First: This is analyzed for plutonium content?

Dr. Martell: Right.

Dr. First: Am I drawing the correct conclusion from your statement that of the plutonium, insoluble plutonium in the total dust, only 25 to 50 percent is in the respirable size, and that 50 to 75 percent is nonrespirable; is that correct?

Dr. Martell: That is correct. And in that same connection, it is such a small fraction of the soil that is in respirable size particles that are insolbule that, as a consequence, one picocurie per gram of bulk soil means 10 to 100 picocuries of plutonium in insoluble particulates of respirable size. So, the size fractionation and solubility fractionation gives you between one and two orders of magnitude Pu enrichment in the size of more serious character, of the respirable size fraction.

Dr. First: I am afraid I do not follow that. Are you saying that the total aerosol sample is both soluble and insoluble?

Dr. Martell: The total aerosol sample is mostly bulk materials made up of particles too big to inhale.

Dr. First: No, I am talking about the plutonium fraction.

Dr. Martell: The plutonium fraction, in a limited number of measurements, was between 25 and 50 percent in particles of respirable size. But, when viewed as activity

concentrations in particles of respirable size, this becomes 10 to 100 picocuries per gram for a soil that has one picocurie per gram. So, looking at it this way, it is easy to see that chronic exposure to urban dust or surface soils that have one picocurie per gram will have an expected steady-state lung burden of 10 to 100 picocuries per gram in the accumulated dust. As I said before, you can expect somewhere between one-half gram and one and one-half grams when you go from a young adult to an old adult.

Dr. First: But, this is what you have accumulated over a period of some decades; is that right?

Dr. Martell: Yes, that is right. But, I have been talking about chronic burdens and chronic health effects. And so the fact that it takes time to accumulate these burdens is beside the point. The main question is, "what are the health consequences, and to what extent do they give rise to higher tumor incidence and the whole pattern of diseases of relatively old age? To what extent does it translate these effects to increased risks at middle age?" I think that this is the main issue here.

Chairman Mills: Doctor Taylor?

Dr. Taylor: Just one question, you are proposing or recommending more extensive epidemiological studies of people who have been exposed to various levels of transuranics, of plutonium particulate?

Dr. Martell: Yes.

Dr. Taylor: Now, by whatever model or hypotheses you use for dose effect relationships, and I do not think any of them are worth an awful lot when you come right down to it, you ought to be able to make some kind of modest estimate as to the size of sample that you would need to determine a given percentage effect within given confidence levels. This has been done for some other types of conditions other than those elements. Have you made any such estimates as that?

Dr. Martell: Not specifically. I have recommended the experimental appraoches that might be used to assess the risk in the general population, especially for the cigarette smokers in the general population, and of course the same considerations would apply to plutonium workers. There are sensitive techniques for looking at the alpha activity burdens of tissue, and you can look at insoluble particulate per gram as well as soluble activity per gram in various organs. If you follow the type of study that has been done for uranium miners, and if you determine the concentration of activity and burdens as a function of age in each group, it is an argument against my hypothesis if there is no correlation of tumor incidence with burden and cumulative dose. But, on the contrary, you may develop a very nice dose-risk relationship similar to that which they are find-

ing for the uranium miners. There are obvious approaches for testing this hypothesis, and I suggest that, regardless of the merits you may think it has, I think that the stakes are so large that we had better look at every possible hypothesis and mechanism that we can conceive of and that can be justified. And we had better test these in detail before we commit ourselves to accept any one of them.

Dr. Taylor: I certainly agree with that in principle. The uranium miners, however, represent exposures that are enormous compared to any that I believe were involved in the cases of plutonium exposures.

Dr. Martell: On the contrary, I would disagree with that because uranium miner doses have been averaged over the actual depth of tissue in cells being irradiated, and we are talking about doses here that range from tens to a few hundreds of rads -- that is, cumulative alpha doses -- in some of the miner groups that show significant tumor incidence. This dose range is way below that of the animal Pu inhalation experiments. We are getting away from the excessive waste of radiation by overradiating the cells around the hot particles. I think that it is very easy to extrapolate from the uranium miner dose experience and tumor incidence to the tobacco radioactivity levels and doses and tumor incidence. Thus, if we can extrapolate in this lower range without difficulty, then I suggest that my interpre-

tation of the hot particle risk, as due to a very small fraction of dissolved or ablated material, also deserves a very careful look. Now, you can test that experimentally also. In fact, it is already apparent from the differences for plutonium-239 and -238 -- the rate of translocation, the tumor incidence, etc. -- all tell you that something like this is going on. I think you could base my hypothesis on the difference in results for the Los Alamos and Battelle experiments. But I think that if you approach it from the low dose rate level, then it becomes more apparent that we are dealing with only a very tiny fraction of the dose and the dose rate for the hot particles.

Dr. Taylor: I am not an epidemiologist, but I do not share your optimism about the ease in which you can make these extrapolations, and I hope that before we spend a lot of time and effort on this, that you have a good team of epidemiologists take a look at the planning of this type of study, because I think too many studies of this sort have been made largely retrospectively, and which of course they have to be in this case, but also on not too well conceived, in my opinion, judgments as to sample sizes, as to technology, and so on. I do not profess myself to be any expert in epidemiology.

Dr. Martell: I would say one thing about this, a uranium mining group is generally a small and unsatisfactory

group to study effects of this kind. But, I suggest that we have never before had a human experiment that involved a large number of people like the cigarette smoking experience. And I think we should look carefully at the nature of the changes in tumor cells, and the difference in the effectiveness of alpha-emitters as opposed to the weak chemical carcinogens. We ought to test this possibility, realizing that cancer in smokers may be the result of insoluble alpha-emitting particles. As I say, we can make an impressive argument for alpha-induced tumors at sites other than the bronchial epithelium in smokers. But, now there also is another larger group than uranium miners -- the plutonium workers. I would say, there must be somewhere between ten and twenty thousand plutonium workers, past and present. And if we got a larger sampling in the Transuranium Registry and assessed the kinds of burdens plutonium workers have in various facilities, and in various departments for various periods of work, I think you would have a pretty good idea what the exposures were for those you do not do autopsy samples on. So, if we combine a good analysis program with an epidemiological study, this group is large enough to get some meaningful epidemiological results. It certainly ought to be tried. Up to the present time, as you know, the medical followup has been limited to a handful of people, 26 at Los Alamos, a few elsewhere, who have exceeded this so-

called, 16 nanocurie, permissible lung burden. As a result we do not have any statistics. We must have this before we go much further.

Dr. Garner: If your hypothesis is correct, you should be able to compare the inhalation of insoluble plutonium particles with the effect of the inhalation of tobacco smoke? Can you tell me what concentration of plutonium in an average person is equivalent to smoking one pack of cigarettes a day?

Dr. Martell: Yes. Then I will tell you why this is not a reasonable procedure. First of all, the average organ burden of the general population of the Northern Hemisphere of plutonium from fallout alone is about 0.5 microcurie per killogram of lung tissue, and 0.7 picocuries per killogram of liver tissue. We already have got this. Now, this is about 10 percent of the typical heavy smoker's burden. And if the above agrument is correct, fallout levels in man are already contributing significantly to cancer and other diseases of old age. In other words, it appears that, in the pre-atomic age, people who lived in clean rural environments would be expected to live a lot longer. I will not compare them directly, I will not equate a picocurie of plutonium in a hot particle with a picocurie of polonium-210 in smoke, because, you see, there is no waste of alpha radiation in the low activity smoke particle. I would say

that I would equate similar burdens of uranium oxide and thorium oxide and certain alpha-emitters in industrial pollutants with the smoker particles. But, I think it would take something like 100 times as much plutonium-239 to have the same effect because you are wasting so much of the radiation instead of dispersing it in tissue with a large population of particles. Now, as you go to very much higher specific activity particles, however, or if you go to smaller particles of higher specific activity, then the surface ablation and dissolution rates go up. Thus, you irradiate many more cells and you get a more rapid translocation. So, you will have a higher risk in all organs.

On this basis, I would say that perhaps plutonium-239 is somewhere near the minimum in tumor risk among alpha-emitters. If we come to lower activity particles, there is a higher tumor risk per alpha disintegration by my hypothesis, which is, simply, the old somatic mutation theory of carcinogenesis. At the other extreme, for the hotter particles, you have a population of high specific activity particles, generating small fragments and molecular dispersed material which can migrate through tissue and irradiate many cells without an excessive dose. Now, I think that is the key. My own conclusion, tentatively, is that the way to produce cancer with alphas is to irradiate as many cells as possible with a very low interaction rate,

a risk proportional to R^2 t^3. It would apply approximately in the low dose rate range up to a few hundred rads cumulative dose. As soon as you get above that dose -- as soon as you start hitting each chromosome two or three times per cell generation -- then you have got to put in other factors. You will begin to waste the radiation, and you will be killing the mutated cells. Therefore, from that point on, it takes more and more activity to do the job. Once we get high enough in specific activity, you will start the process all over again by a different mechanism -- by ablation and dissolution of extremely hot particles which is a function of particle surface area and specific activity.

Dr. Garner: Just to come back to the ablation business, you mentioned this that the plutonium deposit on soil would greatly assume smaller and smaller size, but at the same time you have got the compensating factor that this stuff is moving down in the soil in a sort of profile. I think this is a proven fact that it does move down.

Dr. Martell: There is something very interesting about that. The only old profile of plutonium is that down at the Trinity site, the site of the first nuclear explosion, in New Mexico. There one finds that there is a higher rate of vertical transport downward in the soil for the higher specific activity plutonium-238. Plutonium-238 migrates more rapidly downward than plutonium-239, but it also shows

a remarkable increased uptake in the biosphere. It is highly enriched in vegetation and in small animals in this region. So, the very properties of higher specific activity that make it more mobile in soils also makes it more mobile and more readily taken up into the biosphere and man. Therefore, I am not reassured by an aging process which makes it more available for biological uptake at the same time as it tends to weather and degrade it. You have to look at all aspects of these limited observations to appreciate the full implications of weathering.

Dr. Morgan: Dr. Martell, I was fascinated by your presentation and your theories. You refer to the theories, explanations of Philip Burch, Robin Hall, and others, namely that prolongation of the alpha radiation of the chromosomes or protracted radiation is greater than the high dose, this you realize, of course, is borne out by the rather recent observations on radium-224 studies by Mays at Salt Lake City and Spiess, and others, namely that with the protraction of the dose you get a higher carcinogenesis.

Dr. Martell: Yes.

Dr. Morgan: I feel also that your point is well taken that we should look at other indices besides lung cancers, bone tumors, in the case of plutonium, for example, look at things like arteriosclerosis. You realize, course, for many years it was felt that Thoratrast was a completely safe

material to use as a contrast medium. Thorium is very much like plutonium, and it was only 30 to 50 years later that these cases of epatic tumors began to show up, so at these low levels of exposure it may be that we are not even focusing on the primary target. I feel that a hypothesis, however, is only as good as its experimental evaluation, and you mentioned the case of the spallation of plutonium particles and using this as a possible explanation for the greater risk of plutonium-238 as against plutonium-239. You also mentioned that the risk seems to vary with R^2 t^3. I wonder if these same relationships can be checked with your studies on Polonium-210 and the cigarette smokers. Is that a possibility?

Dr. Martell: Well, it will take a bigger effort than I have at my disposal. My research group working on this problem is one full-time experimental assistant, one-half-time student assistant, and the occasional assistance of one professional colleague. There are only a limited number of things that we can do. What we are doing now is working with Dr. Radford on lung tissue and lymph node tissue specimens from deceased smokers and nonsmokers. I am discussing possible collaboration with two different groups that are concerned with the nature of arteriosclerosis plaques and their alpha activity concentrations. We are doing a few preliminary tissue measurements of main aorta tissue at the

present time. We are also taking some large tissue specimens from the lung and other sites, and are separating the insoluble and soluble components and measuring lead-210 and polonium-210 in each fraction, so that we can directly get at the kind of specific activity distribution in advance of being able to do a separation of particular segments of the tissue that have higher concentrations.

Dr. Morgan: Do you get spallation from these parts?

Dr. Martell: I mentioned spallation work only because it is a very nice analysis to explain the observed rapid migration and the apparent higher dissolution rate for the hotter particles. It was done by a Dr. Robert Fleischer, an outstanding man from the General Electric Research Laboratory in Schenectady who has done a lot of work on the development of fission track techniques of analysis of transuranium elements and isotopes. Simple experiments could demonstrate whether this hypothesis of his is correct or not. But, you see, even if it is simply a rapid dissolution of high specific activity particles as a consequence of radiolysis of fluids and the chemical reactivity of free radicals formed -- even if that is the case -- then we know from experience that this dissolved activity will, in course of its migration away from the hot particle, coagulate, leading to the formation of small focal points of activity. There are a number of studies of inhaled, dissolved soluble compounds of plutonium which have demonstrated the formation of these

focal points. If you start with dissolved activity, you get particles. If you start with particles, you degrade them. So, we are almost always dealing with small focal points of plutonium, no matter whether you start with dissolved activity or with particles. And the specific activity and surface area will determine to what extent the hot particles degrade into smaller materials. If you have dissolved materials, you are still going to wind up with concentrated focal points of low activity, but not a uniform distribution. You essentially never get a uniform distribution for plutonium, no matter what compound you start with.

Chairman Mills: If there are no more questions, I would like to declare a five-minute recess.

(Whereupon, a short recess was taken.)

Chairman Mills: If we could, we would like to move along. We are determined to get this hearing completed today or tonight, therefore we appreciate the patience of a lot of speakers staying with us until we get through with the thing.

The next speaker is Mr. J. Fowler of the Colorado Organic Growers and Marketers Association. Is Mr. Fowler in the audience?

(No response.)

Chairman Mills: Perhaps we could go to the next speaker and come back to Mr. Fowler.

Based on available public information, I and others at UNC have determined the total quantity of plutonium-239 and americium-241 that have been spread over the Rocky Flats area during the last 15 years. I might say this was extremely difficult, since the figures published were in different units and made a difference, and we do not know now whether the units that I am going to give you include the americium or they do not. But, we believe that certainly if we just take the information that I have and it is quite extensive, it does appear that somewhere between 13 1/2 and 16 1/2 curies of plutonium have been spread over the Rocky Flats area, and perhaps up to 3 1/2 curies of americium-241. As far as I know, you could either subtract the amount of americium or you could add it.

Also, we would like to support the Colorado Public Health 239 toxicity figure of .2 of a DPM per gram instead of the higher figure of 2 DPM, because we belive that the Academy of Science information of two years ago which I have in here as a reference indicates that the lower figure would be a much better figure.

It is interesting to note that Colorado is one of the few states that does have a toxicity of limit on land areas, and if I am correct, neither EPA nor AEC has the toxicity requirements for areas, and neither EPA, AEC, CPH have toxicity requirements for americium-241, which is certainly

I find that it is much easier to obtain information concerning the hazards of radiation than it is to find out that a meeting such as this is being held. We citizens certainly were without early alert, but I hope that the policy makers are not so slow when it comes to stopping this radiation hazard.

I am a natural hygienist, and as one, know that our health is maintained with sunshine, rest, fresh air, and pure water, as well as unpoisoned food, and know that our health will be upset and we will get cancer and leukemia from radioactive debris in our soils, our food, and our water. I do not want these plutonium particles in my lungs, and I do not want them on my apples.

Dr. Virginia Vetrano, a natural hygienist practicioner from San Antonio, Texas, has been compiling information about the hazards of radiation since 1954. Her findings indicate that younger people, those born since 1942, have more heart deformities which cause heart murmurs than those born before the war. Now this could likely be one of the effects of ionizing rays. It may not be 100 percent conclusive of radiation effects, but the timing indicates a good possibility. We have got considerable reason for concern in the fact that leukemia and cancer have been increasing so fast that one in every three or four persons is now destined to contact cancer. We doubt that we could

afford to let any extra contaminants that might cause these to increase to be released. Now, Charlevioux County, Michigan, has an infant mortality rate 49 percent higher than the State, and the immature infant rate is 18 percent higher, leukemia 400 percent higher, cancer deaths 15 percent more, birth defects 230 percent higher than the State. Charlevioux County is the site of the Big Rock Point Nuclear Power Plant.

Dr. Linuis Pauling, a Nobel Prize recipient, states that the only safe level of strontium 90 in the bones of children is zero. He also tells us that radiologists have a five-year shorter life expectancy than physicians. Now, Time Magazine in 1962 carried a news summary showing that constant exposure to radium was causing a higher rate of deformities among radiologists than the general public.

Schubert and Lapp explains how rapidly dividing cells of embryo in young children are more sensitive to all kinds of radiation and are very easily damaged. An older person receiving a dose of radiation has a better chance of dying before he develops cancer, but there is more than ample chance that infants will develop cancer early in life.

There is already as much or more background radiation than we stand. This, of course, has been increased by x-ray, T.V., and past nuclear tests.

Dr. Phillip Bursch (Director of Environmental Health

Research in Leeds, England) finds that four of every 1-thousand cases of cancer is due to natural radiation.

The Journal of American Health carried an article reporting that there are 50 percent more deformities in the areas of New York where there is a higher background of radiation.

Dr. Herman Muller, a scientist who over 40 years ago experimented with the fruit fly, came to the conclusion that there is no dose so small that it does not cause mutations.

Experiments with animals were carried on at the time of the Manhattan Project. They found that one group of animals, given so small a dose of x-ray as to think there was no concern, showed no effects at first but later generations did begin showing genetic damage and this lasted as long as 21 to 23 generations.

George Weil, author of "Nuclear Energy Promises," states that there is no way to completely contain elements from an operating power plant, and that release of these into the environment is routine, and that they rapidly pass through the food chain causing leukemia, cancer, and genetic damage which may show up years or generations later.

Drs. Golfman and Tamplin, of Lawrence Radiation Laboratory in California and the authors of "Poisoned Power," state that there is no way that nuclear power can be generated without also generating radioactive poisons. Once these are

released into the environment...and they believe that this is likely to occur...the pollution of the environment will be irreversible and will remain so for centuries.

Shubert and Lapp state that no cell fully recovers from a dose of radiation. While cells may appear to recover, there is irreversible damage to the genes and chromosomes.

Dr. Grubbe, who was the first to use x-ray in attempting to treat cancer, died a painful death from radiation-produced cancer which caused his arm, some of his fingers, and chin to be eaten away. He was concerned about his plight and others that might be exposed, and he emphatically proclaimed that all ionizing rays are dangerous.

Now, test analysis for testing animals is not altogether conclusive, for Shubert and Lapp found that man is more susceptible to ionizing rays than most animals. It takes twice as much to be a lethal dose for a rat as for a man, and a cockroach can stand a lot more than either one of us.

Now, since we do not drop dead from the effects of these rays, the AEC, it seems, have been bidding on the fact that we, when we have problems with cancer, leukemia, and deformities, would not know where our problems came from. We will not be able to trace them.

Roswell Park Memorial Institute, this seems to be a part of the Department of Health of New York, state there are hazards of a reactor blowup that would make headlines,

but the invisible genetic damage done during routine operations is of more serious risk and cumulative promises show that painful death for children would result, and many of these are still unborn. Often visible effects will show up during the life of the person exposed. They conclude that a single x-ray plate seemed to be of little risk to an individual, but invisible damage, that to the genes, and materials of cells, this damage can show up in the one who has been exposed to this x-ray, his children, and his grandchildren, and follow on from there.

They also found that x-ray during pregnancy strikingly increases the child's allergies and certain diseases. This increase was 5-hundred percent. They found that supposed safe levels of x-ray radiation dosages resulted in children being vulnerable to leukemia and other diseases. Many of these children would not live long enough to get leukemia. See, that might be one of their advantages.

Alex Carrol, Nobel Prize winner who wrote "Man the Unknown," states that man knows quite a bit about science and he knows quite a bit about medicine. But what he does not know is an awful lot more. I think where us citizens are really concerned is that there is considerable known damages, there is considerable known hazard, but there might be a lot more than we yet know about. Now, since the insurance companies are free of the hazard, the Government will

not cover us. But, these people are not going to protect us. Who is? Norway and Sweden do not seem to want nuclear power plants. If they do not want them since they do not have vested interests there, I do not think we might want them here. I am concerned for my fellow man, for the unborn children, and I hope that the policy makers will have the courage and the conscience to protect us by setting a zero standard for radiation above what we normally have. It will be too late if it requires a disaster to stop this menace.

Now, I have brought a paper here, and since we thought that the AEC was protecting us, it states -- I would like to read what the AEC has to say, while we were under this assumption. This is May 4, 1974:

> "The Atomic Energy Commission announced that a cloud of radioactive tritium accidentally discharged from its Savannah River plant was drifting across South Carolina. At 200 feet, the cloud will dissipate in "a matter of days.' 'The hazard comes through breathing or ingestion,' said AEC's spokesman."
>
> "On March 15, another 2,500 gallons of highly radioactive fluid leaked from storage tanks in Hanford, Washington, making the total amount leaked since 1958 approximately half a million gallons. It is the seventeenth such leak reported, this one was spotted with new atomic detection equipment installed last year. The AEC's representative said the liquid is expected to be absorbed in soil before it reaches the water table, 210 feet down."
>
> "In February 1973, the AEC's former top secruity officer, William T. Riley, was sentenced to three years' probation. --

Chairman Mills: Mr. Pelton, I am really not sure that is relevant to our purposes to getting information on stand-

ards, I think. So, could you confine it to those remarks?

Mr. Pelton: I guess I was getting around to the fact that I was trying to conclude more that we probably have not had very much protection from the AEC. As concerned citizens, we would like some more, and we hope we can get it from whoever the policy makers are now.

Chairman Mills: Thank you very much. I had on my agenda your name was Felton, but I assume it is Pelton, "P" as in plutonium?

Mr. Pelton: "P" as in plutonium.

Chairman Mills: Could you give us your full address?

Mr. Pelton: 3175 South Clarkson.

Chairman Mills: Are there any questions?

(No respone.)

Chairman Mills: If not, Mr. Fowler?

(No. response.)

Chairman Mills: Well, I will assume that he did not last.

Is Dr. Sorteberg here?

(No response.)

Chairman Mills: Is Dr. Anders from the University of Northern Colorado here?

(Whereupon, Dr. Anders approached the podium.)

