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Project Summary

Plutonium Burdens in People Living Around the Rocky Flats Plant

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A study was conducted to find out whether the tissue of people who had lived near to or downwind from Rocky Flats Nuclear Weapons Facility in Colorado contained more plutonium (Pu) than the tissue of people living farther away. In addition to tissue analyses, investigators obtained information on age; sex; smoking, occupational, and residence history; and causes of death. The tissue samples were collected from autopsy cases during the period 1976-1979. The purpose of the study was to measure levels of Pu-236, Pu-238, Pu-239 and Pu-240, and the Pu-240/239 ratio in the tissue of people who had not been occupationally exposed and who died in Colorado over that three-year period.

Samples were collected from human autopsies in each of three collection areas: Area A -- up to 25 km from Rocky Flats; Area B -- between 25 and 50 km from Rocky Flats; and Area C -- all of Colorado outside a 50 km radius of Rocky Flats and east of the Continental Divide.

With plutonium concentrations in lung and liver tissue as the dependent variable, a stepwise, multiple regression analysis was used to test the data with independent variables of age, packyears of cigarette smoking, and distance of residence from Rocky Flats, analyzed separately by sex and for selected areas.

The Pu-240/239 ratios in the liver were significantly higher than in the lung, and the total amount of plutonium burden in the liver was about 10 times greater than in the lung. These observations reflect the longer retention time of plutonium in the liver.

Results indicated that sex, age, and smoking history were all more strongly related to plutonium burden in the liver than distance from Rocky Flats. Additionally, results show that a male at the average age of 65.4 years, as in this study, would have 1.5 times more plutonium in his liver if he had been an 80-packyear smoker than if he had been a nonsmoker. For a 50-packyear smoker at the average age, the ratio would have been 1.3 times more plutonium.

The data on concentration and total lung burden and on the Pu-240/239 ratio in lung and liver suggest that releases of plutonium from Rocky Flats contributed only a small amount to plutonium burdens in humans east and southeast of the site, as the total amount of plutonium in human tissues was small and not very different from that observed by other researchers who have studied people from other locations in the nation.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

At the request of Senator Haskell of Colorado, a study was conducted to find out whether the tissue of people who had lived near to or downwind from Rocky

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Flats contained more plutonium than the tissue of people living farther away. For those deceased who were autopsied and who had lived in eastern Colorado at least five years, information was collected on age; sex; smoking, residential, and occupational history; cause of death; and presence of pulmonary or liver disease. Samples of lung, liver, gonads, adrenals and rib were collected for plutonium analysis. The isotopes for which the samples were analyzed were Pu-236, Pu-238, Pu-239, Pu-240 and the ratio of Pu-240 to Pu-239. Plutonium in tissue from Colorado residents can arise from both worldwide fallout and from local sources such as the Rocky Flats plant near Boulder, Colorado.

The amount of global atmospheric plutonium varies from year to year, depending on the types of atomic bombs being tested; however, the bulk of plutonium from American and Russian nuclear test programs fell from the atmosphere by 1968. Subsequent measurements show that the amount of plutonium has been declining ever since.

A possible source of plutonium in Colorado was a September 1957 fire at the Rocky Flats plant, which released plutonium-seeded smoke that was swept southward by a prevailing wind (Hammond, 1971). Another release occurred between January and June of 1968 and during 1969, when drums containing oil contaminated with plutonium were being moved. Several were damaged, releasing into the soil plutonium particles that were then resuspended in the air during high winds (Seed, 1971). These are two known acute releases from Rocky Flats; others could have occurred, and a continual, very low level was probably released from normal operations.

Several other possible sources of plutonium exist in Colorado. Until September 1980, there had been 565 tests at the nuclear test site in Nevada, of which 140 tests produced measurable amounts of radiation outside site boundaries (Hicks, 1981). Also, since 1968, the Peoples' Republic of China has conducted about 20 nuclear weapons tests that added to the global plutonium inventory. Since the Chinese tests were relatively recent and the retention half-time of plutonium in lung tissue is 500 days, a related contribution of plutonium to the lungs of people recently living in Colorado could exist.

Atmospheric transport and diffusion processes would have dispersed the nuclear test site and Chinese debris clouds before they reached Colorado, so that plutonium loads would have been randomly distributed in the soil of the state. By contrast, weapons-grade plutonium released by the Rocky Flats plant would be concentrated near the facility. In addition, Rocky Flats plutonium has an isotope ratio (240/239) of 0.06 compared to a worldwide fallout isotope ratio of 0.18, so that measurement of the Pu-240/239 ratio in a sample permits an estimate of the Rocky Flats contribution to the sample.

