EPA 902/4-78-002

Excerpts from

RADIOLOGICAL QUALITY OF THE ENVIRONMENT IN THE UNITED STATES, 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

The following pages are excerpted from the EPA publication

EPA 520/1-77-009 "RADIOLOGICAL QUALITY OF

THE ENVIRONMENT

IN THE UNITED STATES, 1977"

The document is 295 pages long; to conserve paper, we have reproduced the most frequently requested information here. If you wish to read the entire report, you may request a copy from:

Regional Office of Radiation Programs
USEPA
Room 907J
26 Federal Plaza
New York, New York 10007

SUMMARY

The purpose of this report is to summarize the individual and population doses in the United States resulting from each category of radiation source and to assess these data. When the literature on radiation sources was searched for information, it became readily apparent that an immense amount of data had been published during the past 15 years. It was therefore considered necessary, first to organize the sources into the categories described in this report, and secondly, to summarize, examine and interpret the data with respect to these categories. In doing so, it was also necessary to assume that the data extracted from the literature were valid. Because of the many different purposes for which environmental data were generated, the results are not only expressed in different units, but they were accumulated over different time periods and frequently were obtained without quality control. For this reason, many tables of data carry detailed notes and annotations. Readers are cautioned that before data in this report are used for their purposes, they should read the text and the notes to assure proper interpretation.

The individual and population dose data resulting from the various categories of radiation sources discussed in this report are summarized in table 1-1. The information in this table is divided according to whether the primary mode of exposure is external or internal. Exposure to direct radiation from radionuclides in the ground, water, buildings, and air around us, or from radiation-producing machines, such as x-ray equipment and particle accelerators, is considered to be external exposure. Exposures of this type usually result in a radiation dose to the whole body of the person exposed. In contrast, internal exposures occur when radioactive materials are inhaled, ingested, or absorbed through the skin. Internal exposures result in radiation doses to specific organs of the body, such as the lung, gastrointestinal tract, or bones.

It is evident from this table that there are radiation sources for which data are not available. Consequently, the discussion and comments that result are based upon the data which were available at the time of writing. Also, it is worth noting that although population doses from the different source categories, in general, can be added together to gain a perspective of overall impact, it does not necessarily follow that individual doses can be added together because an individual in one population group generally does not receive the radiation dose common to another population group. For this reason, the data in table 1-1 only show totals for population doses in the various source categories.

Dose to United States population

Based upon the limited data in table 1-1, it is apparent that the source category of highest population dose is the external dose from cosmic radiation. An overall population dose from ambient ionizing

radiation is not given because population doses from the worldwide radiation and terrestrial radiation components is not available. Judging from the figures given for individual doses from these three categories, it would appear that the population dose from terrestrial radiation might be equal to or greater than the 10 million person-rem dose from cosmic radiation. The second largest source of population dose is from medical and dental radiology. This dose was estimated to be about 14.8 million person-rem to the U.S. population.

The third largest category of population dose for which data are available is from the use of radiopharmaceuticals for medical radiation purposes, which is estimated to contribute an internal dose of approximately 3 million person-rem per year to the population dose. The fourth largest category of dose is estimated to be from technologically enhanced natural radiation which contributes approximately 3 million person-rem per year to the population dose. Finally, it is of interest to note that all the population doses from all the other source categories for which data are available are less than 0.1 percent of the total population dose.

It is important to mention that the population dose values noted here are based upon the data available to us at this time. It is possible that these values, and thus the relative contributions of population dose from the source categories considered, could change in the future as more information on this subject becomes available.

Dose to individuals

For individuals, the largest dose is derived from technologically enhanced natural radiation. It contributes internal doses as high or higher than 100,000 mrem/y to the tracheobronchial surface tissue of the lung as a result of the inhalation of radon daughter products from uranium mill tailings.

The second category contributing to a high individual dose is medical radiation which contributes internal doses as high as 5000 mrem/y from radioactive cardiac pacemakers. Artificial teeth were found to contribute a local tissue dose as high as 1390 mrem/y to the individual due to their uranium content. Occupational and industrial operations were found to contribute a dose of 1230 mrem/y to the individual worker, essentially to maintenance personnel working around boiling water nuclear power reactors. Finally, the next largest dose is that which might be received by individuals at the boundary of federal facilities, 258 mrem/y.