Chairman Mills: Dr. Anders, will you give us your full address?

Dr. Anders: My address is 1525 - 15th Avenue, Greeley, Colorado.

In Greeley, we are preparing for the advent of the Saint Vrain Nuclear Reactor, and as you know, there will be two more reactors that are scheduled to go into this area. So, we are going to be having our hands full.

What we have done, though, in the past three and a half years is take a tremendous number of samples up there. We have taken air samples every day. We have taken water samples all over the area, and we have taken soil samples. I wish today that I could tell you that we could prove once and for all that plutonium oxide has been found in the samples, but I cannot at this present time. I hoped that I would have that information for you today, but I do want to point out that I believe we will show plutonium oxide getting as far as Greeley, and perhaps from Rocky Flats.

Dr. First: How far away is that?

Dr. Anders: That is about 60 miles directly --

Dr. First: Which direction?

Dr. Anders: Northeast approximately. Now the winds do not blow that way very often, but we are getting increased alpha counts, and we do not know whether it is plutonium or americium or what it is at the present time. The fact is we asked for assistance in this area and were turned down by the Public Health Department of the State.

I am one of the prime litigants that have been the litigant against EPA, and so far I have been quite successful. One thing I want to mention though is that I think EPA is absolutely required for the people of Colorado. We exist in the highest altitude where we have, as you know, the highest number of millirems, around 240 coming from natural resources. We have nine millirems that come to us from fallout, and then we get on an average of around 100 millirems from our doctor and dentist, and according to the Academy of Science, we do not have many millirems to go. So Lord knows, I do not know why we have so many radioactive designs on us up here. It seems that everyone wants to put something radioactive here, including the latest I heard is a possibility of putting a processing plant north of Greeley. So, we have got to try to help the EPA to do its job.

One of the ways that we could be helped, I believe, is to help us communicate with one another in this field. I give you the following example: I think I was the first to receive the isopleths of Rocky Flats information especially on plutonium. I got them early in 1971, and I tried to get the information out, and have been unable to. In other words, I was unable to get it through the local newspapers and of course they have their reasons for it. I am hoping that some day we might find a way of getting information like this to the people who would be interested in it.

Based on available public information, I and others at UNC have determined the total quantity of plutonium-239 and americium-241 that have been spread over the Rocky Flats area during the last 15 years. I might say this was extremely difficult, since the figures published were in different units and made a difference, and we do not know now whether the units that I am going to give you include the americium or they do not. But, we believe that certainly if we just take the information that I have and it is quite extensive, it does appear that somewhere between 13 1/2 and 16 1/2 curies of plutonium have been spread over the Rocky Flats area, and perhaps up to 3 1/2 curies of americium-241. As far as I know, you could either subtract the amount of americium or you could add it.

Also, we would like to support the Colorado Public Health 239 toxicity figure of .2 of a DPM per gram instead of the higher figure of 2 DPM, because we belive that the Academy of Science information of two years ago which I have in here as a reference indicates that the lower figure would be a much better figure.

It is interesting to note that Colorado is one of the few states that does have a toxicity of limit on land areas, and if I am correct, neither EPA nor AEC has the toxicity requirements for areas, and neither EPA, AEC, CPH have toxicity requirements for americium-241, which is certainly

as toxic as plutonium-239.

During the last several years, as I say, we have had continuous air sampling being taken in the Greeley area, and I have been present when the measurements were made. Many times the counters gave readings which were in excess of background count. As I have mentioned before, we are not sure where it is coming from, but we suspect that it is coming from down here. Dozens of examples, not dozens really, hundreds of samples since we have been doing it for three and a half years every day without fail await the EPA or state confirmation of our results.

Is has been established that the particle size of plutonium particles is a very important variable in establishing the toxicity to humans, and it appears to us then that the longer plutonium oxide particles are left alone, the more toxic it will become. Therefore, it does appear that this is so; we have to get rid of what is out there or perhaps the transferring of Rocky Flats. Therefore, it is suggested that EPA include particle size in its toxicity standards.

Finally, I have included a copy of the recent history of Rocky Flats, a document I made for the Rocky Flats Action Committee. I hope you will find it useful, because it gives a complete history of the Rocky Flats area. I have many questions I would like to ask, but I have put them in a form here so you might be able to answer them for me.

RECENT HISTORY OF ROCKY FLATS

BY FRANK W. ANDERS 24082

(All information taken from Rocky Mtn. News or Denver Post) and many other local sources

10/10/52	Rocky Flats sited
2/7/69	Rocky Flats to get $113 million for new plutonium recovery facility and 4,640 acre buffer.
5/5/69	Rocky Flats Fire- AEC claims radioactivity escaping "minimal" 400 workders exposed "up to 17 times permissable levels".
9/29/71	AEC announces for 1st 6 months of '71 contamination of Rocky Flats is within limits.
1/4/72	Rocky Flats to get $130 million to avoid repetition of 1969 fire.
2/9/72	AEC finds 18 Dow employees were subjected to plutonium leak.
3/10/72	Dr. Martell disagrees with Colo. Health Dept. and AEC measurements of plutonium amounts around Rocky Flats.
10/19/72	Dr. Martell finds 5 curies plutonium east of plant boundary. Dow claims this from oil drums spillage, not from 1969 fire.
10/25/72	Dow and AEC claim plutonium in soil is not dangerous and state there are no limits on ground bearing radioactive wastes.
10/26/72	Dow summarizes for Jan.-June 1972: 7% of guidelines in air for plutonium, 1% for uranium, 6% for beryllium. In water 1% Pu, in drinking water .04% Pu. Be (yr)=4.3 grams
4/26/73	17 air samples at plant site exceeded annual average allowance of radioactivity. Average Pu concentrations were less than 2% of guidelines in air and water. CHD, EPA agree with Rocky Flats. Toxicity of Beryllium is at less than 2% of normal. During 1972 releases of long-lived alpha particles per year equalled 58 million pc+8.7 million pc from uranium enrichment. Community air samples Pu-24% of air standard. At plant <10% Pu standard. 2-4 miles from plant 2% standard air plutonium. For water at plantsite <1% standard for U and Pu. Off-site Walnut Creek .6%U, .5%Pu, <1% Am(in H_2O). Tap H_2O- .02%. In plants 300,000 pc/gm ash (dry grams).
9/7/73	Hundreds of tons of radioactive wastes are buried at the plant- buried for as 17 years. CHD declares no health hazard. CDH didn't know of this until 1969. Plutonium lying under 4" in asphalt at east side of plant will be removed many years from now.
10/10/73	Dow believes in threshold theory rather than linear theory. $1\frac{1}{2}$ years ago Dow had 150-180 workers with excess radiation patterns (15-20 of whom had abnormal amounts.
10/10/73	Dow refuses to name employees exposed to tritium to Union or anyone. Seven workers contain abnormally high amounts of tritium.
10/16/73	Lawsuit filed against EPA for not regulating contamination of Broomfield water supplies. EPA has no standards for radioactive discharges into water- especially for tritium. AEC admits discharges of radioactive wastes into Broomfield's water supplies including Pu239, Am241, H_3 into Baseline, Ralston, Gr. West. Reserv., Stanley Lake.
9/20/73	AEC reiterates Dow not responsible for radioactive contamination found in Broomfield's water supply. SHD claims levels of tritium 1/100 maximum state regulations.

9/19/73 Discharge into Walnut Creek (tritium) ~1200 pc/l average but in July and August ~23,000 pc/l. Dow expects new plant in 1976 to solve problems. Walnut Creek supplies 2% of Broomfield's drinking water.

9/25/73 First announcement by State Health officals:
~Bldg. 771 102,440 pc/l
North Plant 33,000 pc/l
Broomfield 23,000 pc/l (water supply)

9/25/73 Broomfield City Council requested AEC to divert Walnut Creek from Reservoir. Aghast at time of discovery and notification at Governor's press conference- time lapse: April 24 to Sep. 14.

8/7/73 AEC says soil <u>above</u> RF burial grounds has never been sampled before!

Burials at RF were

1952-1968 ash from burning ¼ lb. depleted uranium
1954-1962 metal drums filled with Uranium scrap metal (thought it had been removed)
1954-1968 Number of empty crushed drums which had contained enriched U.
1968-1972 20-55 gal. drums of sewage sludge of U
1969- 320 tons of asphalt and contaminated soil from May, 1969 fire buried under bldg. 881!
1969- 6 curies Pu leaked onto ground from corroded drums (on east side of plant) Pu particles are [illegible] covering 30,000 sq. ft.
1970-[illegible] 1000-5 gallon drums of laundry wash water (contam.)
1956-1957
1961-1965 4 lbs. of depleted U waste burned.

10/10/73 Broomfield City Council went to Court to prevent AEC from discharging wastes.

12/8/71 Gov. Love: wants RF located elsewhere.

6/12/73 AEC to begin $113 million building in Oct.'73.Pu-$18,000/# Low level wastes being shipped to Arco Kdaho (only 75% reduction is forseen). New facility won't pollute: "be so low as to be of no significance to environment.")

10/18/73 Sr90 and other radioactive isotopes "of a classified nature" wer were found in small amounts in Walnut Creek.

12/21/73 New contract to run Rocky Flats will be let next month. AEC announces tritium was released from stacks in 1968 and "occasional" releases since 1970. 500-2000 curies tritium were released from stack at 779-A (From a Livermore shipment) Sr90 was found and will be monitored from now on.

3/21/72 Of 18 cancer deaths reported by RF, brain cancer is leading type of cancer with 4 male deaths followed by lund cancer with male deaths.

Short history of RF radiation incidents:

6/14/57	2 employees,	in glove box explosion, $31,000 cost
2/4/58	1 employee	changing filter
6/1/62	3	processing Pu
4/23/63		Nitric acid and Pu spillage
6/20/60		Leakage in Pu line $8,364 damage
6/12/64	1 employee	explosion glove box$56,500 damage
5/6/65	3	Leakage in Pu line $7,557 damage
10/15/65	10	Pu explosion $17,057 damage, up to 7 times lung burden
11/9/65	12	Pu explosion $23,253 damage
3/19/65	1	Torn glove in glovebox $1,306 damage, Up to 2½ times lung burden
3/30/67	3	Glove box (no shielding)
3/30/67	1	Am241 poisoning (excessive handling)
6/30/67	3	Pu radiation.
9/30/67	6	Pu radiation.
9/30/67	--	Pu radiation. $10,246 damage.
10/14/68	1	Pu fire (full burden)
3/23/69	1	Pu fire (4X burden)
8/22/71	1	Pu fire (16X burden)
2/8/72	1	Glove box rupture (4X full burden)

12/16/73 Tritium doesn't stay in body very long ½ that swallowed passes on in 12 days. 3,000,000 picocuries of Pu/liter during peak days now at is 3,000 pc/l (1,200 pc/l natural level)
The current international safety standard for maximum average radioactive (tritium) content is 1,000,000 pc/l!!
Drinking H_2O for 1 yr at 10,000 pc/l is equivalent to 2 mrem/yr compared to complete dental x-ray of 5000 mrem.

9/28/73 EPA to recommend new tritium limilt: 30,000 pc/l. In April CHD found 23,000 pc/l in Great Western Reservoir (water supply for most of Brcomfield residents; State standards are 1,000,000 pc/l! No specifications are assigned to actinide series.
Public health questions can't be resolved until 1981 (Dr. Rowe EPA)

11/8/73 AEC to divert Rocky Mountain wastes: proposal to quit putting 250,000 gallons liquid into Broomfield's water supply (60% industrial waste, 40% sewage)

9/16/74 Since 1953, according to AEC report of Rocky Flats 271 fires, 410 contamination cases, 25,000 drums of traces of plutonium. 3700 people work there. Plant cost $250 so far plus $45 million for 1969 fire plus $20 million for buffer zone. A new plant would cost $500 million.

9/7/74 1 curie tritium released into air (¼ max. allowed) Rain caused pools of 1/20 max believed to be from 1973 incident.

9/22/74 Truck loses RF containers, 16X24, empty, returned by passing material.

9/29/74 AEC: tritium release was traced to RF (not from outside AEC Agency).

3/21/72 According to Ed Martell: Pu239 1000 times normal at Eastern boundary to 10 times 43/4 mi. away (1 mile from Arvada). Normal Pu239 ~1500 pc/m^2 (from fallout). At eastern boundary Pu239: 2,000,000 pc/m^2 He says standards exist for Pu in air and water but not in vegetation or on ground. Dow claims wind and erosion can concentrate the Pu. Martell says Pu241 is not reported tho it decays into Am241. Also Pu239 toxicity in rats is same for man.

2/15/73 Hearing sontinue on Pu soil standards. Proposal 1+ disintegrati rate is greater than .2/minute/gm of dry soil then land is unfit for residential use. AEC is against soil pollution standards. Hanes, genl manager of RF, claims only 1 teaspoon of Pu is dispersed over 50 sq miles: "There is less radiation leaving our stacks and sewage plant than is coming into plant by satural source."

10/26/73 AEC admits error in tritium handling, but not in Pu wastes.

12/12/73 AEC invites bids for RF- before 1975 (July) Fire cost $50 million- most costly industrial fire in history. Dow admits Pu poisoning of area east of plant.

9/30/73 Dr. Sangoy Dasgupta was threatened with deportation because of AEC pressure for releasing info on chromosome damage on Dow workers (34).

7/8/73 Uranium-enrichment plant (@$2 billion) eyed for Rocky Mountains.

9/30/73 Tritium was traced to Bldg. 779. Chromosome changes were found in 34 workers at Dow by Dr. William Brandom. He said Dow workers' urine abnormally high in tritium.

9/20/73 Dow claims no tritium leakage from them: tritium passes thru body in less than 600 days and a non-Broomfield resident had 3600 pc/l of tritium in his urine because he wore a tritium painted watch. Broomfield's residents were harried and angry.

10/17/73 AEC claims discharges of tritium, Pu, Am into water supply. Of 3 Denver suburbs are well below permissable standards (Broomfield, Westminster, Thornton)

10/18/73 Possible aeration of sediments in bottom of retention ponds could account for Pu increase in Walnut Creek. Construction in this area may have been responsible. The retention ponds were drained if Pu were soluble it would not have been removed by water treatment. It would enter into drinking pond - 285 pc/l were found 10/2/72

9/26/73 Dow admits no tools to measure tritium. No beta emitters is measured./ Figures from CHD: 33,000 picocuries tritium per liter, (natural background= 1200 picocuries/l). Dow estimates 70 curies of tritium have leaked into environment (1 gram tritium=10,000 curies)

9/26/73 At plutonium recovery facility drain- CHD found 102,440 picocuries per liter. USGS is analyzing underground water at plant site. Dow doesn't know source.

10/25/73 CDH says radioactivity in Broomfield water supply not dangerous. AEC disputes CDH.

12/21/73 CDH responsible for monitoring Rocky Flats found the tritium releases described below. Wastes were not monitored by Rocky Flats before they were discharged into Walnut Creek.

12/21/73 Occasional releases of tritium have occurred at Rocky Flats since 1970 without a report being made to anyone.

12/21/73 AEC charged Dow failed to report accidental releases of radioactive materials in 1968- 600 curies of tritium thru smoke stacks and greater than 600 curies of tritium thru exhaust sytem into Broomfield reservoir.

1/16/74 AEC confirms that 'dangerous levels' of tritium were found in Great Western Reservoir. AEC will keep SHD apprised of all released substances. Nitrate levels rose to 8 times acceptable levels.

2/5/74 No Sr89,90 found by AEC, EPA finds 4pc of Pu per gram of sediment vs. .6pc/g earlier. No standards for Sr! Rocky Flats will not discharge any more Pu.

2/5/74 AEC finds 18.6 grams of Pu239 leaked into 2.85 acres of ground from buried drums of Pu wastes which had rusted. AEC said there are 17 other areas where wastes are buried- only 60 ft. from this area. is a 3 acre blanket of asphalt covering 86 grams of Pu spilled in '68./

2/7/74 124,000 ft^2 has 7 grams or 3 curies of Plutonium (24,000 yr. half life). Previous AEC reports show wind blowing plutonium contaminated oil into this area (security fence) between 1958-67. Vanderhoof shown 17 other contaminated areas. In SE sector 60 yds^3 of Pu contaminated soil was buried . Non-radioactive lithium buried in 1956-70 period. 'No health hazard.' In oil-drum storage field: 3,572 drums of Pu @ 1,254 drums of Uranium contaminated oil buried.

5/15/74 AEC finds 'no health problem' from Pu239 found in core samples driven into mud at reservoir area.

5/16/74 AEC finds radioactively contaminated mud in Miamisburg, OH and Hanford, Washington- newly formed teams search for contamination- all a result of Rocky Flats debacle.

6/1/74 Because of contaminated Miamisburg facilities, Monsanto withdraws from Rocky Flats bidding.

7/21/74 GAO tells AEC to warn pregnant women working at Rocky Flats and other plants of dangers to fetus arising from AEC standard at .5 rem. GAO says this figure is 10 times higher than Nat. Acad. of Science recommendation.

7/25/74 By Jan. 1975 a $\frac{1}{2}$ to 1 mile buffer zone will be bought for $11.6 million. This buffer zone will extend around Rocky Flats.

8/1/74 EPA accuses AEC and Dow of negligence and poor attitude in checking for tritium after it was found by CHD and confirmed by EPA.

RECOMMENDATIONS CONCERNING ROCKY FLATS (FWA 11/74)

1. Plutonium concentrations over land areas have no specifications whatsoever. Lethal limits must be sought, possibly 10% greater than fallout values.

2. The time between finding radioactive pollution and the time of reporting must be reduced from 3 years (nukes), 6 months (Rocky Flats) to days or hours.

3. Public permission must be given to Rocky Flats to check its radiation pollution. Also, the State Health Department must allow unbiased groups to analyze plant pollution.

4. Recriminations from AEC or others must be prevented whenever public information is involved. AEC must be severly limited in what it calls "security matters."

5. Investigations into finding other areas for Rocky Flats must begin now- before Nort West Denver is engulfed in pollution.

6. All radioactive materials and all chemicals produced by Rocky Flats must be analyzed. Only .1 of 1% is being analyzed for now on a continuous basis. To do this, State Health must be given more money for more qualified people and more exotic testing equipment.

7. The State Department of Health must not be given the power to veto other qualified groups from analyzing radioactive pollution.

8. US Government, State Government and private groups have specifications on radioactive pollutants which vary by as much as 6 orders of magnitude. These differences must be brought into line- pressing for the least toxic specification.

9. AEC must be prevented from buying more and more property, to hide its pollution. Putting land permanently "off limits" is the ultimate sin.

10. AEC must publish for all to see its isppleths on all material pollutants out to 100 miles.

11. Everyone must fight for the right to get adverse criticism of AEC into print. It is ridiculous to be told by the editors that they are afraid of being sued by AEC or PSC or any other powerful group.

E IRONMENTAL PROTECTION AGE /

JAN 24 1975

Dr. Frank Anders
University of Northern Colorado
Greeley, Colorado 80631

Dear Dr. Anders:

I am responding to the five questions you submitted to me at the recent Public Hearing in Denver on plutonium.

Question 1: "Do we have for Colorado today a capability of detecting and evaluating transuranium nuclides in either EPA, AEC, CHD or other facilities?"

Response: Yes, EPA, AEC, and the Colorado Department of Health have the capability of making measurements of the transuranic nuclides, especially for plutonium. The detection of americium, curium, and some of the other radionuclides, however, may involve considerable analytical capabilities. I believe that the testimony given by the Atomic Energy Commission, which was referred to by Dr. Burr during the hearings, should be helpful to you in this regard.

Question 2: "Has anyone made a calculation of the cost of removing Rocky Flats elsewhere?"

Response: Yes, there have been estimates made of the replacement cost for Rocky Flats. In 1970, this cost was estimated as $500 million to $750 million. These estimates were given in the AEC's response in the environmental statement on the plutonium recovery facility, Rocky Flats plant. (WASH-1507, January 1972.)

Question 3: "Has anyone made an analysis of birth defects in the Rocky Flats area?"

Response: No. It is my opinion that it would be quite difficult, if not impossible, to determine any changes in birth defects associated with radiation exposure in the Rocky Flats area, because the rather low levels of potential exposure involved and the size of the population group are inadequate to provide a conclusion as to a causal relationship. I should call to your attention that the type of defects you are raising a question about requires either deposition of radioactive material in genetic tissues or the transmittal of these materials across the placenta during prenatal development. For your information, I am enclosing a copy of the 1972 NAS report entitled, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," which I believe will be informative in this matter.

Question 4: "Has anyone noticed that because of our altitude and position in the mountains that this should be one of the last places in the U.S. where proliferation of nuclides should be allowed. After we receive our 250 mr from natural sources and fallout and we add 100 mr/yr from average dental and medical x-rays -- Can we stand multiple increases of 5 mr from this and that source?"

Response: This question does not lead to a direct yes or no answer. You are aware, of course, that there is a geographical variation in natural background radiation, as well as a variation in the amount of radiation received from its use in the healing arts. We cannot, under the present assumptions of a linear, nonthreshold dose-effect relationship, determine a "safe" acceptable level of radiation. Therefore, the additional exposures, which individuals or populations experience, must take into consideration the health impact, the economics to control that impact, and a judgment as to the benefit of the activity. Such an evaluation is, as you might gather, quite complex. Keep in mind, however, that with an assumption of a linear, nonthreshold dose-effect relationship, the incremental risk increase with increase in exposure is independent of prior exposure.

Question 5: "Has anyone looked at the isopleths of Sr-90, Ce-144, Cs-137 around Rocky Flats?"

Response: Yes. The DOW Chemical Company and the Colorado Department of Health conduct routine environmental surveillance programs in the vicinity of Rocky Flats, which include the sampling and analysis of media for the radionuclides which are most likely to be released from the Rocky Flats plant. The Health and Safety Laboratory of the AEC has also performed surveys in this area. These data are reported

as individual sample measurements and not as radionuclide isopleths. Although Sr-90 is not a routine analysis in either of these programs, it has on several occasions been the object of special environmental studies. The AEC (ERDA) has done extensive aerial surveys by use of their Aerial Radiological Measurement System aircraft. This survey mapped the Rocky Flats area and would have detected very low levels of these radionuclides.