The highest known concentration of plutonium in the air in Colorado occurred during the 1957 fire. The relatively high level at that time was probably of short duration as compared to the lower, more sustained levels associated with the oil drum spills during 1968 and 1969.

Many measurements of soil plutonium concentration levels have been made around the perimeter of Rocky Flats. They show a much higher concentration of plutonium east and southeast of the site than at distant locations. This is probably due to prevailing winds that blow from west to east. Relatively little soil contamination was found south, west, northwest, or northeast of the site.

If the fire and spills at Rocky Flats between 1957 and 1968-1969 caused plutonium exposure to local residents that was excessive in comparison to plutonium exposure from worldwide fallout, then an increased concentration of plutonium in tissue could be expected now among those who lived downwind from Rocky Flats during that period. This could be detected by a low ratio of Pu-240 to Pu-239 in lung tissue, where the retention half-time of plutonium is relatively short.

The usefulness of the study was not limited to the questions about Rocky Flats but included inquiry into the relationship between smoking history, age, sex, cause of death, and plutonium concentrations in liver and lung.

Methods and Procedures

The study was coordinated by the U.S. Environmental Protection Agency (EPA), Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, and conducted by the University of Colorado Medical Center and the Colorado State Health Department. Fifteen hospitals in Denver, Pueblo, and Colorado Springs collected tissue samples for the study.

Samples were collected from human autopsies in each of three collection areas: Area A -- up to 25 km from Rocky Flats; Area B -- between 25 and 50 km from Rocky Flats; and Area C --all of Colorado outside a 50 km radius of Rocky Flats and east of the Continental Divide. A total of 519 samples were collected, 147 from Area A, 182 from Area B, and 190 from Area C. (See Figure 1.) Samples came mostly from heavily populated areas around Denver, Colorado Springs, and Pueblo, with scattered cases from all of eastern Colorado. Only three samples came from places within 10 km of Rocky Flats, because the area was very sparsely settled.

Each set of samples generally included one whole lung, 750 grams of liver, both gonads, if available, both adrenals, if available, and a sample of rib. Interviews with next of kin yielded places of residence of the deceased, any possible occupational plutonium exposure, smoking history in packyears, age, sex, and cause of death.

In lung tissue, the plutonium is less evenly distributed than in the liver, and much of it is deposited in the lymph nodes. Hence, only samples that included more than 90 percent of either the right or left lung were used.

The U.S. Air Force McClellan Central Laboratory of Sacramento, California, analyzed the lung and liver samples by both alpha pulse height analysis (APHA) and mass spectrometry. In addition, standards were checked by the Lawrence Livermore Laboratory, Knolls Atomic Power Laboratory, and Los Alamos Scientific Laboratory. The EPA, in consultation with the Health Departments of Colorado and Jefferson County and with the University of Colorado, decided which tissue and how many would be collected, based on what was then known about plutonium distribution in the body from inhaled plutonium oxide particles. Because pulmonary lymph nodes tend to concentrate plutonium particles from the lungs, lymph nodes were included in all lung specimens.

During preparation of samples at autopsy, organs are removed from the body and sliced in such a way that blood or other fluids seep out and are washed away. Measurements indicated that if the liver lost about 10 percent of its weight in fluid seepage, only about 1.5 percent of resident plutonium was lost. By far the largest part of the plutonium burden is evidently rather firmly fixed to the tissue and does not drain off with the fluid. Consequently, due to changes in tissue fluids at time of death, total organ burden of plutonium is more meaningful than the organ tissue concentration alone and therefore was measured in the study.

Only individuals who lived in eastern Colorado for at least five years since 1968, who neither worked at Rocky Flats nor had been otherwise occupationally exposed to plutonium, were included in the study. Distance from Rocky Flats was noted for three time periods: the last five years of life; the period from 1968 to 1970; and the time of the fire in 1957. The distribution of the causes of death was compared to the distribution of causes of death for the entire state for the same period of years to determine the degree to which the samples were representative of the population who died in Colorado during those same years.