As has been mentioned above, the relative contributions from each of the source categories are subject to revision as may be required by new data.

Table 1-1. Summary of dose data from all sources, United States

Source	External: Individual dose (mrem/y)	External: Population dose (person-rem/y)	Internal: Individual dose (mrem/y)	Internal: Population dose (person-rem/y)
Ambient ionizing radiation	-	-	-	-
Cosmic radiation	41-45	9.7×10^6	-	-
Ionizing component	28-35	9.2×10^6	-	-
Neutron component	0.33-6.8	4.9×10^5	-	-
Worldwide radioactivity				
Tritium	-	-	0.04	9.2×10^3
Carbon-14	-	-	1	-
Krypton-85	[a].035*	-	-	-
Terrestrial radiation	30-95	-	18-25	-
Potassium-40	17	-	16	-
Tritium	-	-	4×10^{-3}	-
Carbon-14	-	-	1	-
Rubidium-87	-	-	0.6	-
Uranium-238 series	13	-	2-6*	-
Thorium-232 series	25	-	7*	
Technologically enhanced natural radiation	-	-	-	2.73×10^6
Ore mining and milling	-	-	100,000*	-
Inactive uranium mill tailings piles	-	-	[b]140-14000	[c]2.5-70000
Phosphate mining & processing (occupational)	10-300*	-	[b]6,000*	-
Fertilizer	1.7*	-	-	-
Thorium mining and milling	-	-	-	-
Radon in potable water supplies	-	-	[b]4,000([d]1,250)*	-
Radon in natural gas	-	-	[b]15-54	2.73×10^6
Radon in liquefied petroleum gas	-	-	1-4	30000
Radon in "health" mines	-	-	-	-
Radon daughter exposure in natural caves	-	-	-	-
Radon and geothermal energy production	-	-	-	-
Radioactivity in construction material	-	-	-	-
Airplane travel				
Jet (cosmic), per trip over Atlantic	2.6(500-crew)*	-	-	-
SST (cosmic), per trip over Atlantic	2.0(1,000-crew)*	-	-	-
Coal-fired electric generating station	-	-	5-70*	$0.12\text{-}2 \times 10^6$*
Oil-fired electric generating station	-	-	0.04*	15*

Table 1-1 cont. Summary of dose data from all sources, United States

Source	External: Individual dose (mrem/y)	External: Population dose (person-rem/y)	Internal: Individual dose (mrem/y)	Internal: Population dose (person-rem/y)
Fallout	[e]$\sim$ 2	-	-	-
Uranium fuel cycle	-	2014	-	-
Mining and milling	-	-	[f]4.5×10^{-2}	2.5
Fuel enrichment	[g]<0.1	<0.1	[h]0.3	[i]0.64
Fuel fabrication	-	-	[j]2×10^{-4}	[j]0.66
Power reactors BWR	[k]76 max	[m]1564	-	-
Power reactors PWR	[k]4 max	[m]21	-	-
Research reactors	-	-	-	-
Transportation - Nuclear power industry	-	[n] 100-9600	-	-
Transportation - Radioisotopes	-	[n]<170		-
Reprocessing and spent fuel storage	[p]6	[p]23	[p]14-257	-
Radioactive waste disposal	-	-	-	-
Federal Facilities	-	[q]480	-	-
ERDA	[k]<0.1-258	<1-180	-	-
Department of Defense	<0.01	-	-	-
Accelerators	[k]0.04-4	0.4-65	-	-
Radiopharmaceuticals	-	[r]<0.1	-	[s]3.3×10^{6}
Medical radiation				
X radiation	[t]103	14.8×10^{6}	-	-
Cardiac pacemakers	-	-	<5000	-
Occupational and industrial radiation				
BWR	[u]1230	-	-	-
PWR	[u]1080	-	-	-
All occupations	[v]0.80	28,400	-	-