Sincerely yours,

W. A. Mills

William A. Mills, Ph.D.
Director
Criteria & Standards Division (AW-560)

Enclosure

cc: Paul Smith, Region VIII
A.J. Hazle, CDH
bcc: Dr. Augustine
Mr. Harward
Mr. Weaver
Dr. Burley

Chairman Mills: Thank you, Doctor. Are there any questions?

(No. response.)

Chairman Mills: If there are no questions, Mr. Dwight Filley, from the Colorado Open Space Council, Inc.

(No response.)

Chairman Mills: Mr. Albert Nunez of Environmental Action of Colorado. I apologize if I did not pronounce your name correctly.

Mr. Nunez: You did quite well. I hope you can do as well by setting some very, very, very low standards.

Chairman Mills: Would you give us your address?

Mr. Nunez: Environmental Action of Colorado is affiliated with the University of Colorado at Denver, 1100 14th Street, Denver, Colorado, 80202.

The comments that I have are just very brief. I would like to say that there is probably nothing that I am going to add technically speaking that has not already been very more than adequately covered by expert witnesses that preceded myself.

I would just like to point out a few things from my own background which has been in planning, urban planning in the Denver Regional Area, and that I am very concerned about the area surrounding Rocky Flats, not only Rocky Flats, but

other nuclear facilities around the country, the public awareness of these facilities, and the potential hazard involved with them. The urbanization of these areas within a 50 or 100 mile radius I think is considered a potential hazard zone in the event of a nuclear accident.

I do not know exactly how you are going to take into account possibilities for an accident when setting your standards, but one suggestion that I would like to enter into the record and that would be that as monitoring stations are set up around these facilities, particularly the ones close to urban areas, but even those not close to urban areas -- I will touch upon that a little further down the line -- that a posting of the hazard zones, if you will, the isopleth showing the different concentration levels of these radionuclides be acturally posted by the highways so that people will become more and more aware, just as the Surgeon General has posted a caution label on the side of cigarettes. A similar type action if, for no other reason but just to increase public awareness and to start people to become more and more aware of the potential hazards involved. I do not know if you can work that into your standards or not, but I would just like it to be included in the record.

I would also like to ask what knowns do you know about -- what are the knowns about plutonium, and what are the unknowns compartively speaking? How much is there on this spaceship?

How much plutonium is there? Where is it all? These kind of questions are necessary for you to ask, considering the extreme toxicity of this particular element, and of course the other transuranium elements that are also being considered.

My own personal feeling is that the hazards involved are not knowns at the present time judging from what I have heard thus far in the testimony, and that I really do not see how you are going to be able to set any standards whatsoever until further research is done; and that for all intent and purposes, we have kind of opened a Pandora's box. We have already produced certain amounts of plutonium, but have no real assurances of how much, what is a safe level for human or other animal consumption.

Well, my major concern here is again public awareness and public participation in these hearings, and other means of getting the word out to the people that there is a definite threat and a definite health hazard.

I would like to say that I think a greater effort could have been done on the part of the Environmental Protection Agency to not only alert the media in the surrounding Region but also to have incorporated or included in their press release mailing lists of other states outside of Region VIII. It is my understanding that just the Region VIII media was sent these releases. I hope, I pray that the

amount of plutonium that has already been created on the spaceship is able to be gathered up, if you will, and sorted or removed from the biosphere sufficiently. Covering it with asphalt or other surface materials to fix, if you will, it in the ground is not going to work for the next half a million years, and that is what we are going to have to deal with. I am really here not only talking for myself but for my son and his children, and his children's children, and his children's children's children. Only God should determine our genetic heredity.

I would like to at this point in time ask one of the other coordinators who works with me at Environmental Action, and who is active in other organizations, Mr. Morey Wolfson, to come up and give some testimony that he has prepared, but has not been included in the record. I do not know whether you plan for him to speak later on, but if he could talk now, that will be appreciated.

Chairman Mills: That will be okay, if you can confine it.

Mr. Nunez: Are there any questions or comments?

Chairman Mills: Any questions for Mr. Nunez?

(No response.)

Mr. Nunez: I would like to say one other thing, that nuclear power is not necessary. It should be like a last-ditch effort when all else, all other energy forms have been

totally exploited. We should not be producing these cancer genetic materials. It just is not conducive to global survival, and I would urge you to take into consideration the global comments.

Dr. Snyder: I would like to comment especially on the last statement. I take it from that statement then you are of the opinion there is no carcinogenic risks from, say, fossil fuels; that the risk is zero; that all others should be exhausted before we enter on the nuclear fuels?

Mr. Nunez: I do not know. Maybe you cannot see the lapel button that I have here, but it says "Solar Energy" on it, and basically we are of the belief that the cleanest and most abundant and evenly distributed source of energy available to man at the present time and for all past decades and for all future decades that concerns him is the sun. It is indirectly the form of all the fossil fuels. If you believe in the big bang theory, even uranium came from the sun, and for that, hydroelectric and wind energy. All these natural forms of energy are the alternatives that we should be going toward if we are to survive as a species on this spaceship.

Dr. Snyder: This just raises the question, what is the hazard involved with these other forms of energy which have not even been developed, you see, except in conceptual form? What will their massive use entail?

Mr. Nunez: The massive use and hazards involved with solar energy development is really anyone's guess. If we go with proposals, such as Peter Glasier's proposal with microwaving, collecting solar energy outside of the biosphere and beaming it on down, which, by the way, Peter says is the only thing that competes with LMFBR on an economic scale, and apparently this is the thing that makes any sense in this country is the almighty buck. Well, it could be catastrophous, I agree. We could disrupt the heat balance of the planet and do worse harm possibly, but not probably.

Chairman Mills: What is the length of your comments?

Mr. Wolfson: Ten minutes. Before I start my testimony, I would like to make a few generalized comments about the way that this proceeding has taken palce.

First of all, the sound system, there is a very big problem with that, and I would suggest that any time the EPA, all of you are involved in a hearing, that you be certain that the sound system is adequate.

Secondly, I would recommend that there be a rule of no smoking at these hearings in the interest of public health.

Third, I would like to just underscore the statements that have been made earlier about the fact that the public information about this EPA hearing has not been adequate.

Also, I would just like to ask a question out of my own personal curiosity. How many people here are from EPA right

at this present minute?

(Whereupon, there was a showing of hands in the audience.)

Chairman Mills: is that relevant?

Mr. Wolfson: Yes, this is an EPA hearing, so it is very relevant.

My name is Morey Wolfson. I am a Coordinator for Environmental Action of Colorado, People for Radional Energy Sources, and the Rocky Flats Action Group. I have served as a member of the Youth Advisory Board to the Environmental Protection Agency and was past Associate Director of Citizens Concerned About Radiation Pollution. My interest in radiation pollution of the environment dates back to the time immediately prior to the Rocky Flats fire in 1969. Since that time, a major portion of my participation in environmental affairs has centered on positively resolving this energy/environment conflict by increasing the public's appreciation of the viability of solar energy. I have received a Masters in Urban and Regional Planning/Community Development at the University of Colorado at Denver, where I have been employed by the Bureau of Community Services and the Center for Urban Affairs.

I am here today to discuss the consequences of the potential contamination of the environment by radionuclides

of the transuranic elements -- especially plutonium. It is my understanding that the purpose of the hearing is to learn of ways in which the EPA can protect the general environment from radioactive material. The EPA has expressed an interest in finding suitable limits on radiation exposure, or levels, or concentrations, or quantities of radioactive materials.

Due to the fact that scientists with special expertise on radioactive levels are providing testimony at the hearing today, my testimony will relate to the broader issues that constitute the context in which a discussion of acceptable levels center. These broader issues are necessarily an integral part of the decision-making process process exercised by the EPA, and therefore, have a useful function at this public hearing. My scientific training does not allow me to adequately direct comments to the more esoteric issue of radioactive limits, but my experience has provided me with information quite pertinent to this hearing.

It seems to me that the EPA is faced with the question of how they should protect the general environment from radioactive material. It is becoming generally apparent that there are two basic approaches to environmental protection. Simply stated they are MITIGATION or PREVENTION MITIGATION appears to be the most expedient, financially rewarding, and most popular approach to the problem. MITIGATION is a policy accepted by most Governmental

agencies, planners, developers, and the like. MITIGATION implies that SOME negative environmental impact is INEVITABLE in certain development. Therefore, the objective becomes to MINIMIZE that negative environmental impact as much as possible.

The second approach to environmental protection is PREVENTION. This does NOT presume the INEVITABILITY of a certain project. It does not give a project as acceptable or inevitable, but rather, prevention of environmental damage accepts the fundamental existence of the CHOICE. In the long-range view, when an environmental policy decision-maker is opting for either the mitigation or prevention course, the decision to prevent a dubious project will become more cost-effective. That is to say, that if a project must eventually be abandoned because of an inherent environmental threat that is involved, it would be a much sounder decision to abandon early on rather than attempting to stop the project after it has already developed economic and political momentum.

The EPA has the CHOICE to purposefully abandon the nuclear course set by the Atomic Energy Commission, General Electric, and Westinghouse, etc. In fact, the EPA has the prime responsibility to assert that option. It is hard to imagine that the EPA will ever be able to provide the public with a guarantee that they have made arrangements for 100%

containment of plutonium from the biosphere for a quarter of a million years. That becomes rather apparent, without such a guarantee, all we can expect are bland reassurances that the levels of radioactivity are "within acceptable limits." These reassurances, so often voiced by the outgoing AEC, will not alleviate the feeling that the public is having that their health is being compromised by the dubious societal "advantage" of nuclear-generated electricity and nuclear weapons. Should the EPA -- by opting for mitigation -- risk the possibility of breaking the delicate ecological chains that support human life as we know it?

It is my recommendation that the EPA fully recognize the significance of the biological effects of ionizing radiation. Any increase in the amount of radioactivity will have a negative health effect. This information should lead to an attitude that there is no "suitable" or "acceptable" radiation exposure, level, or concentration.

At this point it might be instructive to outline the source and uses of plutonium and some of the problems associated with containment of the plutonium from the biosphere. Plutonium is created in nuclear reactors for the purpose of either creating material used in the production of warheads or fuel for reactors. This man-made element is incredibly toxic, has a half-life of 24,000 years, and has a pyrophoric nature.

Complete containment of plutonium has been -- and will continue to be -- an impossible task. Plutonium has contaminated air, land, water, vegetation, humans, and other animal life. With the continuance of nuclear arms production and recycling, coupled with the exponential growth expected with the advent of the fast breeder reactor, plutonium recycling, the planetary inventory of plutonium will be truly staggering in a relatively short time. We are talking in 1975 about one fact of life, about a certain amount of plutonium inventory on the planet. By the year 2020, we are looking at a very different kind of situation. The decisions that you gentlemen make and the EPA makes today is going to impact very heavily on that decision of whether or not we are going to have these massive tonage of plutonium in the future. Plutonium handling facilities have already experienced theft, fires, and explosions.

After the expenditures of BILLIONS of dollars on plutonium-related projects, Government and industry have failed in every way to provide for safe plutonium containment from the biosphere. In fact, this failure is so clearly recognized by the insurance industry, that not a single American dwelling has insurance covering radioactivity. The Price-Anderson Act is a public subsidy and incentive to a Government-spawned nuclear power industry. Why should a reactor, or why should a plutonium-handling facility maximize on

radiation containment when they won't be legally or financially responsible in the event of contamination?

Plutonium would obviously be released in the event of a nuclear war. Now, this is very serious, and this is very real, and could, in fact, be a major cause of radiation pollution of the environment in the future. The global environment has already been irreversibly contaminated by radioactive fallout. A major nuclear war would undoubtedly risk the genetic integrity of all mankind. Some scientists have declared that full-scale nuclear warfare would be so damaging that the radioactivity would prevent the birth of children worldwide. In other words, if these scientists are correct, nuclear warfare might mean the extinction of the human race. I would just like to underscore that I am not making this up. This is a global reality.

Chairman Mills: May I ask a question, getting off to nuclear war, is that relevant to the establishment of plutonium standards, or do you have any information? I fail to get the connection here. Could you clear that up before you go further?

Mr. Wolfson: As I read the eight-page EPA report announcing the hearing that was generated by the Office of Radiation Program, it clearly delineated the sources of radiation pollution of the environment, and it did mention that we are now exposed to radioactive fallout. The fact of

the matter is that they way the momentum is building, we will, in fact, have more radioactive fallout as a results of our activity.

Chairman Mills: Okay, fine.

Mr. Wolfson: Secondary effects of a nuclear war might be just as catastrophic. Here I quote from Dr. Fred Ikle, Director of the U. S. Arms Control and Disarmament Agency. He says, "There is a possibility that a large number of nuclear explosions might bring about the destruction, or partial destruction, of the ozone layer in the stratosphere that helps protect all living things from ultraviolet radiation. We know that nuclear explosions in the earth's atmosphere would generate vast quantities of nitrogen oxides and other pollutants which might deplete the ozone that surrounds the earth. But we do not know how much ozone depletion would occur from a large number of nuclear explosions -- it might be imperceptible, but it might be almost total. We do not know how long such depletion would last -- less than one year, or over ten years. And above all, we do not know what this depletion would do to plants, animals, and people. Perhaps it would merely increase the hazard of sunburn. Or perhaps it would destroy the critical links of the intricate food chain of plants and animals, and thus shatter the ecological structure that permits man to remain alive on this planet. ALL WE KNOW IS THAT WE DO NOT KNOW."

Dr. First: I think we are getting a little off the topic, if you do not mind me saying so. I wish you would speak on the subject of standards, because this is clearly irrelevant.

Mr. Wolfson: I turn now to a producer and recycler of the nuclear warheads which are poised for ecological suicide: ROCKY FLATS. The American Friends Service Committee Rocky Flats Action Group feels that there is patently nothing good for humanity that can come from the manufacturing of more atomic weapons. We have expressed our concern to the Atomics International Division of Rockwell International, the new contractors at the Rocky Flats Plant. Just last month Former Secretary of the Air Force and now U. S. Senator Stuart Symington said: "One miscaluclation, one sudden terrorist activity, one paranoid leader, could set the spark to a worldwide holocaust." The manufacturer of the nuclear weapon, Rocky Flats, and the Governmental agencies, EPA, employed to monitor and control the manufacturer will share the responsibility of the use of the nuclear weapon.

ROCKY FLATS poses a unique ecological threat to the Denver area. The threat must be removed. The initial decision to site the plutonium handling facility near Denver did not conform to siting criteria utilized in establishing other nuclear facilities. The plutonium works at Hanford, Washington, for example, were sited on a half million acres of arid land in a remote location. General Leslie Groves,

the head of the Manhattan Project, rejected siting a new plutonium facility near Oak Ridge, Tennessee, Because he "felt uneasy about the danger to the surrounding population. Oak Ridge is not far from Knoxville," he said. "If a reactor were to explode and throw great quantities of radioactive materials into the atmosphere when the wind was blowing toward Knoxville, the loss of life and the damage to health in the area might be catastrophic." Apparently, this kind of caution was not employed when siting Rocky Flats.

Dr. Edward Martell of the Colorado Committee for Environmental Information, who so eloquently testified today, has detailed the potential problems associated with Rocky Flats. This is taken from, I believe, around 1970: "In the not too unlikely event of a major plutonium release, the resulting plutonium contamination of Denver could require large-scale evacuation of the affected area, the leveling of buildings and homes, the deep plowing and removal of topsoil and an unpredictable number of radiation casualties among people exposed to the initial cloud in the more seriously contaminated areas. The human casualties and economic losses from such an eventuality would greatly overweigh the costs of relocating the plant before such an accident occurs."

Not long after the Rocky Flats fire, General Giller, head of the AEC's $800 million a year Division of Military Application, was seeking $265 million to rebuild and remodel

nuclear facilities.

Chairman Mills: Mr. Wolfson, we tried to accommodate you, and I asked you how long it was going to take and you said 10 minutes. You have been going on now for 15 minutes.

Mr. Wolfson: I have three more pages left.

Dr. Taylor: I suggest that a page of presentation is 25 lines, ten words per line, that takes two and a half minutes.

Chairman Mills: You recognize, of course, that there are a lot of other people --

Mr. Wolfson: Could you please tell me how long Dr. Geesaman testified?

Chairman Mills: I am speaking to you, sir. Would you try to summarize your statement now.

Mr. Wolfson: Yes. The information which I have been providing to you, and, of course, I could go on as long as Dr. Geesaman or as long as Dr. Martell with this type of information. The reason you are trying to silence me basically is because it is so sensitive that it gets into the political area.

I would like to mention to you that I am a member of a number of organizations that believe in citizen action, political action. I want to let you know that we have provided testimony on many occasions to many public hearings, and on many instances we have been silenced as you are

doing. However, we usually leave with a warning that says, if you do not take care of this business on behalf of the people of Denver and Colorado and the United States, do not be surprised if two things happen. One, people do it anyway. We supported, we worked and coordinated the initiative to stop underground blasting in Colorado. We went before hearings and we were closed down. We went before another hearing, and we were closed down. We are going before this hearing, and we are getting closed down. I am saying, do not be surprised if there is going to be no nuclear power plants in this country, and no nuclear warhead construction in this country in the hear future, regardless of what you do here.

The second thing is, is do not be disturbed if you gentlemen lose your jobs as a result of not listening to the public when they come to you at a public hearing.

That is a summary of my statement.

(Applause.)

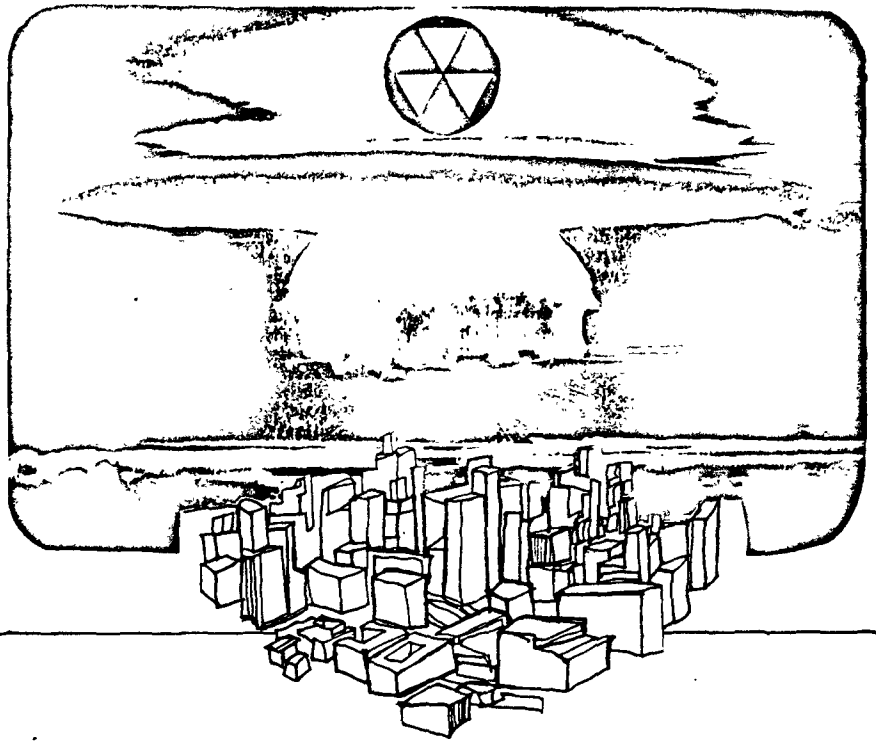
Chairman Mills: Any questions?

(No response.)

Chairman Mills: Thank you very much.

#96

NOT ROCKWELL at ROCKY FLATS



The Rocky Flats nuclear weapons facility, located fifteen miles northwest of Downtown Denver, is one of the most threatening pieces of property on the surface of the Earth today.

The super-secret Atomic Energy Commission facility was situated in Colorado in the early 1950's because the nuclear weapons establishment wanted to conduct their work far from population centers.

Twenty years later, Rocky Flats is quickly becoming encircled by a rapidly expanding (and enlightened) population.

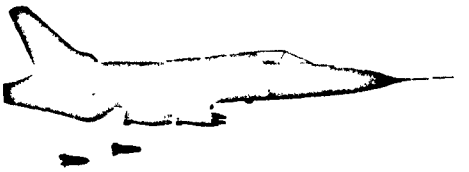
Two thousand people are employed every day manufacturing radioactive components for nuclear weapons. Trains and trucks traveling through Colorado deliver and remove highly radioactive materials from Rocky Flats regularly. The Atomic Energy Commission has permitted the management to bury lethal materials that have escaped into the environment.

Plutonium, cesium, and tritium have been released into the Metro Denver area- contaminating the land, air, and water.

Workers at the plant have become unwitting nuclear guinea pigs.

Now that Colorado has elected new political leaders who are conscious of environmental priorities, real action on Rocky Flats should be forthcoming.

The votes to stop the Olympics and underground nuclear blasting are a clear indication to public officials and Rocky Flats that the public will not remain complacent to a health menace and a threat to global peace. ROCKY FLATS WEAPONS PLANT MUST BE CLOSED DOWN!



WHY IS ROCKWELL REPLACING DOW?

The Atomics Division of Rockwell International will be replacing Dow Chemical Company as the managers of the Rocky Flats facility. Dow's mismanagement of the plant, as demonstrated by the hundreds of accidents, spills, and fires that have occurred (including a $50 million fire in 1969 that was the most expensive industrial fire in American history) are the major reasons why Dow is being replaced.

WHAT KIND OF COMPANY IS ROCKWELL?

Rockwell's products for the aerospace/defense market include liquid and solid propellants, rocket engines, target drones, aircraft air-to-ground missiles, and nuclear reactor components. Rockwell is also the prime contractor for the Air Force's B-1 bomber program, which has been declared obsolete before the first test flight.

25% of Rockwell's total business is with the military.

Rockwell also manufactures power tools sold in many Denver area hardware stores and WOOLCO department stores.

ROCKY FLATS NUCLEAR WEAPONS PRODUCTION MUST BE STOPPED!

Weapons production at Rocky Flats must be stopped, but stopping it is not enough. Unless we change the policies and powers responsible for Rocky Flats, there will be two or three new military projects developed for every one that we stop. It is essential that we work to end the "need" for Rocky Flats in the following ways:

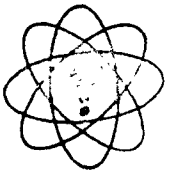
-Challenge the crackpot logic of the MAD (mutual assured destruction) arms race. Demand a serious commitment to disarmament.