Alpha Spectrometry

Plutonium samples were analyzed by alpha spectroscopy for the presence of Pu-236, Pu-238, and Pu-239+240. Each sample was counted on either a Frisch Grid detector for approximately 2000 minutes or on a silicon solid state detector for approximately 3000 minutes.

Mass Spectrometry

Plutonium samples were loaded by evaporation on rhenium filaments, placed in the source of the mass spectrometer and ionized by heating to 1900°C. From this, the Pu-240/239 atom ratio and dpm were determined.

With plutonium concentrations, organ burdens, and isotope ratios in lung and liver tissue as the dependent variable, a stepwise, multiple regression analysis was used to test the data with independent variables of age, packyears of cigarette smoking, and distance from Rocky Flats. Samples were analyzed separately by sex and for selected areas.

Results

Of the 519 sample sets obtained for the study, those from 41 control area residents have not been analyzed for plutonium because of budget constraints. Ten were excluded from analysis because of various problems (See Figure 1.). For the 468 with interviews, 19 were excluded from the study because the individual might have been occupationally exposed to plutonium or had lived in an area where other plutonium exposure could have occurred.

The remaining 449 sets of samples included in the study represented an aged population with females slightly older than males. The males were much heavier smokers. Almost two thirds of the females were nonsmokers. People who resided within 50 km east and south of Rocky Flats during the 1957 fire had a minutely lower average ratio of Pu-240/239 in their livers than did those living in the other study areas, but distance from Rocky Flats did not show any consistent relationship for this group.

Males had a slightly but significantly higher average liver burden of plutonium than females, but they also smoked significantly more. Liver burden appears to be low and weakly related to any of the variables in females; however, in males, both age and packyears of smoking were