Table 1-1 cont. Summary of dose data from all sources, United States

Source	External		Internal	
	Individual dose (mrem/y)	Population dose (person-rem/y)	Individual dose (mrem/y)	Population dose (person-rem/y)
Consumer products	-	-	-	-
Timepieces	[x]<0.5*	[y]∿6100	-	-
Smoke detectors	[z]0.007*	0.001*	-	-
Artificial teeth	-	-	[aa]140-1390*	-
TV	[bb]0.025-0.043	-	-	-

Source	Individual exposure ($\mu W/cm^2$)
Nonionizing electromagnetic radiation	
Broadcast towers and airport radars	10
All sources	0.1-1

[a]Maximum individual dose to skin surface
[b]Trachea-bronchial dose
[c]Lung-rem/y
[d]Stomach dose
[e]50-year dose commitment divided by 50
[f]Average individual lung dose within 80 km
[g]Maximum potential exposure per facility
[h]Maximum potential exposure
[i]Cumulative exposure per facility within 80 km radius
[j]Estimated bone dose within 80 km
[k]Fence line boundary dose
[m]Within a radius of 80 km
[n]Estimated for the year 1973
[p]For NFS Reprocessing Plant, West Valley, N.Y.
[q]1965 data
[r]Based upon data from 5 institutions
[s]Estimated 1980 dose
[t]Estimated mean active bone marrow dose to adults-mrad/y
[u]Average occupational exposure/y
[v]Average exposure for all occupations & 3.7 · radiation workers/1000 persons in United States
[x]From digital watches
[y]From timepieces containing tritium or radium-activated dials
[z]Estimated
[aa]Dose to the superficial layer of tissue
[bb]5 cm from TV set; units of mR/h
- No dose data available
*Indicates new or revised information

Table 2-2. Estimated annual cosmic-ray whole-body doses *(2.10)* (mrem/person)

Political Unit	Average Annual Dose	Political Unit	Average Annual Dose
Alabama	40	New Jersey	40
Alaska	45	New Mexico	105
Arizona	60	New York	45
Arkansas	40	North Carolina	45
California	40	North Dakota	60
Colorado	120	Ohio	50
Connecticut	40	Oklahoma	50
Delaware	40	Oregon	50
Florida	35	Pennsylvania	45
Georgia	40	Rhode Island	40
Hawaii	30	South Carolina	40
Idaho	85	South Dakota	70
Illinois	45	Tennessee	45
Indiana	45	Texas	45
Iowa	50	Utah	115
Kansas	50	Vermont	50
Kentucky	45	Virginia	45
Louisiana	35	Washington	50
Maine	50	West Virginia	50
Maryland	40	Wisconsin	50
Massachusetts	40	Wyoming	130
Michigan	50	Canal Zone	30
Minnesota	55	Guam	35
Mississippi	40	Puerto Rico	30
Missouri	45	Samoa	30
Montana	90	Virgin Islands	30
Nebraska	75	District of Columbia	40
Nevada	85		
New Hampshire	45	Total United States	45

Table 2-13. Estimated annual external gamma whole-body doses from natural terrestrial radioactivity *(2.10)* (mrem/person)

Political Unit	Average Annual Dose
Alabama	70
Alaska	60*
Arizona	60*
Arkansas	75
California	50
Colorado	105
Connecticut	60
Delaware	60*
Florida	60*
Georgia	60*
Hawaii	60*
Idaho	60*
Illinois	65
Indiana	55
Iowa	60
Kansas	60*
Kentucky	60*
Louisiana	40
Maine	75
Maryland	55
Massachusetts	75
Michigan	60*
Minnesota	70
Mississippi	65
Missouri	60*
Montana	60*
Nebraska	55
Nevada	40
New Hampshire	65

*Assumed to be equal to the United States average.

Political Unit	Average Annual Doses
New Jersey	60
New Mexico	70
New York	65
North Carolina	75
North Dakota	60*
Ohio	65
Oklahoma	60
Oregon	60*
Pennsylvania	55
Rhode Island	65
South Carolina	70
South Dakota	115
Tennessee	70
Texas	30
Utah	40
Vermont	45
Virginia	55
Washington	60*
West Virginia	60*
Wisconsin	55
Wyoming	90
Canal Zone	60*
Guam	60*
Puerto Rico	60*
Samoa	60*
Virgin Islands	60*
District of Columbia	55
Others	60*
Total United States	60

Chapter 7 - Radiopharmaceuticals

Radiopharmaceuticals are used in the diagnosis and, in some cases, the treatment of disease. Their use has increased fivefold from 1960 to 1970, and it has been estimated that an increase of sevenfold may be experienced from 1970 to 1980. If this trend continues, and there are no technical changes, it is estimated that the whole-body dose to the United States population in 1980 from the use of radiopharmaceuticals will be 3.3 million person-rem *(7.1)*.