-Expose the self-serving narrow economic interests of the military-industrial complex which is fed by unresponsive politicians.

-Push for community and national planning for converting the dominant automobile/petroleum and military/industrial complexes into economic forces that serves humanity.

-Demand that politicians take clear-cut stands on the issue. Simply setting up "study groups" is no replacement for action.

THE FORCES OF DEATH WEIGH HEAVY IN THE BALANCE, THE CRITICAL MOMENT IS UPON US. WE ARE ALL PRISONER OF WAR. IF HUMANITY DOES NOT PUT AN END TO WAR, WAR WILL PUT AN END TO HUMANITY.



Your contribution is greatly appreciated:
The Rocky Flats Action Group
% American Friends Service Committee
2801 East Colfax Avenue #304
Denver, Colorado 388-5896

Text reprinted from

SCIENCE 22 September 1972

Vol. 177, No 4054

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(Reprinted by permission from Science. Copyright 1972 by the American Association for the Advancement of Science.)

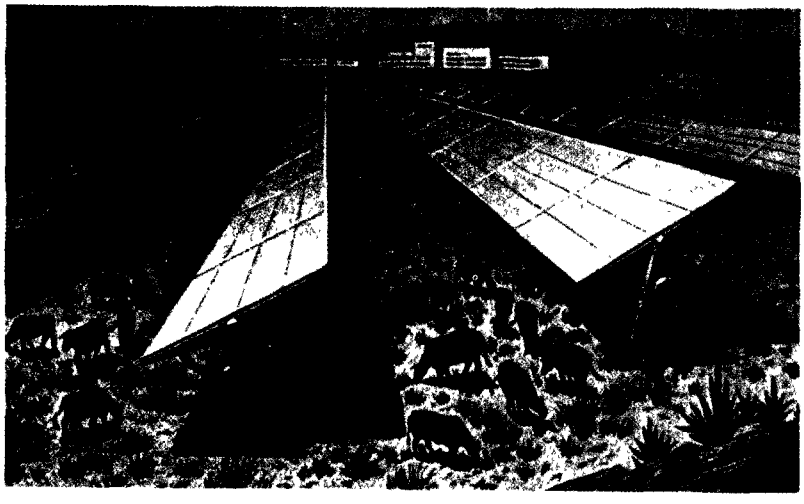
Solar Energy: The Largest Resource

ENERGY

Not long ago, proposals for using the sun's energy were apt to be received with considerable skepticism. Within a few agencies of the federal government and at an increasing number of university and industrial laboratories, that is no longer the case. Indeed, perhaps the most impressive testimony to the prospects for this type of energy is the score of prestigious scientists and engineers who have begun working on methods for converting the sun's radiation into forms more useful to man—heat, electricity, or chemical fuels.

Within 5 years, many of these scientists believe, solar-powered systems for heating and cooling homes could be commercially available at prices competitive with gas or oil furnaces and electric air conditioners. Still more significant, but farther in the future, may be means of using heat from the sun to generate electricity; experimental solar-thermal units have been constructed in several countries, and several groups in the United States are designing systems to take advantage of improved materials and manufacturing techniques. Eventually the direct conversion of solar radiation to electricity by means of photovoltaic cells or its bioconversion to wood, methane, or other fuels on a large scale may become economically feasible.

Solar radiation is the most abundant form of energy available to man, and is so plentiful that the energy arriving on 0.5 percent of the land area of the United States is more than the total energy needs of the country projected to the year 2000. Sunlight is diffuse and intermittent, however, and its use on earth requires large areas to collect sufficient amounts of energy and, for most applications, the means to store energy. Despite its abundance, solar energy has not been exploited except in a limited way in water heaters, furnaces, and space applications; nor are the technologies that would allow widespread use commercially available. Systems for heating and cooling houses or for generating electricity with sunlight could be built now, but they would cost more than comparable systems that burn fossil fuels. For some applications, however, the disparity in cost may rapidly disappear as solar technology improves and as the costs of fossil fuels rise.



To reap the tremendous amount of energy from the sun, Professor Aden Meinel and his wife, Marjorie, propose to cover areas of the Southwest with solar energy collectors. Inside these collectors, gaseous nitrogen would be heated to temperatures of 1000° F. and then flow into tanks of molten salts, capable of storing the heat for night-time use. Steam, heated by the molten salts, drives turbines to produce electricity. The Meinels estimate that the power for a city of 60,000 could be supplied by one square mile of solar collectors.

Whether or not solar energy becomes generally available in the near future, there is growing agreement that this source of energy will be important in the long run. That being the case, proponents believe that it is the most underfunded area of research in the energy field, accounting for less than 1 percent of federal research expenditures related to energy.

Of the proposed uses of solar energy, heating and cooling for homes and low-rise commercial buildings are the most developed and will almost certainly constitute the first significant use of solar energy in this country. Solar water heaters are already in commercial use in Florida and in several countries overseas. Experimental houses have been equipped with solar heating systems and preliminary development of cooling systems has begun.

Solar Heating in the Home

For space heating, the solar collector is typically a black metal surface that readily absorbs sunlight and is covered with one to three panes of glass to reduce the heat loss. The glass is transparent to the incoming sunlight, but absorbs the longer wavelength radiation emitted by the hot metal, so that a "greenhouse" effect is created and the effectiveness of the collector is increased. The heat is collected in water or air that is circulated through the collector during the day, and part of it is stored for release at night or in bad weather. Hot water, hot rock, and chem-

ical (change of phase) storage systems have been experimentally tested, depending on the type of heating system envisioned (*1*).

For air conditioning, most investigators believe, refrigeration systems that depend on absorption of the coolant fluid appear to offer the best choice. Experimental cooling units are being developed by several university and industrial research groups. At the University of Delaware, for example, a group headed by K. W. Boer is designing complete household energy systems that would utilize heat pumps for space conditioning.* In other prototype systems, such as that developed by Erich Farber** at the University of Florida, heat from the sun is used to drive ammonia from an ammonia-water solution, and the ammonia is collected and condensed. When cooling is needed, the liquid ammonia is allowed to evaporate and expand as in a conventional cooling system, and the spent vapor is reabsorbed in water.

For absorption refrigerating systems to work smoothly, temperatures around 120°C or higher will be needed, and thus solar collectors that are more efficient than those for heating purposes alone will be required. One possibility may be surface coatings of the type developed in recent years for space applications, which emit very little of the solar radiation that they absorb and which consequently attain higher temperatures than uncoated metal collectors. If such coatings can be produced on a large scale, their use might help to reduce the cost of solar heating and cooling, since collectors are the most expensive item of a solar energy system. Combined cooling and heating systems, which have not yet been built, are also expected to improve the economic prospects for both because of the joint use of the collector.

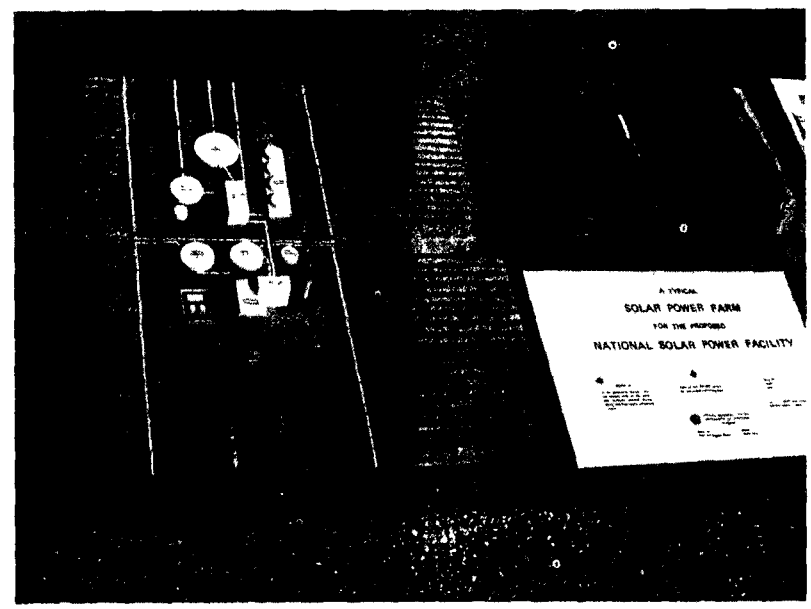
Substantial technical problems remain to be solved in the design of cooling systems, in the manufacture of surface coatings for improved solar collectors, and in the optimization of combined solar heating and cooling systems. In most regions of the country backup systems based on conventional fuels will be needed for extended periods of bad weather. Nonetheless, one estimate indicates that if systems were commercially available now, solar heating would be cheaper than electric heating in nearly all of the United States and would be competitive with gas and oil heating when these fuels double in cost (*2*). Proponents believe that solar heating and cooling systems could ultimately supply as much as half of the nearly 20 percent of total U.S. energy consumption that is now used for residential and commercial space conditioning and could reduce the peak use of electricity in summer.

For implementation of this technology, however, some means to overcome what are essentially social problems is likely to be necessary. As Jerry Weingart of the California Institute of Technology put it, "developing the technology is not enough," because the fragmented building industry is traditionally slow to adopt new techniques. Solar heating systems, despite their lower fuel costs, will entail higher initial costs, thus discouraging consumer acceptance; some observers have suggested that governmental encouragement in the form of tax incentives or energy performance construction codes should be part of a national energy policy. The slow rate of replacement of housing, in any case, guarantees that several decades will pass before a new heating system could have a significant impact on total energy use. Given the growing shortage of fossil fuels, however, it seems clearly advantageous to move in that direction.

The generation of electricity with heat from solar energy is a more difficult challenge, and there are conflicting ideas about the best approach to the problem. Some engineers believe that small generating units located where the electricity is to be consumed are the ideal way to utilize a resource that is inherently diffuse and well distributed. This group favors the use of power turbines that would operate at temperatures considerably lower than those common in nuclear or fossil-fuel power plants, despite the low thermal efficiency, between 10 and 15 percent, that these units would have. Others have proposed large solar-thermal facilities modeled on existing central power stations. The two concepts differ both philosophically and technically.

Small vapor turbines that used heat from solar collectors to generate electricity were demonstrated by Harry Tabor of Israel's National Physical Laboratory in Jerusalem at the United Nations conference on new sources of energy, held in Italy in 1961. A miniature solar power plant in Senegal is already in operation, and experimental solar engines have been developed by several investigators in the United States. Typically, these units operate at temperatures below 200°C. Their economic advantages relative to other sources of electricity have not been demonstrated, and the concept has attracted only limited interest, in part because of the difficulty of decentralizing the present electrical generation and distribution system.

Preliminary efforts to develop large

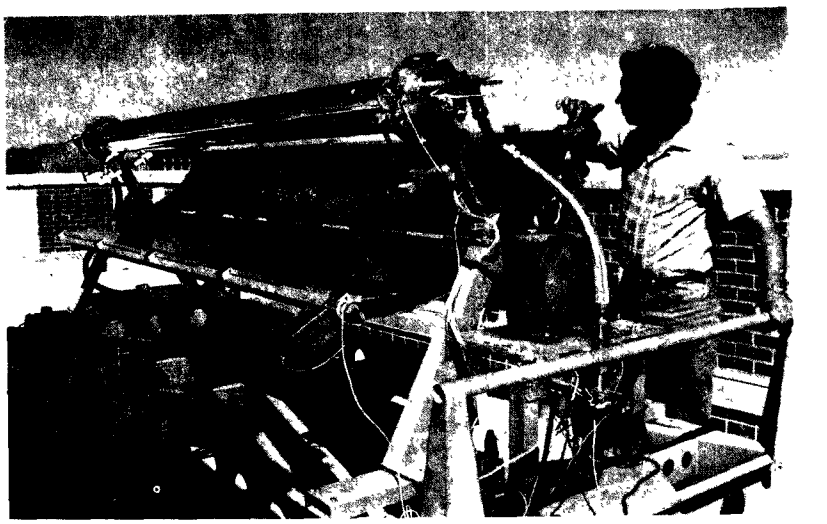


A model of the Meinels' proposed "Solar Power Farm." The black horizontal lines depict the solar collectors.

*An explanation of "Solar One," the house designed and built by K. W. Boer's group, is available from EARS, in an article titled "Turning on the Sunpower" (Catalog No. 130A). See page 4 for the address of EARS.

**A 12-page description of Dr. Farber's work, which includes 49 photographs, is available through EARS (Catalog No. 200A)

500 central power plants are under way. This concept has attracted considerable interest, although substantial problems remain to be solved before such plants could be economically competitive. Still higher temperatures, between 300° and 600°C, are required to operate modern steam turbines, complicating both collection of solar radiation and the storage of thermal energy. To capture enough energy at these temperatures, mirrors or lenses larger than any yet built will in all probability be needed to concentrate sunlight. Because large areas will be required—in most designs, about 30 square kilometers for a 1000-megawatt power station—the transfer of heat from the far-flung solar collectors to the generating facility is also a complicated process. The cost and endurance of the collecting apparatus under operating conditions is a critical but undetermined factor.



George Kew

A laboratory model of the solar collectors proposed by the Meinels.

Central Power Station

One design proposed by a group that is headed by Aden Meinel of the University of Arizona would use Fresnel lenses to focus sunlight onto a stainless steel or glass ceramic pipe, thus concentrating the solar flux ten times above its normal value. The pipe is covered with one of several types of selective coatings that emit only a small proportion, between 5 and 10 percent, of the energy they absorb and is enclosed in an evacuated glass chamber to reduce conductive and convective heat losses. Nitrogen gas is pumped through the pipe at velocities of about 4 meters per second to transfer the heat from the collectors to a central storage unit. The Arizona team plans to use a eutectic mixture of salts, mostly sodium nitrate, as a heat storage medium; the heat would be used to produce steam for a turbine as needed. Liquid metal or the molten salt mixture itself, despite the greater difficulty in handling these substances, might also be used to transport heat from the collectors to the storage unit.

A second group, headed by Ernst Eckert of the University of Minnesota and Roger Schmidt of Minneapolis-Honeywell, Inc., has also begun work on the central power station. Their design includes a self-contained, decentralized system for collecting and storing solar heat. A parabolic reflector would concentrate sunlight onto a heat pipe, a device that can transport heat along its length efficiently by convective processes and that does not require a fluid to be pumped through it. The pipe's outer surface would be a selective coating, and the pipe would be enclosed in an evacuated chamber. A small heat storage tank attached to each heat pipe and reflector would complete the unit; no centralized heat storage facility would be used. Underground pipes would bring water to each storage tank and return it as steam directly to a turbine—thus reducing the pumping costs, the Minnesota team claims, compared to the nitrogen system. In addition, they believe, the self-contained system would be easier to construct and maintain.

The effectiveness of the selective coating with which the collecting surface is covered largely controls the temperatures that can be achieved. Two types of selective surfaces are known, both of which absorb much of the incoming radiation—in the visible region of the spectrum—but which emit only a small portion of the infrared heat radiation. Surfaces such as one developed by Minneapolis-Honeywell for the Air Force rely on optical interference between two reflective layers separated by a transparent layer of the correct thickness; thin films of this type have been routinely produced by vacuum coating techniques in the commercial manufacture of tinted glass for the exteriors of new office buildings. A second type of surface, developed by B. Seraphin at Arizona, is composed of silicon or similar materials that naturally have selective properties. Layers of silicon and nonreflecting materials are laid down on a highly reflective substrate by chemical vapor deposition techniques; the silicon absorbs sunlight, but transmits infrared radiation, so that the composite surface has a high reflectance—and hence a low emittance—in the infrared.

These selective coatings are particularly important for solar collectors that are built without mirrors or lenses. Simple planar collectors have several advantages over the concentrating systems in that the concentrating collector must focus sunlight on the absorber and hence must follow the sun's motion in the sky, machinery to allow daily tracking complicates the collector design. In addition, focusing collectors operate only on direct sunlight, whereas planar collectors can utilize diffuse sunlight as well—and thus can function in cloudy or hazy weather. Because the performance of some of the most selective coatings decreases markedly at high temperatures, however, power plants using them would have to operate at temperatures below 350°C, with correspondingly reduced efficiency in the steam turbines. Improved selective coatings may allow planar collectors—which Meinel and his co-workers believe, in principle, to be the most effective in areas of the United States other than the cloudless Southwest—to be used. But most initial designs are based on the assumption that concentration of the sunlight will be necessary, and in these systems the fabrication, cost, and durability of the concentrators are the major concern.

The trade-offs between different types of collectors are not the only feature of the design of solar thermal plants still open to debate. Even with concentrating collectors, it may prove advantageous to operate the system at a reduced temperature, according to the Minnesota team. Their analysis shows increasing efficiency of the collectors, but decreasing efficiency of the thermodynamic cycle of the turbines as the operating temperatures are reduced, with the op-

timum temperature dependent on detailed design of the system and on the heat storage medium chosen. Heat pipes of the size envisioned have never been built, and other hardware details remain to be considered.

Both groups of investigators believe that the cost of solar-thermal plants will be not more than two or three times what fossil-fueled or nuclear-generating plants cost now, and that rising fuel costs will eventually tip the balance in favor of solar-thermal plants whose fuel is "free." Before accurate estimates of costs can be made, they agree, more detailed engineering studies and some additional research are necessary. But Meinel, at least, believes that full-scale solar-thermal power plants could be built as early as 1985 with an adequate research effort. Other estimates are somewhat less optimistic, but a group of western utility companies is considering the development of a small solar-powered facility that could serve as a prototype for peak load applications.

Although solar energy has probably the fewest potential environmental problems associated with its use of any of the major sources of energy, some problems, none of which appear to be insuperable, do exist. Collecting surfaces absorb more sunlight than the earth does, and while this is not likely to alter the local thermal balance in household or other small-scale use, the larger expanse of collecting surface in a central power plant might. Thermal pollution will also be a problem if water-cooled turbines are used—indeed, more so than with nuclear power plants because solar installations are expected to have even lower thermal efficiencies. If waste heat is returned to the atmosphere, it could help to restore the local thermal balance. The effects of small changes in the thermal balance would depend on the local meteorological conditions, but are expected to be small. The lack of particulate emissions or radiation hazards might allow solar-thermal power plants to be built close enough to towns or industrial sites so that their waste heat could be put to use. Finally, like other industrial facilities, large-scale plants would also carry some risk of accidents, with the attendant possibility of leaking heat transfer or storage media into the environment.

Yet another option for generating electricity with sunlight is direct conversion by means of photovoltaic cells. But the cells available now—which were developed for space applications—are relatively inefficient and very expensive to manufacture. As a long-term prospect, however, both cadmium sulfide and silicon cells are attracting considerable attention. This option, and the bioconversion of sunlight to fuels, will be discussed in future articles.

Space heating and cooling with solar energy are not available today. Solar-thermal power plants have yet to be built on any but the smallest scale, and key elements of the necessary technology have not been adequately demonstrated. But both options appear to be close enough to practical tests of their economic feasibility to warrant increased efforts. The ancient dream of power from the sun may not, after all, turn out to be impossible.

—ALLEN L. HAMMOND

References

1. *Proceedings of the United Nations Conference on New Sources of Energy, Rome, Italy* (United Nations, New York, 1961).
2. R. Tybout and G. Lof, *Natur. Resour. J.* **10**, 268 (1970).

Copyright 1972 by the American Association for the Advancement of Science.

Reprinted by EARS
Environmental Action Reprint Service
University of Colorado at Denver
1100 14th Street
Denver, Colorado 80202
Phone (303) 534-1602

Distributed by:

INDUSTRY SOLAR ENERGY PLAN TO BE URGED

By Don Kirkman
Scripps-Howard Staff Writer

WASHINGTON – The government is about to ask private industry to begin developing solar-powered heating and air conditioning equipment.

The National Science Foundation (NSF) will offer a number of competing giant corporations contracts to study the possibilities of producing solar energy equipment for use anywhere in the nation with only minor changes for local climate variations.

The request will mark the government's first major effort to harness the sun as a partial answer to the nation's deepening energy crisis.

As now conceived, the solar energy heating and air conditioning program will take at least five years and proceed in three phases, NSF officials said. The first phase will comprise the upcoming study contracts, the second will develop equipment, and the third will test the equipment in homes, apartments, industrial plants, schools and public buildings.

The solar energy idea was proposed by President Nixon in 1972, given a modest $3.8 million allocation in the government's fiscal 1973 budget and upgraded to $12.3 million in the proposed fiscal 1974 budget. Even larger funding for the program is expected in later years, NSF officials said.

Currently, solar energy is little used in the United States in comparison with other nations, said NSF's Donald Beattie, but the technology for a vast new industry already exists. Thus, the NSF's solar energy program aims at providing seed money to stimulate such an industry.

At best, no more than 25 American homes or buildings now are heated by solar energy, most of them curiosities built by avant garde architects or university groups.

Interest in solar energy has been spurred in recent years by NASA's successful and widespread use of the technique to provide electricity on board spaceships and satellites.

Beattie noted that the equipment NSF hopes will be developed will not necessarily replace conventional heating units. But, he said, in some areas it could cut by 50 to 70 per cent demands for electricity, natural gas and oil by supplementing those conventionally powered heating units and air conditioners.

NSF expects most of the solar energy equipment to use glass sheets as a roofing material to focus the sun's rays into a chamber. The heat generated in this chamber would then be circulated through the building. The same system also would be used to heat water and power air-conditioning units.

By 1985, the NSF believes 10 per cent of the nation's new buildings will be equipped with solar energy equipment for heating and cooling. Additionally, the NSF estimates that by the year 2000 about 35 per cent of all heating and cooling in the nation will be by solar energy and 20 per cent of the nation's electricity will be generated by the sun.

"Nobody ever has made a concerted attempt to make solar energy a feasible way to heat and cool buildings," Beattie commented. "We're trying to take solar energy out of the realm of being a curiosity and make it a workable, feasible reality."

Any workable systems developed by the NSF will be offered to private industry for mass production.

Government installations may be among the first customers for the new equipment, Beattie noted, with the Army and General Services Administration interested in solar heating for military bases and federal buildings.