In June 1976, the Bureau of Radiological Health published a report on a pilot study of nuclear medicine in United States hospitals. This study compares current nuclear medicine data obtained from six hospitals with survey data collected from the same institutions in previous years *(7.2)*. Although these data cannot be considered to be representative of nuclear medicine practice in all U.S. hospitals, the study notes that several trends are apparent.

These trends are:

1. An average increase in nuclear medicine procedures in excess of 17 percent per year.

2. An increase in the average whole body and gonad radiation doses per radiopharmaceutical administration when compared to 1966 national data.

3. A high proportion (21 percent) of nuclear medicine procedures performed on patients under the age of 30.

The contribution of nuclear medicine to the total medical radiation exposures to the population may be greater than previously estimated if the trends indicated in the pilot study are a reflection of the practice of nuclear medicine throughout the United States.

Although radiopharmaceuticals used in diagnosis and treatment of disease result in the major doses to man, additional doses to man result from the manufacture of radiopharmaceuticals and from the discharge of these materials to the environment from patients and medical facilities.

A search of available literature unfortunately has not revealed any information concerning the release of radiopharmaceuticals to the environment during manufacturing processes, thus, the effect of these materials cannot be determined.

In order to estimate the total contribution to population doses from the discharges of radiopharmaceuticals, each medical facility would require evaluation because of the unique ways each might contribute to the environmental contamination. Thus, it is concluded that little inference can be made at this time about the dose and contamination that results from the discharge from radiopharmaceuticals from patients and medical facilities.

References

(7.1) NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL. 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, Washington, D.C. 20006 (November 1972).

(7.2) MCINTYRE, A. B., D. R. HAMILTON and R. C. GRANT. A pilot study of nuclear medicine reporting through the medically oriented data system. FDA 76-8045, Bureau of Radiological Health, Rockville, Md. 20857 (June 1976).

Chapter 8 - Medical Radiation

The responsibility for controlling medical exposure to radiation is divided between the Federal and the State governments. Within the Federal Government, the Bureau of Radiological Health in the Department of Health, Education and Welfare has the responsibility of administrating the Radiation Control for Health and Safety Act (Public Law 90-602). The Secretary of Health, Education and Welfare is required by the act to submit an annual report to the President for transmittal to the Congress *(8.1)*.

A model State Radiation Control Act containing suggested model regulations for control of radiation was published by the Council of State Governments with the cooperation and assistance of interested Federal Agencies *(8.2)*. This publication assisted the States in making regulations compatible with each other and with the Federal Government. Fifty states, the District of Columbia and the Commonwealth of Puerto Rico now have laws for the regulation of ionizing radiation *(8.3)*.

The use of radiation by the medical profession is recognized as the largest manmade component of radiation dose to the United States population. This includes medical diagnostic radiology, clinical nuclear medicine, radiation therapy, cardiac pacemakers, and occupational exposure of medical and paramedical personnel. However, the main contributor of the total dose from medical exposures is diagnostic x radiation; the contribution from dental radiation, radiopharmaceuticals, and radiation therapy being far lower. Medical diagnostic radiology accounts for at least 90 percent of the total manmade radiation dose to which the U.S. population is exposed. This is at least 35 percent of the total radiation dose from all sources (including natural radioactivity) *(8.4, 8.5)*.

Genetically significant dose

The Bureau of Radiological Health (BRH), in cooperation with the National Center for Health Statistics (NCHS), conducted an X-ray Exposure Study (XES) in 1964 and another in 1970. A dose model was developed for use in calculating the gonad dose from the XES data and a report was published in April 1976 illustrating changes in gonad and genetically significant dose (GSD) from diagnostic x-ray procedures between 1964 and 1970 *(8.6)*. However, the report considers only medical radiographic examinations and the radiographic portions of fluoroscopy. Dental x-ray examinations and doses from therapy were not included.