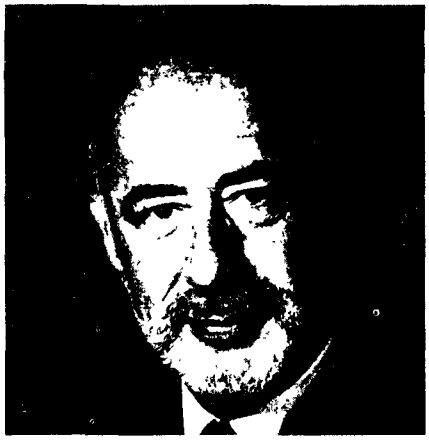
Reprinted with permission from Rocky Mountain News, April 30, 1973

(Reprinted by permission of the Bulletin of the Atomic Scientists.
Copyright (c) 1971 by the Educational Foundation for Nuclear Science.)

Nuclear Power and Ecocide: An Adversary View of New Technology

With his Lawrence Radiation Laboratory colleague, Arthur R. Tamplin, John W. Gofman, M.D., is a leading critic of the Atomic Energy Commission's radiation safety standards. In this article, he relates the radiation controversy to the broader issue of technological motivations in American society. He proposes an adversary method of controlling ecologically unsound or dangerous technical innovations. He suggests that the development of a sustaining body of technological criticism and challenge is incumbent on the scientific community. Dr. Gofman is professor of medical physics at the University of California, Berkeley, and former head of the Biomedical Division at the Lawrence Radiation Laboratory, Livermore, where he now conducts research.

JOHN W. GOFMAN



Our society is based upon the premise that initiative, innovation and promotion, all leading to economic profit, will by their very nature insure the delivery of goods and services that will steadily upgrade the quality of life for the greatest number. It does seem reasonable to suggest that with the extremely viable enterprise system we have, with the obvious talents and accomplishments of our scientists and engineers of a variety of specialty disciplines and with abundant resources and a beautiful land, we should easily be able to create this high quality life for any reasonable-sized population in the United States.

The present environmental crisis clearly indicates that such a desirable result is anything but automatic. The threats posed by food adulteration, poisonous chemicals of agriculture and commerce, and radioactivity may individually, or by synergistic activity, guarantee ecocide.

Science and technology *are* prominently applied in the service of the established system whatever be the privileged currency. And this means that large scale change comes very quickly and can affect the entire population of the country. We have learned, to our dismay, that there may exist serious secondary implications of technological innovations, or of by-products of such innovations. These can take the form of severe environmental degradation or of an uncertain debt, in the form of a future health burden to society. It would seem to accrue to the advantage of a nation, even ultimately to survival itself, to *anticipate* the secondary, or adverse, effects of technological innovation upon society. We do not have appropriate institutions which will guarantee an early alert to potential, possibly subtle, secondary effects of technology. If no *early* feedback information becomes available concerning potentially detrimental consequences, the technologically-based industry grows apace, and the unanticipated detrimental effects will necessarily afflict the entire population. This is dangerous, and it would seem to compel rational humans to place a premium value upon comprehensive foresight.

Once an enterprise is launched, we are faced with a new set of imperatives. And these imperatives grow, probably as a power function, with the investment in the venture. What are these "investments"?

The entrepreneur invests capital. Big capital.

Reprinted by permission of Science and Public Affairs, the Bulletin of the Atomic Scientists. Copyright 1971 by the Educational Foundation for Nuclear Science.

Today, endeavors of any consequence even worth considering here are very big business, encompassing in a short period of time the efforts to distribute goods and services to 200 million people nationally, and to even larger numbers when foreign outlets are considered. If the particular technological entrepreneurial project has gone along for a reasonable period, the capital funds committed can be huge. It is then indeed a matter of considerable importance concerning which the entrepreneur must be extremely protective. Losing money is *not* the way privilege is preserved and extended.

The scientists and technologists invest career and economic opportunity. Indeed, they often prepare themselves at great cost for a particular enterprise. And if the technology has persisted for any length of time, such men have achieved position, prestige and a very high personal economic stake in the future of the enterprise. A case in point is the nuclear energy technology. Whole university departments have devoted themselves to the training of nuclear engineers and related technologists. Beyond the educational level, there are thousands of nuclear engineers, health physicists and biomedical scientists with well-established careers predicated upon the continuation and growth of nuclear energy technology, in particular nuclear electricity generation. And this doesn't begin to take into account the lower echelons, some 140,000 atomic industrial workers, with a large stake in the continuation and growth of this industry. Indeed, the governmental regulators themselves have a *not* inconsiderable stake in the nuclear energy enterprise.

Optimism Common

These are not precisely the ingredients for a continuous process of self-examination, searching criticism or the discovery of undesirable secondary effects of a particular technology. It is common to find an amazingly unbroken wall of optimism about the future promise of the technology for "mankind."

The elite among the scientists and technologists who promoted the enterprise to the entrepreneurs have a major investment of ego, prestige *and* position. These men have generally committed themselves to the glowing promises of the technology in full public view. Again, the longer the enterprise has persisted before possibly adverse features become evident, the greater is the ego-prestige commitment of such elite, and the more difficult it becomes for this elite group to reverse its position.

In nuclear energy, one might consider the difficult position of AEC Chairman Glenn T. Seaborg, who has proudly admitted his position as a prime salesman for nuclear electricity generation, and his intention to create a plutonium future for us all. From a myriad of platforms, and in countless printed statements, he has stated, "The atom came to us in the nick of time." Is it, therefore, truly difficult to understand why Dr. Seaborg is having difficulty facing the realization that the hazard of ionizing radiation is far greater — 20 to 30 times greater — than was thought a decade ago? Is it difficult to understand why Dr. Seaborg dodges the question of the likelihood of a catastrophic accident at a nuclear power plant?

Is it difficult to understand why Congressman Chet Holifield, having pushed appropriations of billions for nuclear energy development through Congress, clings to a thoroughly discredited concept of a "safe" amount of radiation exposure? The evidence he cites for the concept of "safe" doses of ionizing radiation has been rejected by a whole series of distinguished scientists, as well as all the scientific bodies involved in the study of radiation hazards.

Unrealistic Hopes

It should be unrealistic for any of us to hope that dangerously misguided technological-industrial endeavors are going to come to an end through: (a) Economic suicide of the capital-investing entrepreneur, (b) Career and job suicide of the technologists and workers, or (c) Ego and prestige suicide by leaders, promoters and apologists for the enterprise. To argue that a higher morality should guide any of these groups, with their varied vested interests, is simply to produce a totally unreal and unrewarding image of men. It is obvious that long-range *ecocide* will necessarily win out over short-range, parochial economic suicide, career suicide or ego, prestige suicide. And morality won't even visibly enter into the consideration, for the mechanism of rationalization will surface in abundance to protect against even the most obviously indefensible position.

There are those who believe that government will take the necessary steps to seek out adverse side effects of technology, especially in this new age of environmental awareness. This idle dream neglects the fact that once an enterprise is well along, government and enterprise are snuggly bedded down together. To be sure, there will be an occasional, restrained rebuke from a regulatory agency, a mild ritual of wrist-slapping, and even a token fine. Nothing more is to be anticipated.

Still others hope that a deep sense of public responsibility will motivate some scientists, technologists or elite within the enterprise to speak out in the public interest. There are several reasons why this fond hope will accomplish but little. Few within the enterprise will speak out for reasons previously cited. If they do speak out, they will, in general, be demolished by the public relations steamroller of the enterprise, aided and abetted silently or loudly by their colleagues within the enterprise itself.

Lastly, citizen groups may try to stop an eco-destructive enterprise. Noble as many of these have been, they are pitifully under-financed and no match for the professionals of the entrepreneu-

rial juggernaut. We have yet to see a major victory in this arena.

There really does exist a constituency for preserving a livable world, one that is not strictly limited to the "little man," fortunately. As F. Lundberg pointed out in "The Rich and the Super-Rich," even the pursuers of privilege view with dismay some of the depredations of their confreres. Among scientists and technologists there are many who are enthusiastic environmentalists and ecologists for all technologies but their own. And there is the constituency of women who are possessed of a strange, but vehement, desire to have their children grow up with a reasonable chance to survive. Altogether these groups possess considerable clout, provided it can be effectively mobilized. That is, there are several essential institutions that must be developed. And all of them are essential if the desired goal of transition of anti-societal to pro-societal enterprise is to be achieved.

The broad constituency just described must insist that we develop — at the earliest possible moment — centers of technology assessment, outside the reach of the enterprises or government bureaucracies. The explicit responsibility of such centers should be the development and presentation of an effective *adversary* position on the implications of on-going and new technologies. The successful execution of this mission would require high scientific competence. The reports of such "adversary" centers should be made widely available directly to the public. And a mechanism must be set up for an open-forum dialogue between the promoters of the technology and the adversaries. If an adversary position is developed before massive investment is committed, even entrepreneurs will be quite interested. They are not unaware that much of the advice rendered them by their own advisers has been poor in the past. But for those technologies that are far advanced, the numerous types of investment previously described represent a powerful combination. Even the most rational, convincing adversary position will not turn things around without additional features.

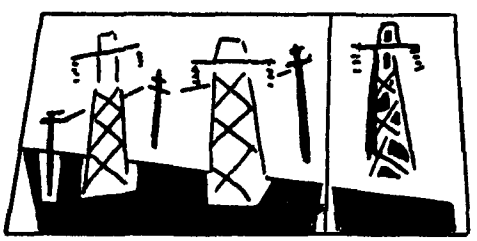
Technological unemployment, or the fear of unemployment, must be abolished. So long as this is not accomplished, the technologists-scientists in a particular technology cannot possibly be objective in an assessment of their own technology. Objectivity is readily buried in a morass of pseudoscience and rationalizations if the disappearance of positions and careers threatens. The labor force in a particular technology can also provide a powerful, unfortunate lobby to obscure a public objective evaluation of the technology and its hazards.

If both of these groups (technologists and labor) are to participate in a constructive re-direction of technological enterprise, where required, it is essential that they be protected against the prospect of unemployment. It must become mandatory that conversion jobs be provided, without loss of position level or salary level when a particular technology is discontinued And I would urge that scientists-technologists form a powerful, determined organization, cutting across specialty boundaries, to demand an end to the pernicious institution of unemployment. For those who might argue that this is unprofessional, I would suggest they are contributing to the prospect of ecocide. And labor should, of course, insist upon the abolition of unemployment and fear of unemployment, too. If fear of unemployment is eliminated, conversion from anti-societal to pro-societal enterprise becomes possible. If the threat of job loss persists, the prospects for a rational approach to conversion are dim indeed.

There is no doubt that the privilege system has found the fear of unemployment to be an extremely useful tool in the past to keep all levels of employees in line, obedient and servile. Possibly this luxury accorded themselves by the entrepreneurs in the past can only be criticized as diabolical and inhumane. In a technological era, where misdirected enterprise can provoke potential eco-disaster, such a luxury simply cannot be afforded.

Economic details undoubtedly will require some imaginative efforts. One of the ways to stimulate imaginative effort is to develop a very powerful constituency insisting upon an early solution. This particular economic problem does not appear to be one of the most profound ones that man has faced.

At the economic-entrepreneurial level, the necessary ingredient is indemnification against loss of capital investment, when technology assessment dictates a change in direction. A punitive approach to investors in technology-based enterprises which turn out to be ecologically unsound seems to appeal to some. However, such an approach can



only be expected to meet with fierce resistance; subterfuge, distortions, half-truths and lies in the effort to preserve short-term, parochial economic interest, whatever the societal cost. Certainly the effective implementation of an adversary technology assessment *very* early in the course of new technologies would minimize the need for indemnification, simply because obviously misdirected ones would not get off the ground so easily as they do now. But even with the best of alert systems, the secondary, adverse effects of some technological innovations will not become evident early. The fear of capital loss is, without doubt, a fantastically powerful motivating force to continue even the most blatantly eco-mad endeavors. It is difficult to believe it is more economic to continue on the road to oblivion than to indemnify investors so they will at least not fight with desperation against a rational change of direction.

Evaluating Reactors

Nuclear electric power technology certainly is one which comes up for consideration. Obviously there exists a wide range of opinions concerning whether the current program of heading toward a plutonium-based energy economy makes sense. A considerable segment of thought holds that the current burner reactor-electricity program makes no sense whether or not there is a future breeder energy economy. It is extremely difficult to believe that a rational evaluation of this problem can take place under circumstances where some of our giant corporations would stand exposed with the capital stake they hold in this enterprise.

But it is even more difficult to believe that the cost of conversion, including indemnification, can possibly approach the cost of continuation with potentially disastrous enterprises. In an economy which sustains some $70 billion of annual dumping into obsolescing and useless armaments, it seems that the indemnification costs of redirecting enterprise cannot be forbidding. Talent, training and many of the facilities can readily be salvaged to embark upon societally useful ventures. In the case of electric power generation, scrapping the nuclear electricity program will still require talents, facilities and organization to proceed with approaches to environmentally sound generation of electric power. The industrial giants are not going to disappear in any event. It is sensible to have

them doing something that meets societal needs rather than something which thwarts human survival. If this be ransom, I would consider it well worth paying. Maybe, one day, a more rational approach will become available, but we don't have time for the appearance of utopia.

We are a culture that worships "success." And we all repeat the maxim, "nothing succeeds like success." But we don't really understand the full implications of this maxim. Economics of conversion of mis-directed technology has been discussed above. But economics is really not the whole story in leading to persistence in technological blunders. While thinking about the wonders of "success," we must give some real consideration to "failure." We place such a high ego-premium on being right about what we say, what we do, especially for all endeavors that are in the public or semi-public domain. It is no secret that in scientific academe some men appear to devote a lifetime of research and publication to proving they were right in their Ph.D. thesis. Who in industry or technology in general is unaware of the ego-hazard (over and above hazard of job loss) inherent in having to tell his superior that all is not so rosy in the picture painted last month or last year concerning a specific project? Defensiveness is the obvious result of the high value-premium we place upon success. And defensiveness breeds tunnel-vision, self-deception and rationalization — anything *but* objectivity.

Motivations and Men

This cult of success pervades our education system, produces the wrong kind of competition and virtually insures that human values will be given low priority. We must give men the opportunity to be commended for being self-critical, for being able to conclude that their prior opinions were in error. There is no doubt that the change in attitude with respect to this issue, much more subtle than the economic ones, will require very careful nurturing. It won't be easy to have people appreciate how important it is to honor those who can forthrightly admit error or failure. While this may prove difficult to achieve, it seems we must work toward it if we are to avoid compounding our mis-moves in technological application.

Science and technology, applied in large-scale enterprise, can contribute heavily to the improvement in quality of life. And, alternatively, such application can and does lead to environmental degradation, as well as the imposition of potentially unbearable burdens upon future health and well-being. Unfortunately, the mechanisms required to determine which of these end results is more likely to be the outcome are largely absent. It is all too easy in such a state of affairs to place blame upon bumbling bureaucracies or upon insensitive corporations. But decisions to go forward in enterprises, based upon technological innovation, are not made either by corporations or by bureaucracies. Such decisions are made by men. It is perhaps more pleasant to shy away from this reality because it brings us face to face with defects all of us share. Men, at all echelons of society, are motivated by ego-security, fear and economic considerations. The economic considerations range from privilege and its extension through to simple job security for avoidance of poverty.

In the longer range, perhaps the counterproductive aspects of these motivations may be recognized and men may change. But technology presents us with hazards operating in a much shorter time frame. So we must try to solve our problems as we are. This means recognizing defects which exist and endeavoring operationally to counter them. One defect is the absence of a viable institution for critical assessment of on-going or proposed technologies. We can rest assured that the favorable prospects for such technologies will be amply developed — and widely advertised. We have, at present, no sound method of insuring that potentially adverse effects will receive independent, unbiased consideration. Lip service to this effort we have had, and will have, in profusion.

The Next Step

This particular defect can be rectified through the development of a reprisal-free adversary system of scientific inquiry. While such a system is vitally needed, it will provide only a first step. The next step is the creation of rational, open-forum dialogue, the goal of which is a reasonable constructive *evaluation* of the pro and con information and *implementation* based upon such evaluation. Neither the evaluation nor the implementation will conceivably accomplish anything worthwhile unless we face squarely the real, powerful, underlying motives of men. And these relate almost wholly to economic motives; secondarily to ego-preservation. The economic motives are primary here. If we indemnify the entrepreneurial elite and *abolish* the prospect of economic insecurity all along the chain from top management and top technologists through to the labor force, we may yet see a very reasonable approach to evaluation and implementation. The ego-defensiveness problem is, in part, related to economics and, in part, related to some required changes in our cultural attitudes.

I would expect two answers to these proposals. First, the problem lies in other directions. How dare you make such a brazen analysis of reality? To this I would reply that the time for tranquilizers is over. Second, insuperable economic hurdles would prevent implementation of these proposals. This is why I would suggest the development of a powerful activist constituency to *demand* that the economic hurdles be overcome. I suspect there is a chance for some imaginative progress even in economics once it is realized that the heat is on and will stay on. Ecocide is too high a price to pay for nonimaginative lethargy.

POISONED POWER

by
John W. Gofman and Arthur R. Tamplin

The Case Against Nuclear Power Plants

- In one year's operation, a single nuclear power plant generates as much radioactive poison as one-thousand Hiroshima-type atomic bombs!
- Insurance companies — experts on judging risks — protect themselves against anticipated claims from private citizens for nuclear plant accidents and radioactive damage by specifically excluding such coverage in contracts.
- The AEC — designated as the public's "protector" — is charged with promoting the nuclear industry. This is an impossible conflict of interest.
- There is "not a shred of evidence" that AEC radiation standards for peaceful use of the atom are truly safe.
- Nuclear power is *not* the sole adequate source of electricity for the future. There are efficient alternatives — cleaner, cheaper, safer ones.

In 1963 the Atomic Energy Commission asked Dr. John Gofman and Dr. Arthur Tamplin to undertake a series of long range studies on potential dangers that might arise from the "peaceful uses of the atom." Assuming that the Atomic Energy Commission seriously wanted to know the truth about the safety of nuclear electricity and its generation, the authors attacked the problem with gusto.

Here's what they learned:

1. Radiation from rapidly expanding Atomic Energy programs is a far, far more serious hazard to human life than anyone had ever conceived it to be.
2. Atomic radiation will result in many times more deaths from cancer and leukemia than previously thought possible. The potential damage to future generations from genetic damage has been even more grossly underestimated.

But far from having their findings welcomed, Gofman and Tamplin experienced a torrent of personal and professional condemnation from the nuclear triumvirate — the U.S. Atomic Energy Commission, the Joint Committee on Atomic Energy, and the Electrical Utility Industry. The authors attribute this to their announced unshakeable conviction that the entire nuclear electricity industry was — and still is — developing under a set of totally false illusions of safety and economy. This judgment was inimical to the interests of all these groups.

Poisoned Power is a starkly realistic book. It is also a hopeful one, for the authors firmly believe that citizen action *can* combat the nuclear power group's carefully contrived propaganda campaign. To help the citizen to navigate through the murky and controversial areas of debate Gofman and Tamplin provide an appendix containing the most frequently raised questions on the merits of nuclear power, with clear, direct answers. *Poisoned Power* shows that we *can* have the electric power we need to maintain our high quality of life. And we can do it without destroying our environment through the introduction of radioactive poisons that will last, essentially, forever.

Finally, the authors make a revolutionary proposal — an Adversary System of Scientific Inquiry, which will open all new technologies of national scope to serious, objective scrutiny by qualified scientists. These men would be specifically charged with exploring each proposed development with an eye to uncovering possible physical, social or economic hazards. These points would then be weighed against any advantages by the scientific community and the lay public before further development of the technology would be permitted. The authors believe such a system would long ago have postponed the proliferation of nuclear power stations to allow for detailed investigation into their safety and efficiency compared with alternate sources of power

RODALE PRESS

PB-30

Reprinted by EARS
Environmental Action Reprint Service
University of Colorado at Denver
1100 14th Street
Denver, Colorado 80202
Phone (303) 534-1602

Distributed by:

The Morality of the Nuclear Energy Issue

by Allen V. Kneese

Editor's Note: In its original form, this article was a statement submitted to the Atomic Energy Commission (AEC) in response to a request for comments on one of its documents. The document noted that environmental reports for a nuclear power reactor should contain a cost-benefit analysis which, among other things, "considers and balances the adverse environmental effects and the environmental, economic, technical and other benefits of the facility."

I am submitting this statement as a long-time student and practitioner of benefit-cost analysis, not as a specialist in nuclear energy. It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale, fission-based economy.

To expect it to do so is to ask it to bear a burden it cannot sustain. This is so because these questions are of a deep ethical character. Benefit-cost analyses certainly cannot solve such questions and may well obscure them.

These questions have to do with whether society should strike a Faustian bargain with atomic scientists and engineers.

If so unforgiving a technology as large-scale nuclear fission energy production is adopted, it will impose a burden of continuous monitoring and sophisticated management of a dangerous material, essentially forever. The penalty of not bearing this burden may be unparalleled disaster. This irreversible burden would be imposed even if nuclear fission were to be used only for a few decades, a mere instant in the pertinent time scales.

Clearly, there are some major advantages in using nuclear fission technology, else it would not have so many well-intentioned and intelligent advocates.

Residual heat is produced to a greater extent by current nuclear generating plants than by fossil fuel-fired ones. But, otherwise, the environmental impact of routine operation of the nuclear fuel cycle, including burning the fuel in the reactor, can very likely be brought to a lower level than will be possible with fossil fuel-fired plants.

This superiority may not, however, extend to some forms of other alternatives, such as solar and geothermal energy, which have received comparatively little research and development effort. Insofar as the usual market costs are concerned, there are few published estimates of the costs of various alternatives, and those which are available are afflicted with much uncertainty . . .

Unfortunately, the advantages of fission are much more readily quantified in the format of a benefit-cost analysis than are the associated hazards. Therefore, there exists the danger that the benefits may seem more real . . . Here we are speaking of hazards that may affect humanity many generations hence and equity questions that can neither be neglected as inconsequential nor evaluated on any known theoretical or empirical basis.

This means that technical people, be they physicists or economists, cannot legitimately make the decision to generate such hazards. Our society confronts a moral problem, of a great profundity; in my opinion, it is one of the most consequential that has ever faced mankind. In a democratic society the only legitimate means for making such a choice is through the mechanisms of representative government.

For this reason, during the short interval ahead while dependence on fission energy could still be kept within some bounds, I believe the Congress should make an open and explicit decision about this Faustian bargain.

This would best be done after full national discussion at a level of seriousness and detail that the nature of the issue demands. An appropriate starting point could be hearings before a committee of Congress with a broad national policy responsibility . . . Another possibility would be for the Congress to appoint a select committee to consider this and other large ethical questions associated with developing technology. .

Much has been written about hazards associated with the production of fission energy. Until recently, most statements emanating from the scientific community were very reassuring on this matter.

But several events in the past year or two have reopened the issue of hazards and revealed it as a real one . . .

The recent failure of a small physical test of emergency core cooling equipment for the present generation of light-water reactors was an alarming event. This is in part because the failure casts doubt upon whether the system would function in the unlikely, but not impossible, event it would be called upon in an actual energy reactor. But it also illustrates the great difficulty of forecasting behavior of components in this complex technology where pertinent experimentation is impossible. Other recent unscheduled events were the partial collapse of fuel rods in some reactors.

There have long been deep but suppressed doubts within the scientific community about the adequacy of reactor safety research vis-a-vis the strong emphasis on developing the technology and getting plants on the line. In recent months the Union of Concerned Scientists has called public attention to the hazards of nuclear fission and asked for a moratorium on the construction of new plants and stringent operating controls on existing ones. The division of opinion in the scientific community about a matter of such moment is deeply disturbing to an outsider.

No doubt there are some additional surprises ahead when other parts of the fuel cycle become more active, particularly in transportation of spent fuel elements and in fuel reprocessing facilities. As yet, there has been essentially no commercial experience in recycling the plutonium produced in nuclear reactors . . . Plutonium is one of the deadliest substances known to man. The inhalation of a millionth of a gram – the size of a grain of pollen – appears to be sufficient to cause lung cancer.

Although it is well known in the nuclear community, perhaps the general public is unaware of the magnitude of the disaster which would occur in the event of a severe accident at a nuclear facility . . . With breeder reactors, the accidental release of plutonium may be of greater consequence than the release of the more volatile fission products . . . In addition to a great variety of other radioactive substances, breeders will contain one, or more, tons of plutonium.

While the fraction that could be released following a credible accident is extremely uncertain, it is clear that the release of only a small percentage of this inventory would be equivalent to the release of all the volatile fission products in one of today's nuclear plants. Once lost to the environment, the plutonium not ingested by people in the first few hours following an accident would be around to take its toll for generations to come – for tens of thousands of years.

When one factors in the possibility of sabotage and warfare, where power plants are prime targets not just in the United States but also in less developed countries now striving to establish a nuclear industry, then there is almost no limit to the size of the catastrophe one can envisage.

It is argued that the probabilities of such disastrous events are so low that these events fall into the negligible risk category. Perhaps so, but do we really know this? Recent unexpected events raise doubts. How, for example, does one calculate the actions of a fanatical terrorist?

The use of plutonium as an article of commerce and the presence of large quantities of plutonium in the nuclear fuel cycles also worries a number of informed persons in another connection. Plutonium is readily used in the production of nuclear weapons, and governments, possibly even private parties, not now having access to such weapons might value it highly for this purpose. Although an illicit market has not yet been established, its value has been estimated to be comparable to that of heroin (around $5,000 per pound). A certain number of people may be tempted to take great risks to obtain it

Thus, a large-scale fission energy economy could inadvertently contribute to the proliferation of nuclear weapons These might fall into the hands of countries with little to lose, or of madmen, of whom we have seen several in high places within recent memory.

In [an] excellent article (in Science magazine), Alvin M. Weinberg emphasized that part of the Faustian bargain is that to use fission technology safely, society must exercise great vigilance and the highest level of quality control, continuously and **indefinitely**. As the fission energy economy grows, many plants will be built and operated in countries with comparatively low levels of technological competence, and a greater propensity to take risks. . . Moreover, even in countries with high levels of technological competence, continued success can lead to reduced vigilance. . . .

Deeper moral questions also surround the storage of high-level radioactive wastes. Estimates of how long these waste materials must be isolated from the biosphere apparently contain major elements of uncertainty, but current ones seem to agree on "at least 200,000 years" . . . Furthermore, there is the political factor. An increasingly informed and environmentally aware public is likely to resist the location of a permanent storage facility anywhere. . .

Primary emphasis is now being placed upon the design of surface storage facilities intended to last a hundred years or so, while the search for a permanent site continues. These surface storage sites would require continuous monitoring and management of a most sophisticated kind .

It seems clear that there are many factors here which a benefit-cost analysis can never capture in quantitative, commensurable terms It also seems unrealistic to claim that the nuclear fuel cycle will not sometime, somewhere, experience major unscheduled events. These could range in magnitude from local events, like the fire at the Rocky Mountain Arsenal, to an extreme disaster affecting most of mankind.

Whether these hazards are worth incurring in view of the benefits achieved is what Alvin Weinberg has referred to as a trans-scientific question. As professional specialists we can try to provide pertinent information, but we cannot legitimately make the decision, and it should not be left in our hands.

One question I have not yet addressed is whether it is in fact not already too late. Have we already accumulated such a store of high-level waste that further additions would only increase the risks marginally? While the present waste (primarily from the military program plus the plutonium and highly enriched uranium contained in bombs and military stockpiles) is by no means insignificant, the answer to the question appears to be no. I am informed that the projected high-level waste to be accumulated from the civilian nuclear power program will contain more radioactivity than the military waste by 1980 or shortly thereafter. By 2020 the radioactivity in the military waste would represent only a small percentage of the total. Nevertheless, we are already faced with a substantial long-term waste disposal storage problem. Development of a full-scale fission energy economy would add overwhelmingly to it. . .

What are the benefits? The main benefit from near-term development of fission power is the avoidance of certain environmental impacts that would result from alternative energy sources. In addition, fission energy may have a slight cost edge, although this is somewhat controversial

Another near-term benefit is that fission plants will contribute to our supply during the energy "crisis" that lies ahead for the next decade or so. One should take note that this crisis was in part caused by delays in getting fission plants on the line. Also, there seems to be a severe limitation in using nuclear plants to deal with short-term phenomena. Their lead time is half again as long as fossil fuel plants – on the order of a decade

The long-term advantage of fission is that once the breeder is developed we will have a nearly limitless, although not necessarily cheap, supply of energy. This is very important but it does not necessarily argue for a near-term introduction of a full-scale fission economy. Coal supplies are vast, at least adequate for a few hundred years, and we are beginning to learn more about how to cope with the "known devils" of coal.

Oil shales and tar sands also are potentially very large sources of energy, although their exploitation will present problems. Geothermal and solar sources have hardly been considered, but look promising . . One of the potential benefits of solar energy is that its use does not heat the planet. In the long term this may be very important.

Fusion, of course, is the greatest long-term hope. Recently, leaders of the U.S. fusion research effort announced that a fusion demonstration reactor by the mid-1990s is now considered possible. Although there is a risk that the fusion option may never be achieved, its promise is so great that it merits a truly national research and development commitment.

A strategy that I feel merits sober, if not prayerful, consideration, is to phase out the present set of fission reactors, put large amounts of resources into dealing with the environmental problems of fossil fuels, and price energy at its full social cost, which will help to limit demand growth.

Possibly it would also turn out to be desirable to use a limited number of fission reactors to burn out the present stocks of plutonium and thereby transform them into less hazardous substances. At the same time, the vast scientific resources that have developed around our fission program could be turned to work on fusion, deep geothermal, solar, and other large energy supply sources, while continuing research on various styles of breeders. It seems quite possible that this program would result in the displacement of fission as the preferred technology for electricity production within a few decades.

Despite the extra costs we might have incurred, we would then have reduced the possibility of large-scale energy-associated nuclear disaster in our time and would be leaving a much smaller legacy of "permanent" hazard. On the other hand, we would probably have to suffer the presence of more short-lived undesirable substances in the environment in the near term.

This strategy might fail to turn up an abundant clean source of energy in the long term. In that event, we would still have fission at hand as a developed technological standby, and the ethical validity of using it would then perhaps appear in quite a different light.

We are concerned with issues of great moment. Benefit-cost analysis can supply useful inputs to the political process for making policy decisions, but it cannot begin to provide a complete answer, especially to questions with such far-reaching implications for society. The issues should be aired fully and completely before a committee of Congress having broad policy responsibilities. An explicit decision should then be made by the entire Congress as to whether the risks are worth the benefits.

Reprinted by EARS
Environmental Action Reprint Service
University of Colorado at Denver
1100 - 14th Street
Denver, Colorado 80202

$10

Amateur A-Bomb?

The carefully written note contained a message that was frighteningly clear. Unless city officials paid the letter writer $1 million and assured him safe passage out of the country, he would set off an H-bomb in the middle of town. To make matters worse, the note was accompanied by a crude but telling diagram of a thermonuclear weapon. Consulted by city officials, experts at the Atomic Energy Commission refused to say for certain if the would-be bomber was really capable of carrying out his threat

This melodramatic incident was not conjured up by a TV scriptwriter or a science-fiction novelist. It actually occurred in Orlando, Fla., a few years ago. Only competent police work and a slip-up by the "bomber" revealed that he was in fact a 14-year-old high school honors student in science who was bent on nothing more than a spectacular hoax. What made the mischief so chilling was that nuclear blackmail by terrorist or criminal organizations is far from inconceivable. It is quite possible that a simple but devastating atomic weapon could now be made by one or more terrorists without advanced scientific and technical skills.

That is the conclusion of a growing number of nuclear experts. A report prepared for the Atomic Energy Commission and released last week by the Senate Subcommittee on Executive Reorganization labels the nation's safeguards against nuclear theft and blackmail as "entirely inadequate to meet the threat." A study conducted for the Ford Foundation by Atomic Physicist Theodore B. Taylor and Arms Control Expert Mason Willrich makes the point even more strongly. In "Nuclear Theft Risks and Safeguards," Taylor and Willrich report that amateur bombmakers could probably put together weapons as small as one-tenth of a kiloton (equivalent to the explosive force of 100 tons of TNT). Such bombs, says Taylor, would be powerful enough to topple the twin towers of Manhattan's 110-story World Trade Center or destroy the U.S. Capitol building.

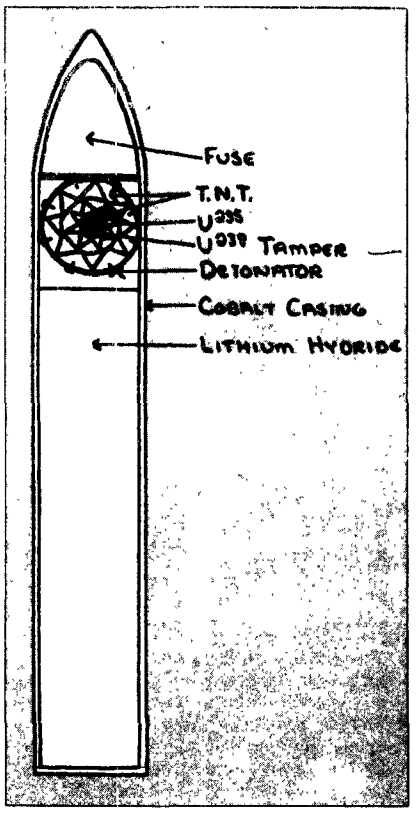
Greatest Deterrent. Physicist Taylor's warning has not been lightly taken; his credentials are impressive. During his seven years at the AEC's Los Alamos Scientific Laboratory, he specialized in the design of compact and efficient A-bombs. Though Taylor admits that the fabrication of such devices is beyond the capability of basement bombsmiths, he feels that the manufacture of less sophisticated and powerful weapons is not.

Until recently, the greatest deterrent to amateur bombmaking was the scarcity of the key ingredient. Both weapons and nuclear reactors need fissionable material to sustain a chain reaction—the familiar energy-producing process in which tiny, fast-moving neutrons released by the breakup (fission) of one unstable atom smash into the nuclei of neighboring atoms, causing them to split. The common reactor fuel—which was also used in the bomb that leveled Hiroshima—is a fissionable isotope of uranium called U-235. But U-235 accounts for only about one out of every 140 atoms of uranium in nature, and it takes enormously sophisticated methods to separate even a small amount of the isotope from the more common, nonfissionable uranium 238. Most of today's so-called light-water reactors run on a mix of only 3% U-235, which is far below the enrichment level needed by weapons makers. In the future, plutonium, which is far more efficient—and lethal—will largely replace U-235 as reactor fuel.

Easy Hijacking. The first manmade element ever to be manufactured in a quantity large enough to be seen with the naked eye, plutonium was used in the more devastating A-bomb dropped on Nagasaki. It is also a natural byproduct of the 20th century alchemy that occurs inside all nuclear reactors using uranium. But plutonium is difficult (and thus expensive) to handle; it is so toxic that the inhalation of only a few specks of dust is sufficient to cause cancer.

Until recently, there has been little peaceful use for plutonium, and most of the small amounts produced by utility companies has been either stockpiled or used for research. But as methods for using this material are perfected, plutonium will become an increasingly common reactor fuel. As a result, traffic in the stuff will swell. It will be shipped from processing plants to fabricating plants (where it is made into fuel rods that are unusable for weapons), to nuclear installations, and then back again for reprocessing. In addition, the AEC's highly touted "breeders," a new generation of reactors that produce considerable amounts of plutonium, will increase the "ploot" supply. According to some estimates, by the year 2000 the annual production of plutonium in the U.S. will be 600,000 lbs.—and most of this will be in commercial rather than Government hands.

Just to clear any doubts you may have about us having a hydrogen bomb, there is a drawing of it with this letter. You will need an expert in nuclear weapons to tell you if it is genuine, but believe me, it is.



NUCLEUS OF A NUCLEAR HOAX

With so much of the material around, terrorists might not find it too difficult to get their hands on it. Hijacking could be relatively easy even though shipments are accompanied by armed guards. The AEC is tightening its security measures against theft, but some weapons-grade material is lost during processing and merely written off as MUF (materials unaccounted for). If an employee-conspirator decided to accumulate a critical amount of plutonium by helping himself to a little MUF at a time, the loss might never be detected. Weapons-grade material could also be taken by force in a direct assault on a storage, fabrication or reprocessing plant. Though protected by fences, electronic devices and armed guards, the plants are still far from impregnable. Last fall, for instance, the Government Accounting Office showed two

of these buildings to be security nightmares. Among its findings: doors without alarms, gaps under fences, flimsy sheet-metal walls, plastic skylights that could be opened in one minute. They also found inadequate liaison with local authorities: when police were alerted in one test, they went to the wrong location 14 miles away

Easier Than Heroin. Taylor, for one, is convinced that terrorists could actually fashion the stolen material into a bomb in a matter of weeks. To achieve the biggest bang, the bombmakers would probably choose to convert their purloined material into a metal. Plutonium and U-235 can be transported as compounds that do not readily lend themselves to the making of the most efficient weapons, but the techniques for purification are, says Taylor, in some respects no more difficult than refining heroin in an illicit laboratory.

As for the actual manufacture of the bomb, the basic information can be gleaned from any number of public documents, some of them published by the AEC. Essentially, all that is needed to achieve a blast is to bring together a sufficient amount of properly shaped fissionable material fast enough to initiate a massive chain reaction. To do that, the Hiroshima bomb used the so-called gun-barrel technique: both ends of a heavy metal pipe were stuffed with U-235 and the charge at one end was used as a projectile. To detonate the bomb, the U-235 projectile was hurled by conventional explosives down the barrel and into the mass at the other end. The density of the material in the combined masses of U-235 suddenly increased enough so that the fast-moving neutrons triggered a chain reaction and the bomb exploded. The Nagasaki bomb used a more efficient method: a hollow sphere of plutonium was enclosed by shaped explosive charges When the explosive was detonated, it sent much of its force inward, crushing the plutonium into a solid ball, a "supercritical" mass that released even more energy than the Hiroshima bomb. With the proper explosive and some plutonium fashioned into the proper shape, a skilled amateur might well produce a powerful weapon.

To keep such potentially murderous materials out of the wrong hands, the AEC study recommends the establishment of a federal nuclear protection and transportation service, stronger links between the AEC and such intelligence-gathering agencies as the CIA and FBI, and tougher testing of the security measures taken by such "nuclear licensees" as fabricators, processors and storage depots. These measures could make it more difficult for do-it-yourself bombers. But perhaps no system is proof against Murphy's Law, which holds that if anything can possibly go wrong, it will Back in the early 1950s, a routine inventory revealed that a U.S A-bomb was missing, and no amount of searching succeeded in locating it As the military sweated, a senior officer happened to visit a dump on a military base He strolled between piles of discarded A-bomb casings that were about to be offered for sale as scrap. There among the rejects he found the missing bomb

Bomb Designer's Warning Ignored by Government 'Regulators'

NEW YORK (UPI) — Any reasonably intelligent person can build a nuclear bomb, claims physicist Theodore Taylor who helped design much of America's atomic arsenal.

With a do-it-yourself bomb guide drawn from publicly available federal government documents or local library, you can buy much of what you need from the hardware store and steal the rest — like radioactive materials — from a nuclear facility, according to Taylor.

The homemade nuclear bomb is what Taylor has been warning the U.S. government about for a year.

CONSULTANT

Taylor, 48, designed nuclear weapons at Los Alamos, N.M. — near where the world's first atomic bomb was exploded — from 1949 to 1957 and has served as a consultant on nuclear physics for the federal government and private industry.

Taylor said in an interview and an article in a recent issue of "The New Yorker" he first talked to the Atomic Energy Commission and government officials about homemade bombs in 1967, but was unable to convince anyone of the threat

In the past few years he has tried to bring the problem to the public's attention "until pressure forces the AEC to stop pushing security under the rug."

According to Taylor, two things are needed to build a crude nuclear bomb: fissile (fissionable material) and know how.

Enough know-how, he said, is available in declassified documents and standard reference works.

"The Encyclopedia Americana is very good and so is the World Book," he said. "Los Alamos Primer No. 1, used to brief scientists in the 40's, costs $2.06 and is available from the Oakridge Technical Information Service."

Most other needed information, all but the "gory classified details," is catalogued in an annual publication, "Nuclear Science Abstracts," available in many libraries, he said.

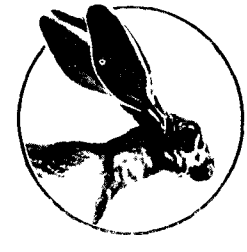
'STANDARD SOURCE'

"Anything else you need can be figured out from the declassified material and standard sources," he said.

Taylor said the only barrier to home construction of nuclear bombs is the availability of fissile material, plutonium or uranium. By 1978, energy demands should begin to cause dramatic increases in existing quantities of both, he said.

"All reactors either make or use plutonium or uranium," he said. "Fast breeder reactors make more plutonium than they use."

Reprinted by EARS, Environmental Action Reprint Service, University of Colorado at Denver, 1100 - 14th Street, Denver, Colorado 80202. Phone (303) 534-1602.



EARS

$12

Committee for Nuclear Responsibility, Inc.
Suite 1100 / 110 East 59th Street / New York, N.Y. 10022 / (212) 759-5387

Lenore Marshall
Founder (1899-1971)

Board of Directors

John W. Gofman
Prof. of Medical Physics, University of Calif. at Berkeley

Charles E. Goodell
Former U.S. Senator from New York

Co-Chairmen

Richard E. Bellman
Prof. of Mathematics, University of Southern California

Ramsey Clark
Former U S Attorney General

John T. Edsall
Prof of Biochemistry, Harvard University

Paul R. Ehrlich
Prof of Biology, Stanford University

David R. Inglis
Prof of Physics, University of Massachusetts

Richard Max McCarthy
Former U.S. Congressman from New York

Ian McHarg
Chairman, Department of Landscape Architecture & Regional Planning, University of Pennsylvania

Lewis Mumford
Honorary Fellow Science Policy Foundation

Linus Pauling
Nobel Laureate Prof. of Chemistry, Stanford University

Harold Urey
Nobel Laureate University Prof. Emeritus, Chemistry Dept., University of California at San Diego

George Wald
Nobel Laureate Higgins Prof. of Biology, Harvard University

James D. Watson
Nobel Laureate Prof. of Biology, Harvard University

A Sunshine Future or a Radioactive One?

by Egan O'Connor

On March 7, 1973, the Atomic Energy Commission issued its revised forecast of nuclear power growth to the year 2000; the forecast omitted the most important figures of all.

In December 1972, President Nixon's Solar Energy Panel issued an 85-page report called **Solar Energy as a National Energy Resource**; few people even know about the report, although it is packed with good news.

While the Solar Energy Panel says there are no technical barriers to using solar power, the cleanest possible source of energy, the AEC forecast means the U.S. is planning to use the dirtiest possible process.

THE NUCLEAR FORECAST

The AEC is predicting that nuclear fission will provide about 30% of the country's total energy in-put in the year 2000; in comparison, fission's contribution in 1972 was less than 1%.

Put another way, the AEC predicts that atomic power plants in this country will have a generating capacity of 1,200,000 electrical megawatts in the year 2000, which is the equivalent of 1,200 atomic power plants each with a capability of 1,000 megawatts. Atomic generating capacity in 1972 was 14,700 electrical megawatts, distributed unevenly among 29 relatively small plants. Many states today have no atomic power plants at all, but by the year 2000, there could be an average of 24 plants in each and every state.

The figures of interest which do not appear in the AEC forecast appear below:

During the year 2000, the forecast 1,200 atomic power plants would create as much strontium-90 and other long-lived radioactive poisons as the fissioning of about 1,200,000 Hiroshima bombs, plus at least 600,000 pounds of radioactive plutonium (more, if there are breeder reactors in operation). During the following year (2001), the same plants would add the same amount of poison to the legacy again, and so on year after year.

Is it possible to imagine a filthier process than nuclear fission? It is the only process for making power which creates pollutants so terrible that they must somehow be kept contained continuously for 100,000 years.

According to the AEC forecast, it would not be just made-in-America poisons which would have to be kept out of the environment and the hands of terrorists for centuries. The AEC predicts that "other non-Communist countries" will have 1,460,000 megawatts of nuclear power by the year 2000, and "the Communist countries" will have 600,000 nuclear megawatts by that time.