Ten statistically significant changes in mean gonad dose per examination from 1964 to 1970 were observed (table 8-1). The largest increase occurred for barium enema examinations of females (578 mrad to 903 mrad) and the largest decrease occurred for intravenous or retrograde pyelogram examinations of males (537 mrad to 207 mrad).

Examination types which involve the abdomen result in high mean gonad doses while those examination types which involve the head, neck, thorax and extremities generally result in low mean gonad doses (table 8-1). Therefore, eight examination types produced over 90 percent of the GSD in 1964 and in 1970 (table 8-2). Theoretically, restriction of the beam size to the film size would have reduced the 1964 GSD by 33 percent and the 1970 GSD by 21 percent. The change in the estimate of the GSD from 17 millirads in 1964 to 20 millirads in 1970 was not statistically significant *(8.6)*. This report notes that recent evaluations indicate that genetic effects should not be considered the primary hazard of radiation and that increasing emphasis is being placed on the somatic effects of radiation *(8.6)*.

Chapter 11 - Health Effects of Ionizing Radiation Exposure

Potential health effects from exposures to ionizing radiation are evaluated in this section. In order to make the interpretation of these estimated health effects more meaningful, the various health effect risk factors that can be applied will be presented.

No attempt has been made to assign individual exposure values to the various health effects for the following reasons. First, then, is a degree of uncertainty for the doses from different radiation sources. Although reported doses are based on actual data whenever possible, many of the values represent estimates having a large degree of variability. A second constraint on estimating potential health effects is the lack of definitive information on population parameters, especially where exposures are reported for specific facilities. This is important as there are differences in sensitivity; for example, children are more radiosensitive than adults. Therefore, while one might apply such risk conversion factors to large population groups where some generalizations as to population parameters are applicable, it is invalid to apply such generalizations when the population under consideration becomes smaller and more specific. Besides these two prime reasons, others, such as the lack of information on the pathway of exposure in many cases, have led to the decision to handle health effects in this general manner.

EPA has adapted the policy of assuming a linear relationship between the population exposure to ionizing radiation and its biological effect. This policy was issued on March 3, 1975, and is included here in its entirety.

"EPA Policy Statement on
Relationship Between Radiation Dose and Effect
41 FR 28409

"The actions taken by the Environmental Protection Agency to protect public health and the environment require that the impacts of contaminants in the environment or released into the environment be prudently examined. When these contaminants are radioactive materials and ionizing radiation, the most important impacts are those ultimately affecting human health. Therefore, the Agency believes that the public interest is best served by the Agency providing its best scientific estimates of such impacts in terms of potential ill health.

"To provide such estimates, it is necessary that judgments be made which relate the presence of ionizing radiation or radioactive materials in the environment, i.e., potential exposure, to the intake of radioactive materials in the body, to the absorption of energy from the ionizing radiation of different qualities, and finally to the potential effects on human health. In many situations, the levels of ionizing radiation or radioactive materials in the environment may be measured directly, but the determination of resultant radiation doses to humans and their susceptible tissues is generally derived from pathway and metabolic models and calculations of energy absorbed. It is also necessary to formulate the relationships between radiation dose and effects; relationships derived primarily from human epidemiological studies but also reflective of extensive research utilizing animals and other biological systems.

"Although much is known about radiation dose-effect relationships at high levels of dose, a great deal of uncertainty exists when high level dose-effect relationships are extrapolated to lower levels of dose, particularly when given at low dose rates. These uncertainties in the relationships between dose received and effect produced are recognized to relate, among many factors, to differences in quality and type of radiation, total dose, dose distribution, dose rate, and radiosensitivity, including repair mechanisms, sex, variations in age, organ, and state of health. These factors involve complex mechanisms of interaction among biological, chemical, and physical systems, the study of which is part of the continuing endeavor to acquire new scientific knowledge.

"Because of these many uncertainties, it is necessary to rely upon the considered judgments of experts on the biological effects of ionizing radiation. These findings are well-documented in publications by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the National Academy of Sciences (NAS), the International Commission on Radiological Protection (ICRP), and the National Council on Radiation Protection and Measurements (NCRP), and have been used by the Agency in formulating a policy on relationship between radiation dose and effect.

"It is the present policy of the Environmental Protection Agency to assume a linear, nonthreshold relationship between the magnitude of the radiation dose received at environmental levels of exposure and ill health produced as a means to estimate the potential health impact of actions it takes in developing radiation protection as expressed in criteria, guides, or standards. This policy is adopted in conformity with the generally accepted assumption that there is some potential ill health attributable to any exposure to ionizing radiation and that the magnitude of this potential ill health is directly proportional to the magnitude of the dose received.

"In adopting this general policy, the Agency recognizes the inherent uncertainties that exist in estimating health impact at the low levels of exposure and exposure rates expected to be present in the environment due to human activities, and that at these levels, the actual health impact will not be distinguishable from natural occurrences of ill health, either statistically or in the forms of ill health present. Also, at these very low levels, meaningful epidemiological studies to prove or disprove this relationship are difficult, if not practically impossible, to conduct. However, whenever new information is forthcoming, this policy will be reviewed and updated as necessary.

"It is to be emphasized that this policy has been established for the purpose of estimating the potential human health impact of Agency actions regarding radiation protection, and that such estimates do not necessarily constitute identifiable health consequences. Further, the Agency implementation of this policy to estimate potential human health effects presupposes the premise that, for the same dose, potential radiation effects in other constituents of the biosphere will be no greater. It is generally accepted that such constituents are no more radiosensitive than humans. The Agency believes the policy to be a prudent one.

"In estimating potential health effects, it is important to recognize that the exposures to be usually experienced by the public will be annual doses that are small fractions of natural background radiation to at most a few times this level. Within the United States, the natural background radiation dose equivalent varies geographically between 40 to 240 mrem per year. Over such a relatively small range of dose, any deviations from dose-effect linearity would not be expected to significantly affect actions taken by the Agency, unless a dose-effect threshold exists.

"While the utilization of a linear, nonthreshold relationship is useful as a generally applicable policy for assessment of radiation effects, it is also EPA's policy in specific situations to utilize the best available detailed scientific knowledge in estimating health impact when such information is available for specific types of radiation, conditions of exposure, and recipients of the exposure. In such situations, estimates may or may not be based on the assumptions of linearity and a nonthreshold dose. In any case, the assumptions will be stated explicitly in any EPA radiation protection actions.

"The linear hypothesis by itself precludes the development of acceptable levels of risk based solely on health considerations. Therefore, in establishing radiation protection positions, the Agency will weigh not only the health impact, but also social, economic, and other considerations associated with the activities addressed."

Within the context of the overall policy statement reprinted above, EPA uses primarily the recommendations of the National Academy of Sciences Committee on Biological Effects of Ionizing Radiation (BEIR) *(11.1)* as expressed in their November 1972 report to arrive at dose-to-health risk conversion factors. Besides the concept of linearity expressed in the policy statement, it is further assumed that health effects that have been observed at dose rates much greater than those represented in this report are indicative of radiation effects at lower dose rates. Any difference in biological recovery from precarcinogenic radiation damage due to low dose rates is neglected in the BEIR health risk estimates. On the other hand, in some cases, the BEIR risk estimates are based on relatively large doses where cell killing may have reduced the probability of delayed effects being observed and hence, underestimate the effects at low doses. The dose-risk conversion factors that EPA has adopted from the BEIR report are neither upper nor lower estimates of risk, but are computed on the same basis as the risk characterized as "the most likely estimate" in the BEIR report, that is they are averages of the two risk models considered in the BEIR report; relative and absolute risk.

One must caution against interpreting the product of dose and risk conversion factor as a prediction of actual number of effects to be sought out in the real world. The dose conversion factors (from concentration to dose) and the risk conversion factors (dose to effects) yield estimates of the actual dose and effects which have a considerable range. For example, the BEIR Committee has made a determination, based on their evaluation of the increase of the ambient cancer mortality per rem, that ranges from 100 to 450 deaths per million persons per rem during a 30-year followup period. EPA has chosen average values to be used for various dose to health effect conversion factors. When new information becomes available these factors will be revised.