So, the combined production of long-lived radioactivity in the year 2000 would be the equivalent of exploding about three million Hiroshima atom bombs per year.

It takes a special sort of mentality to publish forecasts of nuclear growth without a hint of its necessary twin – the stupendous growth of radioactive poison on this planet.

SOLAR ENERGY PROSPECTS

The fact is that we could have a sunshine future instead of a radioactive one. In January 1972, the White House instructed the National Science Foundation (NSF) and N.A.S.A. to organize a Solar Energy Panel to assess the potential of solar energy; nearly 40 experts were appointed from the fields of solid state physics, chemistry, microbiology, power engineering, architecture, photovoltaics, thermodynamics, economics, sociology, and environment.

The following ten statements are quoted from their report, **Solar Energy as a National Resource**, December 1972:

1. Solar energy "is an inexhaustible source of enormous amounts of clean energy."
2. "In principle, solar energy can be used for any energy need now being met by conventional fuels."
3. "There are numerous conversion methods by which solar energy can be utilized for heat and power, e.g. thermal, photosynthesis, bioconversion, photovoltaics, winds, and ocean temperature differences."
4. From sea-thermal energy alone, "the total annual production could exceed the year 2000 projected total energy demands."
5. "In 1969, the total electric energy consumed in the U.S. could have been supplied by the solar energy incident on 0.14% of the U.S. land area," a statement based on U.S. average solar incidence and the assumption of a 10% conversion efficiency.
6. "There are no technical barriers to wide application of solar energy to meet U.S. needs."
7. "For most applications, the cost of converting solar energy to useful forms of energy is now higher than conventional sources, but due to increasing prices of conventional fuels and increasing constraints on their use, it will become competitive in the near future."
8. With support behind solar energy programs, "building heating could reach public use within 5 years, building cooling in 6 to 10 years, synthetic fuels from organic materials in 5 to 8 years, and electricity production in 10 to 15 years."
9. "Solar energy utilization on a large scale could have a minimal impact on the environment if properly planned."
10. "It appears that an objective allocation of R&D funds would call for substantially increased R&D support for a number of solar energy opportunities. There are also international benefits in making a viable solar energy technology available to the world, as well as balance of payments and national security benefits in limiting our almost inevitable dependence on foreign energy sources."

There is an eleventh statement which is so significant that it must be saved for separate consideration later in this report.

IS SOLAR POWER "ECONOMICALLY COMPETITIVE" WITH NUCLEAR?

Obviously President Nixon ignored the Panel's budget recommendations. Why is the President such a powerful advocate of radioactivity instead of sunshine?

FEDERAL BUDGETS FOR NUCLEAR AND SOLAR ENERGY

In January 1973, President Nixon submitted his Fiscal 1974 budget proposals to Congress. For nuclear and solar energy, the figures are approximately as follows:

Nuclear fission:	civilian reactor technology	$456,000,000
Nuclear fission:	regulation	54,500,000
Nuclear fission:	AEC bio-medical and environmental research (at least half of the $99 million budget should be attributed to the principal cause of concern atomic power plants	49,500,000
Nuclear fission:	public relations	(est.)
	nuclear science demonstrations and exhibits	1,100,000
	semi-technical films, press releases, speeches	250,000
	Other information services, $5 million; includes some highly technical ones which are not public relations.	2,000,000 (est.)
Peaceful nuclear explosions ("Plowshare")	the use of nuclear bombs to stimulate natural gas production*	3,800,000
Nuclear fusion:	including military research	70,000,000
Solar energy:	National Science Foundation	12,200,000
	NASA space power work, $6.4 million; assume some transfer to earth-systems	3,200,000 (est.)

*Plowshare is discussed later in this report.

TOTAL FOR FISSION: Approx. $563 million
TOTAL FOR SOLAR: Approx. $ 15 million

How does Nixon's $12 million for solar energy (on earth) compare with the budget recommendations of his Solar Energy Panel?

For a 15-year solar R&D program, the Panel made the recommendations below:

Thermal energy for buildings	$100,000,000
Renewable clean fuel sources:	
Photosynthetic production of organic materials and hydrogen	60,000,000
Conversion of organic materials to fuels or energy	310,000,000
Electric power generation:	
Solar thermal conversion	1,130,000,000
Photovoltaic conversion (solar cells)	780,000,000
Wind energy conversion	610,000,000
Ocean thermal differences	530,000,000

Seven additional tables in Appendix A indicate that the Panel recommended $153 million be spent over the next few years to fund work which is ready to commence right now

If popularity were a consideration, safe and natural solar power systems would almost certainly be more popular than plants each holding 1,000 Hiroshima-bombs of radioactivity.

If technical feasibility were the criterion, solar power would also have the advantage over nuclear fission; both, however, are certain to deliver usable energy. This certainly distinguishes them from controlled nuclear fusion, whose control has not quite been achieved yet.

Can the President claim that nuclear fission will be cheaper than solar power? Let's look at some figures.

The Federal Government has already spent over three billion tax-dollars developing civilian nuclear power. Out of $456 million for reactor technology in the Fiscal 1974 budget, $320 million is for developing the breeder reactor, a power reactor which produces even more radioactive plutonium than today's nuclear power plants. The AEC expects to spend about four billion tax-dollars just developing breeders for commercial use by 1990.

What justifies this investment? The Fermi reactor 30 miles from Detroit, Michigan, is the only commercial breeder plant ever built in this country. When the plant was under construction in 1963, the chairman of Detroit Edison predicted that the plant would earn $92 million by 1970 from selling electricity to Detroit and plutonium to the AEC. But in 1966, Fermi had a serious accident which took about four years to repair. Then there was one problem after another.

By mid-1972, the plant had run at full power for about 30 days and produced about $1.3 million worth of electricity, and too little plutonium for the AEC to buy. Meanwhile, the cost of the Fermi plant had swollen from $50 million to about $130 million.

On November 29, 1972, plans were announced to shut down the Fermi plant forever. Its total electric production was about 32 million kilowatt-hours in its lifetime — which means that Fermi's electricity really cost $4.00 per kilowatt-hour. In comparison, electricity normally sells today to residential customers for about 3¢ per kilowatt-hour.

In short, our only experience with the breeder so far shows it to be very far from an economically competitive and reliable source of power. From the competitive point of view, as well as reliability, solar power looks just as good or better than the breeder.

There have been no commercial solar power systems comparable to Fermi because none has been funded. The only real experience we have with solar power so far is from the space program, where solar cells have been producing electricity reliably for 12 years.

Solar cells happen to be the most expensive solar technology at the moment, and yet experts say even the cells would provide electricity at commercially competitive prices if their cost were reduced about 100-fold. Almost everyone who knows anything about solar cells is confident that the cost-reduction can be achieved in a few years, if a modest R&D investment is made.

In addition to solar cells, there are several other solar energy technologies which could quickly become economically competitive in the opinion of the Solar Energy Panel.

For instance, one member of the Panel, civil engineering professor William Heronemus, testified at an AEC licensing hearing in January 1973 that wind-power (an indirect form of solar energy) could provide as much electricity for Long Island in 1977 as a proposed nuclear power plant — at the same cost or less, and with much greater reliability.

THE QUESTION OF CHEAPNESS

The question of cost deserves examination, whether it is the cost of energy, the cost of saving tall trees in a future housing development, the cost of preventive medicine, or the cost of organizing society's work in a way which might stimulate, satisfy, and include more human beings.

The question, "But is it economical?" is asked invariably, but seldom does anyone ask, **"Is it what people would like to have?"**

"But is it economical?" is a fundamentally anti-human question when it implies that cheapness is more important than any other considerations. If nuclear electricity creates the possibility, even the probability, of poisoning the planet forever, is the cost of solar power the most important issue to be raising?

THE ELEVENTH QUOTE

Let us review what the Solar Energy Panel said about cost. "For most applications . . . it will become competitive in the near future." About technical feasibility: "No technical barriers." About time-frames: commercial readiness within 5 to 15 years.

But then, without elaboration anywhere in the report's 85 pages, the Panel made the following statement which I called "the eleventh quote" earlier:

> By the year 2020, "solar energy could economically provide up to
> 35% of the total building heating and cooling load,
> 30% of the nation's gaseous fuel,
> 10% of the liquid fuel,
> 20% of the electric energy requirements."

All the percentages — especially for electricity — seem extremely low in view of the Panel's other conclusions. There is more than enough solar energy available in this country to make all the figures 100%, if **the nation were determined to have it so.**

The great significance of the 11th quote, in my opinion, is that it reflects political reality. Although solar power makes sense in every way, it is simply **not wanted yet** by the powers who own this country's fossil fuel and fission resources and equipment.

If you agree that these interests have always set the country's "energy policy," you can easily understand how Nixon could say in June 1971 that the nuclear breeder is "our best hope for the future," and blurt out in September 1971 that, "This business about breeder reactors and nuclear energy is over my head." Obviously someone else is making Nixon's fission policy for him.

His concentration on nuclear and fossil fuels matches perfectly the desires of industry. On March 12, 1973, the American Gas Assn., the American Petroleum Inst., the Atomic Industrial Forum, the Edison Electric Institute, and the National Coal Assn. issued a joint statement about energy which called for a strengthened commitment to research and development in both nuclear and fossil fuels. The Electric Research Council is putting the lion's share of its niggard research dollars into the nuclear breeder, a little into fusion, and some into fossil fuels; for solar energy there is lip service.

In Congress, the situation is the same. On March 19, 1973, a bill entitled "The National Energy Research and Development Policy Act of 1973" was introduced into the Senate. Its prime sponsors (there were 28) included the Senate's three most powerful energy figures: Senator Jackson, Chairman of the Interior Committee and member of the Joint Committee on Atomic Energy (JCAE); Senator Magnuson, Chairman of the Commerce Committee; and Senator Pastore, Vice-Chairman of the Joint Committee on Atomic Energy.

The bill, S.1283, proposes to create five energy development corporations — four for fossil fuel and one for geothermal energy. Obviously nuclear fission already has all the government support it can absorb.

As for solar energy, the bill would leave its fate right in the hands of the very people who have been ignoring it for the last several years. The bill proposes that "a comprehensive energy research and development strategy for the Federal Government" be determined by a committee composed of an Assistant Secretary of Interior, a Commissioner of the AEC, a Commissioner of the Federal Power Commission, the Director of the National Science Foundation, an Assistant Administrator of N.A.S.A. and "representatives of other executive agencies which the President finds have a significant and continuing role in energy R&D." The chairman of this committee is to be appointed by the President, too.

A FUTURE WITHOUT SUNSHINE

Unless new forces (grass-roots and industrial) can organize powerful support for solar energy systems, we just won't have any. We will have a grotesque expansion in fossil fuels and fission. There is even a unique combination in the works – the stimulation of natural gas fields by the underground explosion of nuclear bombs.

The program to promote the peaceful use of atomic bombs is called "Plowshare." The AEC has already produced some radioactive natural gas, with the help of industry, in New Mexico and Colorado. A third Plowshare "experiment" is scheduled for mid-May 1973 about 50 miles from Grand Junction and 75 miles from Aspen, Colorado. This one, called Project Rio Blanco, will use three nuclear bombs with the combined power of about five Hiroshima-bombs.

According to the AEC, the explosion of over 15,000 nuclear bombs in the Rocky Mountain area might eventually yield 300 trillion cubic feet of gas – contaminated gas. Over a period of 30 years, that would be 10 trillion cubic feet per year – an energy-equivalent of about 10×10^{15} BTU per year.

The absurdity of atom-bombing for gas is clearest if you study "Figure 6" in the report of the Solar Energy Panel. The same amount of energy (about 10×10^{15} BTU per year) could be provided by solar energy harvested from 2% of our land (48 mainland states) at a 1% conversion efficiency. If the sunshine were harvested with 10% efficiency, the Plowshare gas could be replaced by solar energy from about one quarter of 1% of our land.

Both 1% and 10% conversion efficiencies for solar energy are feasible today. The efficiency of solar energy conversion by trees and grass in natural ecosystems ranges from 0.3% to 3.0%; algae with very much higher efficiencies have been cultivated for at least 13 years at the University of California and elsewhere. As for 10% conversion efficiency, the average efficiency of solar cells on earth today is already 13%, with 16% efficiency in recent laboratory tests. In addition, conversion efficiencies in the range of 20% - 30% are expected in the production of solar electricity using the heat-turbine system (e.g., "the Meinel proposal")

DEALING WITH BIASED REPORTS

People who are familiar with the exaggerated safety and economy claims of nuclear fission experts should view good news from solar energy experts with skepticism, too.

The country's R&D system is organized so that experts in any field almost always have a vested interest in promoting that field. There are virtually no experts without a pronuclear bias since experts who are critical get no grants or are otherwise punished. Such a system guarantees the production of false claims, the compromise of intellectual honesty, and the loss of early warnings.

The report of the Solar Energy Panel deserves for its inclusion of the following recommendation:

> "It is important that a policy of research and review for environmental effects be made a integral part of the R&D process. Continuous feedback into the development program is critically important to prevent the undue expenditure of funds for processes that could ultimately prove unacceptable from a public point of view. One of the major obstacles to public acceptance of new technologies is the fear that there are unknown side effects that have not been adequately investigated or disclosed."

It is refreshing that someone thinks what the public wants should count, and that truth has an intrinsic value no matter where the chips fall.

Ms Egan O'Connor

HOW TO . . . for readers

1. **How to help stop Plowshare explosions:** contact Environmental Action of Colorado, 1100 14th Street, Denver 80202, and/or Senator Floyd Haskell, Denver Federal Bldg. 19th & Stout Sts., Denver 80202.

2. **How to get a solar-energy bumper sticker:** "Switch to Solar Energy." 50¢ for one, or 30¢ for 10 or more, from Environmental Action of Colorado, 1100 14th Street, Denver 80202. Same prices for the bumper sticker which reads "Radioactivity: The Ultimate Pollution."

3. **How to reach the Sun People, Alternate Energy Advocates:** Contact Ruth Fisher, South Dennis, NJ 08245. About 40 members of this group have made themselves sun-power dresses with a yellow sunburst on red and vice versa; the pattern for this particularly attractive sunburst is available from Ruth Fisher, who also has "Solar Power" button with the sunburst. 25¢ for one, 10¢ each in 100.

4. **How to keep up with what plain people are DOING with solar energy:** Subscribe to **Alternative Sources of Energy**, c/o Donald Marier, Route 1, Box 16B, Milaca, WI 54859; $2.00 for 6 issues. Subscribe to **Mother Earth News**, $6.00 for 6 issues.

5. **How to get the full report of the Solar Energy Panel:** Only 3,000 copies were printed and most are gone; a few remain. Contact Dr. Frederick Morse, Dept. Mech. Engineering, University of Maryland College Park, MD 20742.

Reprinted by EARS
Environmental Action Reprint Service
University of Colorado at Denver
1100 14th Street
Denver, Colorado 80202
Phone (303) 534-1602

Distributed by:

THE COMMITTEE ENCOURAGES YOU TO REPRINT ALL OR PART OF THIS PAPER FOR DISSEMINATION AS YOU SEE FIT. NO PERMISSION IS REQUIRED.

This paper contains 70% recycled fibers – Environmental Action Reprint Service

Chairman Mills: The next speaker on my agenda, Mr. Geichman, has left, and he will submit a written statement.

Mr. Lehrburger from People for Rational Energy Sources. Is that correct?

TESTIMONY PREPARED FOR

U.S. ENVIRONMENTAL PROTECTION AGENCY

LIMITATION OF ENVIRONMENTAL CONTAMINATION BY PLUTONIUM AND THE TRANSURANIUM ELEMENTS

January 10, 1975

by

Carl Lehrburger
70 Adams
Denver, Colorado, 80206

Mr. Lehrburger is a representative of

PEOPLE FOR RATIONAL ENERGY SOURCES (PRES)

Good day. My name is Carl Lehrburger, and I am a representative of People for Rational Energy Sources (PRES). I have been working the last three years in the areas of public education on energy policy and energy alternatives to nuclear and fossil fuels. I am currently employed with a solar energy research and development firm.

In establishing standards limiting environmental contamination by plutonium and other transuranium elements, disassociating radiation contamination of the environment from the nuclear industry and the social applications of these elements will seriously misinterpert the problems that confronts us. In setting plutonium standards, it is my contention that the Environmental Protection Agency consider the social implications of the proposed plutonium economy and the decision to undertake plutonium recycling. Only by regulating the sources of Plutonium and man-made radio nuclei's will the E.P.A. be able to assure the public health and welfare.

Plutonium standards are intricately apart of the broader issues of nuclear weapons and nuclear power. To attempt to regulate radiation pollution via standards without regulating the industry and policy-makers which have vested interests in this technology is to play into the hands of those who have the most to gain from perpetuating the use of nuclear weapons and nuclear reactors. It is folly to believe the words of our nuclear priesthood when they define the problems created by nuclear technology simplistically ("the chances of a nuclear reactor accident are one in a million) and the solutions as being primarily technological.

The major problems concerning the use of nuclear energy are social as well as technological in nature. The decisions reguarding the applications of nuclear energy will effect all of society. It's use, therefore, should be regulated by society and for humankind as a whole, instead of by a small technological and political elite. To leave moral and social decisions to those with vested political and financial interests will insure the propagation of those special interests. Once we commit ourselves to a plutonium economy, we will have become instruments of a burgeoning and self-perpetuating industry.

In establishing plutonium standards, the social implications of the plutonium economy should be considered, just as the biological effects of plutonium must be considered. To guard against terrorism, nuclear hijacking, nuclear theft and accidents, a plutonium economy will demand social controls to enforce a constant vigilance over all stages of the nuclear fuel cycle. The catostrophic result of diversion of weapon grade materials will necessitate a national and international police force to safeguard Westinghouse, General Electric and Gulf nuclear facilities and investments, subsidized by the taxpayers. Safe guarding nuclear bomb material ultimately would require a restructuring of the socio-political institutions on a worldwide scale. Stricter social controls and loss of civil liberties are the inevitable consequence of having to protect the environment from radiation contamination and society from the threats of nuclear war, blackmail and theft.

Dr. Alvin Weinberg, former Director of the Oak Ridge National Laboratory has written:

> ". . . The discovery of the bomb has imposed an additional demand on our social institutions. It has called forth (this) a military pristhood upon which in a way we all depend for our survival. It seems to me that peaceful nuclear energy probably will make demands of the same sort on our society, and possibly of even longer duration."

Writting on the same subject, Tamplin and Cochran have written:

> ". . .We suggest that it is beyond human capability to develop a cadre of sufficient size and expertise that can be counted upon to understand nuclear technology, to control it, and to prevent accidents and diversions over many generations". f.n.

With or without the existance of plutonium standards over environmental pollution, contamination to our world is inevitable, unless we begin regulating the amount of plutonium and other transuranium elements in use at any one time and the use that they are applied to.

If the proliferation of nuclear power continues, increased accidents can be anticipated in the production of electricity and in the transportation, reprocessing and storage of radioactive materials. The track record of the nuclear industry demonstrates that accidents are unavoidable. Major nuclear reactor accidents have already occurred at the Fermi experimental "breeder" reactor near Detroit and at Windscale, England, where large land areas were contaminated. A 1973 AEC Task Force Report disclosed approximately 850 "adnormal occurrences" at nuclear reactors over a 17 month period.

The proliferation of nuclear power to foreign countries means that nuclear bomb-grade materials will be diverted to make nuclear weapons, as India's "peaceful" nuclear detonation demonstrates. Even though the United States publically gives lip service to nuclear disarmament, the U.S. nuclear industry is the largest producer and promoter of nuclear weapons and nuclear reators in the world. Exporting nuclear reactors to other nations can only work against disarmament and world peace by giving them the opportunity to build atom bombs. By 1980, 29 countries could have 231 nuclear power reactors, many being supplied by U.S. nuclear corporations.

Will standards established for permissable amounts of plutonium in the environment have any significant effect in avoiding contamination, directly or indirectly, in these 29 countries, which would invariably mean radiation contamination throughout the world? Probrobly they would have no more success then the United States attempts at nuclear disarmament and world peace. The contridiction remains: The U.S. cannot have disarmament if it engages in the sale of weapons, just as an environment free from radiation pollution is impossible to achieve if we continue expanding our nuclear industry.

f.n. "Plutonium Recycle or Civil Liberties: We can't have both" Environmental Action, Dec. 7, 1975

Plutonium is modern man's "death wish". Something so devious, so powerful and so long-lived as plutonium has captured the attention and imagination of our technological "pristhood", for they desire the longevity of their creations. It is well known that plutonium was named after Pluto, the Greek's Lord of Death, and that plutonium is a major substance for producing atomic weapons. Today, sectors of the nuclear industry and the AEC advise us that a "plutonium economy" is the solution to our energy and nuclear waste "disposal" problems. They realize that using plutonium as a fuel for nuclear reactors can immortalize their technology and their profits. For the rest of us and future generations, we will be bound to safeguarding ourselves from this hidious creation of of men for thousands of years, just as we have been beplagued by Pandora's curiosity. Let us not forget the symbolic meaning, or else we may loose sight of the underlying moral significance of what we came here to discuss.

Unless we begin regulating the source of plutonium and manmade radiation, there will never be an environment free from contamination. We as a race must take control over our technological creations and the elite that uses them for personal power and profits, or else fall pray to our technology, which will shape us, rule us and finally destroy us.

This ultimately means limiting the use of and the amount of plutonium and transuranium elements in society. To do less is to avoid our social responsibiltiy to future generations.

Thank you.

Chairman Mills: Thank you very much. Are there any questions?

(No response.)

Chairman Mills: Again, thank you very much.

The next speaker on the agenda is Ms. Nina Conant from St. Mary's Episcopal Church.

Ms. Conant: Learned Gentlemen and Fellow Citizens:

I have here some statements that represent the humanistic point of view. They are statements of sort of average citizens. It was impossible to contact the entire membership of St. Mary's Episcopal Church at 2290 South Clayton. However, the priest, vestry members, and laymen thus far contacted subscribed to the following resolution:

"We urge utmost caution and continuing study by highly qualified scientists to assure protection of the present and future populous from injury through atomic radiation or any noxious product thereof."

The next statement is one subscribed to by 38 individuals, and it reads as follows:

"The AEC has not effectively protected our environment. One example being the radioactive tailings found in some Grand Junction houses. In the absence of probable fact as to harmful radiation levels, we therefore urge more stringent standards be imposed at this time for nuclear weapons

facilities and nuclear reactors than have been established in the past."