Chapter 12 - Nonionizing Electromagnetic Radiation

As its name implies, nonionizing electromagnetic radiation does not produce ionized particles when it is absorbed by the material of interest. Absorbed energy is converted to electronic excitation and to molecular vibration and rotation. The ionization potentials of the principal components of living tissue (water, and atomic oxygen, hydrogen, nitrogen, and carbon) are between 11 and 15 electron volts (eV). Michaelson *(12.1)* considers 12 eV to be the lower limit for ionization in biological systems, while noting that some weak hydrogen bonds in macromolecules may have lower ionization potentials. As a point of reference, an ultraviolet wavelength of 180 nanometers corresponds to an energy of about 7 eV. Thus, for practical purposes, the nonionizing part of the electromagnetic spectrum includes the ultraviolet, visible, infrared, radiofrequency and lower frequency regions. The electromagnetic fields from electric power distribution at 50 and 60 Hz are included, although these fields are not radiative in nature.

Discussion

There is a large difference in the exposure standards of the United States and the U.S.S.R., those of the latter being much more restrictive. The level for unlimited occupational exposure in the Soviet Union is 10 $\mu W/cm^2$, and the proposed environmental level is 1 $\mu W/cm^2$. Controversy continues over the validity of the Soviet standard. The Soviet standard was adopted in Poland in 1961, pending an independent evaluation. In 1972, the Polish standard was revised and the occupational level was set at 200 $\mu W/cm^2$, and the environmental limit was set at 10 $\mu W/cm^2$ *(12.33)*.

Research is now underway in this country and elsewhere to determine and assess any possible biological effect of long-term exposure to low levels of nonionizing radiation and to examine the validity of the present occupational exposure standard of 10 mW/cm^2. Also of concern are the effects of high peak power, low average power, pulsed radiation and the questions of the need for and how to develop standards for the frequency range below 10 MHz where there is currently no exposure standard. Four types of overlapping exposure can be distinguished: (1) exposure in the general environment to intentional signals from the broadcast services, radars, leakage radiation, and other sources, (2) occupational exposures, (3) exposure to leakage radiation from consumer devices such as microwave ovens, and (4) intentional medical exposures. Occupational exposure is subject to control by OSHA. Intentional medical exposure is given at the discretion of a physician, but a performance standard is now being developed by the Food and Drug Administration for leakage and scatter from microwave diathermy units. There is no direct control of environmental exposure from microwave diathermy apparatus. Indirect controls of environmental exposures are the limitation put on effective radiated power by the FCC, their requirement for posting areas about domestic satellite stations where levels exceed 10 mW/cm^2, and the operational procedures employed in using both government and nongovernment sources. Also, any telecommunications system planned for purchase by the government, as a condition for spectrum approval, is reviewed by IRAC-OTP to assess among other factors whether levels in excess of 10 mW/cm^2 will occur and whether operational measures have been provided to insure that people are not exposed above this level.

Two types of environmental exposure can be distinguished. One is the relatively high radiation level from high power sources such as some radars and satellite communications stations where the power density in the useful beam can exceed that thought to be safe for human occupancy even outside the boundary of the facility *(12.15)*. The problems associated with such sources are recognized and instrumentation and techniques for analyzing exposure from them are available. The other type of environmental exposure arises from the superposition of the fields from many sources at different frequencies. This exposure may be high or low depending on the location and types of sources contributing to the exposure and includes the specific source problem as a special case. Nonionizing environmental radiation data are needed to interpret the results of current biological effects research and establish the predominant frequencies in the environment so that future research for the validation of standards can be appropriately directed.

Summary

General environmental surveys have been completed in seven cities in the Eastern United States. The data and population exposure implications for the first four of these are presented here and analysis is continuing on the other three. The measurement program will now continue in several cities in the Western United States.

The results to date suggest that probably 99 percent of the urban population is exposed at levels which would be permitted even under the restrictive proposed Soviet standard of 1 $\mu W/cm^2$. The general environmental data cannot be used to estimate the levels to which the remaining 1 percent of the population is exposed. Further information will require a detailed analysis of specific sources and a detailed knowledge of the locations of the persons exposed to such sources.