And the last is a plea from one citizen, me, to you in behalf of the human race.

"Gentlemen, if mankind becomes extinct on this planet, it will not probably be through terrible wars, plagues, or catastrophic explosions. No. Much more likely it will be through rushing to embrase marvelous discoveries that seem to make our daily lives more pleasant, convenient, and comfortable. We will not recognize the lethal side effects until it is already too late. We are even now flirting with such a course. For the first time in the history of the world, man's future fate is in the hands of a living generation. We must face this fact with a new and more difficult morality. We are not only our brother's keeper, but especially the protector of children yet unborn."

There are three points here, two of them relate to this body, and the third does not, but I will read it anyway, with your permission.

"We must not for any reason proceed on any course of investigation and manufacture where there is a known risk, however slight, of producing defective children."

And the second one: "We must stop rescuing and subsidizing famine-stricken populations whose birth rate overruns and devastates their own land resources. By supplying

them with emergency food, we ultimately compound their misery, like the man who could not bear to hurt the puppy, so he cut off his tail an inch at a time."

The third one again relates to you: "We must cure our voracious appetite and stop opening up greater and greater wasteful sources of energy. Rather, we must find ways of utilizing more wisely resources that we already have."

Gentlemen, the foregoing sounds all very simple-minded and self-evident. However, we have not yet accepted this kind of morality, and we must hasten to do so if we are to get off the collision course upon which we have already embarked.

Thank you.

Chairman Mills: Thank you very much. Are there any questions or comments?

(No response.)

Chairman Mills: Thank you again.

526

It was impossible to contact the entire membership of St. Mary's Episcopal Church 2290 S. Clayton 80210. However, priests, vestry members, & laymen thus far contacted subscribe to the following resolution: —

"We urge utmost caution and continuing study by highly qualified scientists to assure protection of the present & future populace from injury through atomic radiation or any noxious product thereof."

Submitted at public hearing: Environmental Protection Agency
U.S. Post Office Jan. 10, 1975
Read for record by Mina Conant Billmyer
1519 E. Mexico Ave.
80210

Memo to Environmental Protection Agency; 10 January, 1975

Gentleman -

If mankind becomes extinct on this planet, it will probably not be through terrible wars, plagues, catactysmic explosions; No. Much more likely it will be through rushing to embrace marvellous discoveries that seem to make our daily lives more pleasant, convenient and comfortable. We will not recognize the lethal side effects until it is already too late. We are even now flirting with such a course.

For the first time in the history of the world, man's future fate is in the hands of a living generation. We must face this fact with a new and more difficult morality; we are not only our brother's keeper, but especially the protector of children yet unborn.

1. We must not, for any reason, proceed on any course of investigation & manufacture where there is a known risk, however slight, of producing defective children.

2. We must stop rescuing and subsidizing famine-stricken populations whose birthrate overruns and devastates their own land resources. By supplying them with emergency food we ultimately compound their misery;- like the man who couldn't bear to hurt the puppy so he cut off its tail an inch at a time. By stop-gap measures we foster a larger future generation of starving children.

3. We must cure our voracious energy appetite & stop opening up greater and greater wasteful sources of energy; rather, we must find ways of utilizing more wisely resources that we already have.

Gentlemen, the foregoing sounds all very simple-minded and self-evident. However, we have not yet accepted this kind of morality and we must hasten to do so if we are to get off the collision course upon which we have already embarked.

Mina Conant
1519 East Mexico Av.
80210

Statement to be read at the Environmental Protection Agency Public Hearing Jan 10, 1975

The AEC has not effectively protected our environment - one example being the radioactive tailings found in some Grand Junction Houses. In the absence of provable facts as to harmful radiation levels, we therefore urge more stringent standards imposed at this time for nuclear weapons facilities and nuclear reactors than have been established in the past.

Quu Sink - 4720 S. Ogden Englewood, Colo
Helen L. Schwan 2750 S. Washington " "
Vera Hulkower 11500 W. 89th Place (Jefferson Co)
Anne Lee Briggs 5105 S. Franklin Englewood 80150
Margo Sargent 2806 S Pearl St. Denver 80210
Cynthia Zellmer 2916 S. Paris St Denver 80231
William A. Zellmer 2916 S. Paris St Denver 80231
Robert Lagos 328 S Fox St., Denv, Colo

Barbara D. Richards	1090 W. Oxford ave.	Englewood	80
Dick Richards	1090 W. Oxford Ave	Englewood	80
Wanna H. Rowe	485 E. Bellwood Dr.	Engl	80110
Sandy L. Whitaker	3771 S. Clinton	Denver	8023
Ronell Hooper	3801 E. Alexander ave.	Littleton	8012
Marcella Stewart	2445 So Dahlia St.	Denver	80222
Gertrude Alice Guest	2160 S. St. Paul	Denver	80210
Jean C Guest	2160 So. St Paul	Denver	80210
Lydelle Chapman	6378 So Josephine Way	Littleton	80121
Robert F. Shoemaker	1201 RACE ST	DENVER	8020
Vernon L Hopkins	50 Odgen St	Denver	80218
Mark Currah	122 Stuart St	"	80211
E.R. Stob	2886 So Carona	Englewood	80110
John C Yingst	8400 w Bowles ave	Littleton	80123
Charlotte Hearne	1403 S. Eudora		
Don Butterfield	4646 Montview	Denver	80207
John H Love	2555 S. Wolff	Denver	80219
Ike Morgan	720 S Hazelhurst	Denver	80209
Carolyn Morgan	720 S. Hazelhurst	"	80209
Edward M Eddy	6594 So Clarkson	"	80121

Minister, 1st Universalist Church of Denver, 4101 E. Hamden Ave.

Lorin B. Appenzeller	2710 Wheeling	Aurora	80011
Louis Lacey	999 So. Fillmore Way	Denver	80209
Edward White III	545 Circle Dr	Denver	80206

James White 545 Circle drive Denver 80206
Evelyn E White 4801 So Ogden Englewood 80110
T. D. White, Jr. 480 S. Marion Denver 80209
Tiffany Lynn Hewett 1634 S. Kearney Denver 80222
John E. Pillmyer 1519 E. Mexico - Denver Co - 80210
[illegible] Mont, 1519 E. Mexico Av. 80210

Mr. Mark Tryen of South High School here in Denver.

Mr. Tryen: First I want to point out that my name is Mike Tryen, and it is misspelled on the agenda.

Chairman Mills: We will correct it.

Mr. Tryen: Thank you. First of all I want to say that I appreciate being able to make this statement on behalf of my ecology class at South High School and the youth of Denver.

The students and I have been taught some background information about plutonium-239, a very toxic substance, and we feel we should make a stand. Plutonium-239 is an element used in manufacturing triggers for hydrogen devices, and as an element it is one of the most toxic substances known to man. According to the information we were able to find, and I would like to point out that there is not a great deal of information available concerning the chemical and biological effects of this element immediately available to us, it is 20,000 times more toxic than cobra venom or cyanide and 1,000 times more toxic than heroin. It is a high-energy alpha-emitter and is not necessarily dangerous externally, but internally it will do a considerable amount of damage to cells. In the lungs, the alpha emissions will probably cause lung cancer.

Plutonoum-239 is listed on the radioactive nuclide charts as having a half-life of 2.439 times 10^4 years or

24,390 years. This means it will be highly radioactive for this length of time before it decays to half its radioactivity. This contamination, as far as all of us are concerned, is permanent. Our ecology class feels that this problem is being handed down to the next generation (which is us), not necessarily you, and I am here to express our concern. If we are going to let the older generation make decisions for the future which will affect our lives, we feel we should express our feelings also.

It would not take a very large quantity of this material, airborne, to give everyone in Denver lung cancer eventually. We feel its use must be restricted before a major disaster occurs, and we then sit around and wait for the mortality statistics to confirm our suspicions. In 1969 a fire did occur even with strict supervision, and contamination was released to the surrounding area. The public was unaware of this for many years following this, and in the meantime some of them were obviously building homes in the area not knowing what might be in the soil. Perhaps the supervision now in use is not enough.

Some of the problems associated with contamination and use of this material seems almost impossible to imagine. Although strict controls are exercised there, it is still the problem of the contamination already there. Increased risk of lung cancer is only one -- what about genetic damage

to future offspring of contaminated parents and shorter life spans for children playing in contaminated dirt? If the problem were not serious, they would not now have stopped building homes in the area downwind of the Flats. Cows grazing around this area have been found to have plutonium in their lungs. How did this happen? We wonder about their milk and meat also. Is this also contaminated? These questions should be answered before any more plutonium is used at the Flats. The contamination already there seems to be finding its way into our environment in ways that were not considered when Rocky Flats was built.

We feel that keeping Rocky Flats in Denver now makes this area a strategic military target and exposes us to yet another type of danger -- which is just as deadly as contamination.

The first mistake was the placing of a plant such as this in a populated area and we feel, since contamination already exists, that there should be no minimum allowable dosages for emissions established. There should be no allowable emissions and if there are, the manufacturing of plutonium triggers here should be reconsidered.

I had one day in which to speak to my fellow students about this matter and was able to get the signatures of 235 people who also expressed their concern. I will give you this list and I am sure, had we had enough time, we would

have had more signatures of people to support my stand.

I must stress this last point -- that I am here because the students at South High do care enough about this problem to send me here to represent them. The youth of Denver do care.

Chairman Mills: Thank you very much. Are there any questions or comments?

Dr. Taylor: I am especially interested when young people, high school people, engage themseleves in thinking of this type, activities of this type. I try whenever I have the opportunity to help them when they ask for help. I want to compliment this group on having put together some ideas. They seem to have a fair amount of good information and not much more than the normal amount of misinformation. I would be very happy when I get back to try to supply them with some sources for some of the kind of information that might help you in thinking about some of these problems from a purely technical sense. I hope also that some of you will go into physics and biology as you grow older and pursue these subjects in real earnest.

Mr. Tryen: Thank you very much.

536 We support Michael Tirner's plutonium statement.

Catherine Jackson

Jim Bussanich
Beth Dillon
Brad Emmons
Mark Eckhardt
Ed Orelle
Bradley Bargent
James Sennett
Sandra Hopley
Ronald Sims
George C Mulqueen
Robert C Trostle
Dave McGraw
Rick Whitzger
James M Miller
Owen Logan
Jon Ann Hight
Mindy Green
Evon Fernandez
Becky Bolen
Robert Joner
J. Douglas.
Brian Ed Hall
Jeff Rodden
Sylvia Clark

Jon Knecht
Karen Stoumbaugh
Kelli Lewis
Mike Frost
Matt B. Jones
Pam Kesson
Sheila Sains
Sharol Canty
Fay Lux
Etta Blick
Kent Dunn
Henry Hobbing
Chris Holcomb
Kim Colarizzi
Joyce Kimura
Marna Knoll
Cheree Johnson
Bill Steenan
Sue Wagner
Duane Yost
Annette Schaub
Kristin Schlechtweg
Reina Rosetta

We support Michael Friner's plutonium statement.

Kathy Arnold
Brian Butterfield
Jan Bryant
Neal McLaughlin
David Brass
Terri A. Price
Susan Leopard
Brooke Nicholson
Gayla McKillican
Michael Flanders
Libby Jones
MaryAnn Mulqueen
Denise Cutler
Sue Stewart
Kelly Montgomery
Dana Mohr
Nancy Chaney
Richard Mulcahy
Debbie Brown
Becky Ralf
Keith Howard
Willie Zelena
X Bill Sorrowin
Robert Johns
Candy Speed
David Reinke
Debbie Kuypier
Jeff Bridges
Sheri Lantz
Monica Adams
Leslie Bantler
Debbie Boe
Cindy Horton
Donna Hardegree
Peter Fowler
Phillip Downing
Michelle David
Carol Chapman
Karen Harris
Mike Trinen
Karen Shreck
Lydia VanDyke
Gary Buck Lemmy
Glen Butler
Mary Russell

538 We support Michael Triner's Plutonium statement

Steve Pollard
Renée Casey
Gary Galloway
Marta Miley
Maureen McKeirn
Kathy O'Shea
Patty Meyer
Lisa Triner
Darrell Hammond
Karl Pattison
Drew Olian
Bill Fraser
Joe La Drange
Bill Henry
Robb Penrose
Rob Ellis
Sharon Lunlan
Jim McCoy

We support Michael Trinen's plutonium statement

Marcos Chavez
Rachell Scruggs
The last Holtwood
Glynn Chandler
Lynnette Patterson
Tonya Copeland
Edward Pitts
Debbie Haynes
Darrell Jackson
Maria Watson
Bill King
Nancy Egan
Karen Knight
Douglas Hawkins
John E Christensen
Cathy Christian
Claudia Kubish
Lisa Hofsess
April Fair
Sandra Waggener

540 We support Michael Triner's plutonium statement

Laurie Clem
Amy [illegible]
[illegible]
[illegible]
[illegible]
Debbie Texan
[illegible]
Paul Petschauer
[illegible]
[illegible]
[illegible]
Vicki Williams
[illegible]
Chris Hansburg
Kathy DeGette
Ronald Gresquez
[illegible]
[illegible]

We support Michael Trinex's plutonium statement.

John Terrazas
Will Heath
Marla D. Anderson
Carl David M Thayer
Robert Armstrong
Janice Todd
Roxanne Worthington
Mitch Zuckerbrod
Stephen Wood
Eileen Price
Becky Brooks
Karen Stott
Lisa Marzold
Debbie Langhorn
David Harris
James Perry
Carol Price
Polly McLean
Chris Kirkhow
Peter Lux
Janice Mayfield
Cindy Casey
Sonia Copeland
Laurie Thomson
Laura McWilliams
Vicki Mitchell
Nancy Mueller
Mike Myrick
Andrew Nagel
Frank Summie
Anna LaBella
Janet Kruse
L.D. Gron
Robert Wickwar
Dave Mick
Esther Desmarais
Don Davis
Jim Ashe
Lynn VanDemark
Bernadette Blick
Maria Balassa
Debbie Brush
Mindy Dare
Becky Hawley
Dale Strick
Scott Canady

542. We support Michael Triner's plutonium-statement

Bob Ford
Erica Freudenstein
Brian Frame
Robyn Dodd
Ed Montgomery
Mike Merritt
Mike Testa
Scott Martin
Dave Wilson
Debbie Keeton
Cindy Blake
[illegible]
Don Stuart
Steven Ary
Donna Gracey
Jay Johnson
Tracey Edwards
Lafonia DuPont
Lisa Grossfeld
Phil Miller
Brennan Hecht
Vivian Sudan

Joyce J Dickey

Chairman Mills: Mr. William Pace.

(No response.)

Chairman Mills: We have a few additional names that might still be around. Mark Edwards?

(No response.)

Chairman Mills: Mr. Rick Speed.

Chairman Mills: Will you give your address?

Mr. Speed: 70 Adams, Denver, Colorado, 80206.

Hello, my name is Rick Speed. I have been active in the energy resource field for several years, and presently work for a solar energy research and development firm. I am here today to share a few thoughts with you which I consider to be the long-range, realistic solution to the dangers of plutonium that have been amply documented today. In my view, the two most overwhelming dangers that are presented to us are radioactive contamination of the environment through the improper use of nuclear power, and thermonuclear war. Prudent and wise men everywhere now call for the control of these elements, and it is my contention that it should now be obvious that the only reasonable solution for the genetic, health, social, and environmental problems presented by these elements is their destruction, their total destruction.

Fortunately, there are technologies capable of carrying out this mandate and at the same time helping to alleviate another of our major problems, the energy situation. If the nuclear weapons nations, states, could agree on a formula to eleminate their nuclear arsenals, the dangers of thermo-nuclear annihilation would then be eliminated. The bomb

grade materials would then become available and could be diverted to nuclear burner reactors wherein the high grade weapons material could be transmuted to high level nuclear wastes. So, we would have solved several problems at once. We would have generated electrical energy, and we would have decreased the half-life of the materials that we had to contend by several factors of ten, and we would have ended up with materials of nowhere near the toxicity of plutonium. We could carry on this whole process in underground nuclear parks or whatever you will have as suggested by Drs. Teller and Wienberg, where the latest in contaminant and plutonium burn-up fuel cycles could be utilized to destroy these materials. The electrical energy that we have been generating from these totally enclosed recycling units would also eliminate the need to produce any more of our present generation of reactors, and we could continue to burn up our uranium-235 in low enrichment fuel cycles with their obvious advantages from the security viewpoint. And, I think it is also during this period when we were carrying out this solution to the plutonium problem that we begin a massive program in energy conservation and solar energy conversion so that we can develop energy systems that are reasonable, that are rational.

In conclusion, just let me say that I have looked at this problem from a fairly comprehensive viewpoint, and it

appears to me that this is the only real long-run solution to the problem. We just cannot have plutonium and highly enriched uranium-235 in the environment, or it is eventually going to cause us grief, and I just hope that you and your counterparts in Government industry realize this and work for the ultimate destruction of these materials.

Thank you; any questions?

Chairman Mills: Thank you, any questions or comments?

(No response.)

Chairman Mills: Thank you again.

Melody Martin?

(No response.)

Chairman Mills: That seems to have exhausted the list I have. Is there any comments that the Panel would like to make in this regard? Yes?

Ms. Barbara Hanson: Those written questions that you asked to be handed to the members of the Panel, are they going to be addressed now?

Chairman Mills: I have two questions addressed to the Panel.

One question: How will present studies being proposed in Florida phosphate areas be coordinated with the present hearings, especially plutonium? I assume this has reference to the natural radioactivity in the phosphate mine, which is mostly radium, and what we are talking about here is plu-

tonium and the transuranium elements. But, EPA is, in fact, addressing the phosphate problem.

Will the studies already in progress in Idaho Region X be considered or will there be a lot of duplication of different agencies, especially concerning plutonium? I am not sure I really understand that question, whether they are speaking of the phosphate industry in Idaho or plutonium. But, certainly we will make every effort to try to avoid duplication.

In other words, what about phosphate plutonium emission regulations? I am not sure I really understand that question. There is no plutonoium in the phosphates, that I am aware of.

Second question: Judging from the remarks made by Mr. Bean, the AEC representative at Rocky Flats and Assistant Manager of Post-Operations there and his associates this morning, we are led to the inference that the amounts of plutonium leaving the plant at Rocky Flats are below standards or below estimated probable hazard levels. This is based on measurements in air or soil of plutonium itself, but no mention of plutonium in combination with other chemical substances. For instance, the tritium, a radioactive isotope which is used by the Rocky Flats Plant in their development of thermonuclear tritium devices, and it is this tritium (which apparently causes no harm by itself)

acting on the plutonium which releases a highly toxic substance which is released into the air, whose contamination potential is there being much more difficult to assess or control. Could you address this matter, please? I assume what the question is, is there any kind of synergistic action between the tritium releases and plutonium? As far as I am aware that is not a very viable consideration at the moment. When we look at standards for tritium or we look at standards for plutonium, we treat them separately. Maybe I missed the point of your question.

Ms. Barbara Hanson: I believe, from what I have been told and the literature, they are treated separately. But, I was given this information. In fact, there are some who are pretty conservative on pro-nuclear weapons and when they found out that I was interested in coming before this hearing, they did not tell me any more. But, he did say that tritium acts on the plutonium and it is the combination of the two that creates a more dangerous or more toxic substance. It is released into the air and it is harder to control and harder to assess that amount in the air, and I was wondering if you could give me a more technical explanation on that?

Chairman Mills: Well, I am not sure I really understand the question. Any hazards associated with plutonium or tritium by themseleves, one could --

Ms. Barbara Hanson: Don't they combine? Doesn't one

act on another when they are used in combination?

Chairman Mills: Not to my knowledge.

Ms. Barbara Hanson: Well, apparently this is what goes on at Rocky Flats, because he works in conjunction with Rocky Flats, and this is what he said. I am sorry he is not here. I was hoping somebody could give me some more information on it.

Chairman Mills: Does anyone want to try to clarify that? Maybe the concern is with the difference between fussion and fission systems.

Mr. M. A. Thompson: Tritium is like hydrogen, and hydrogen will react with plutonium, okay, chemically to make a compound combination of the two. There is no work going on at Rocky Flats involving tritium plus plutonium. Now, when you talk about the hazard of the combination of these two, you then assume the hazard of the tritium plus the hazard of the plutonium.

Chairman Mills: There is no additional synergistic action --

Mr. M. A. Thompson: No, the combination would not be ten times as much as the addition of the two.

Ms. Barbara Hanson: You are saying one plus one equals two, and I am saying one times one makes something else, and you are saying that that is not going on at Rocky Flats?

Mr. M. A. Thompson: Correct.

Ms. Barbara Hanson: You would not deceive me now, would you?

Mr. M. A. Thompson: No.

Chairman Mills: I will allow one question if it is a brief one. We are pretty tired.

(Question from the auidence) Is the EPA going to give more public hearings, and if not, how do they plan to communicate with the public on issues that you did not consider relevant to this public hearing, such as --

Chairman Mills: I assume you are talking about nuclear safety --

(Question from the audience) How is the public going to communicate with you about that?

Chairman Mills: Well, we in the EPA, and I am not speaking now as part of the Panel, I am speaking of EPA, we in EPA have been looking at some of the reports such as Rasmussen. We have been reviewing the environmental impact statements pertaining to these questions. Our review is all part of the public record. So, we do, in fact, speak out on these issues, and they are, in fact, part of the public record. If you are interested on a particular question pertaining to some particular interest that you have, I am sure you can write to the Environmetal Protection Agency, and they will send you a copy of their comments.

Mr. Wolfson: Does the EPA have the authority to call a

nuclear moratorium and nuclear disarmament, or do they only have the authority to set the standards and limits on radioactivity?

Chairman Mills: Our authority is limited to the law, which says setting generally applicable environmental standards.

Well, if there are no more comments by the Panel or the audience, I want to thank all the participants. I hope it has been informative. It has been informative to us, and I am sure that we have built quite a record on the problem of plutonium.

Thank you very much.

(Whereupon, at 6:00 o'clock p.m., the hearing in the above-entitled matter was closed.)

*U.S. GOVERNMENT PRINTING OFFICE:1975 630-513/794 1-3