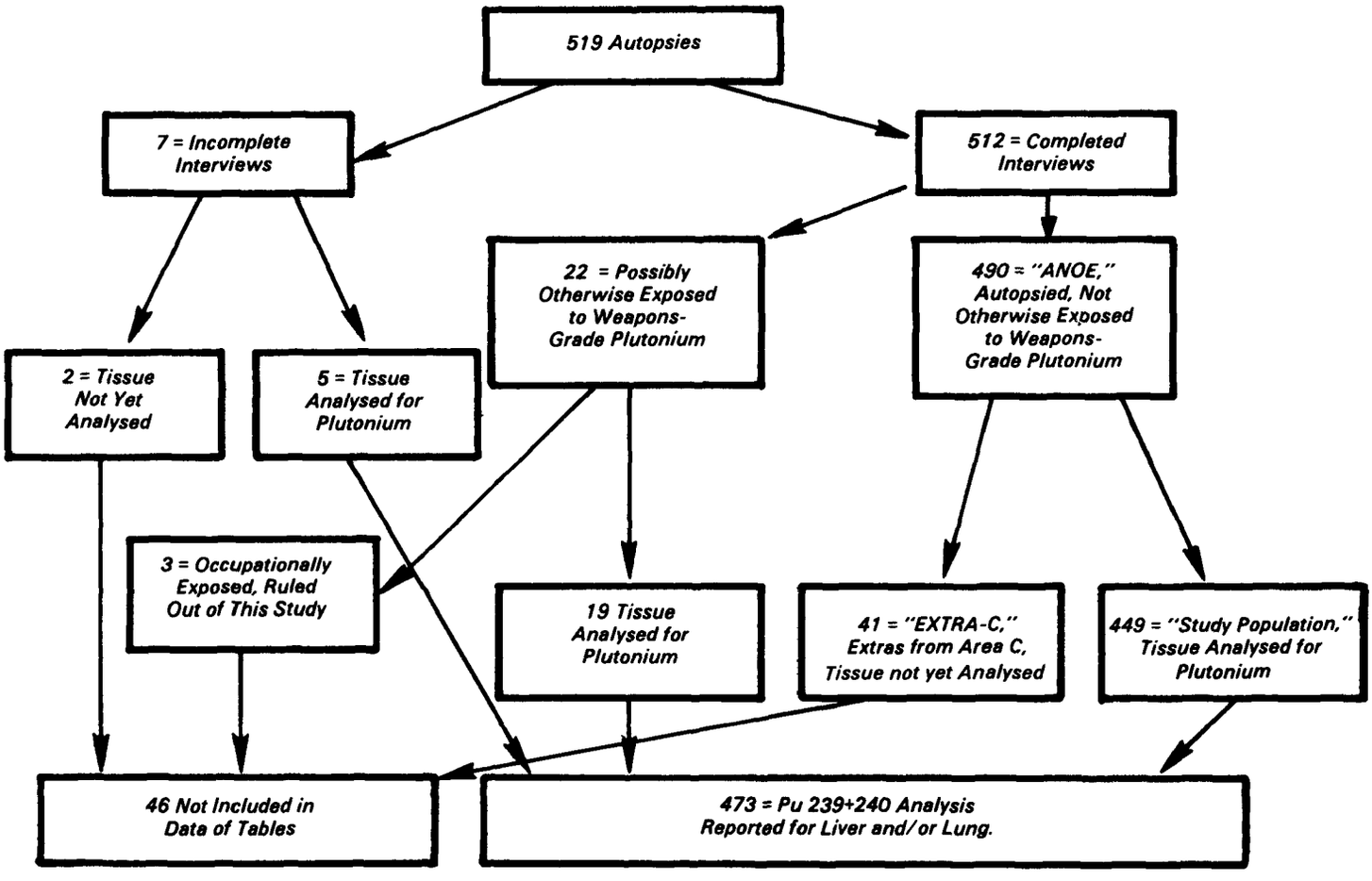

Figure 1. Breakdown of 519 autopsied individuals.

usually positively and significantly related to liver burden. Nonsmokers and light smokers were more likely to have no plutonium in their lungs than were heavy smokers. The data on Pu-240/239 ratio in lungs tended toward the ratio found in soil, as a function of distance from Rocky Flats, but was statistically weak.

The mean value for concentration of plutonium in the lungs of people who had lived in eastern Colorado was very similar to the median value estimated by McInroy (1979) for the Colorado population and is only slightly higher than the median value estimated by Fisenne (1979) for a much younger and healthier population in New York City. For liver plutonium concentration, the mean for eastern Colorado was only slightly higher than the estimated median of both McInroy and Fisenne, which could be accounted for by differences in age, sex, and smoking habits.

Results indicated that sex, age, and smoking history were all more strongly related to plutonium burden in the liver than distance from Rocky Flats. Differences between mean liver burdens for male heavy versus light smokers, between males and females of each group, and between older and younger males were all significant. Females did not show an age difference in liver burden and smoking did not seem to have an influence in women.

Discussion

There are several possible explanations for finding that older people have larger plutonium burdens than do younger people. First, the peak of plutonium pollution from worldwide fallout occurred in 1963, after which it dropped during the next four years by a factor of 15 (Efurd, 1977). Young people born since then would therefore have had considerably less exposure.

Second, young people have healthier lungs in general and are better able to eliminate inhaled particulates than older people. Third, from 1950 to 1970, older people were still smoking more than younger people. Only in recent years have teenagers begun to smoke so much (Last, 1980). Fourth, since plutonium was first used in 1945, an older person would generally have been exposed to more plutonium than a younger person. Finally, for growing children, the amount of air inhaled per unit time increases with increasing lung size, which increases with age. All of these factors would tend to give older people a larger plutonium burden.

Pu-240/239 ratios in the liver were significantly higher than in the lung. Additionally, the total amount of plutonium burden in the liver was about 10 times greater than in the lung. Both of these observations are explained by the fact that retention half-time of plutonium in the liver is 30 times longer than in the lung. Thus, the liver would reflect the accumulation of plutonium over a person's whole lifetime and consequently have a much greater plutonium burden and a higher Pu-240/ 239 ratio.

The results of the study suggest that a male at the average age of 65.4 years, as in this study, would have 1.5 times more plutonium in his liver if he had been an 80-packyear smoker than if he had been a nonsmoker. For a 50-packyear smoker at the average age, the ratio would be 1.3 times more plutonium. The higher plutonium levels probably do not result from a higher intake of plutonium among smokers but from the toxic and irritating substances in cigarette smoke that damage the clearing mechanisms of the lungs, thereby preventing the natural elimination of particles.

Regarding the question of the Rocky Flats facility as a source of plutonium, the results of the study were not conclusive. The data suggest that releases of plutonium from Rocky Flats have contributed to human plutonium burdens east and southeast of the site, but the total amount of plutonium in human tissue is small and not very different from that observed by other researchers who have studied people from other locations in the nation.

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The complete report, entitled "Plutonium Burdens in People Living Around the Rocky Flats Plant," (Order No. PB 83-137 372; Cost: $22.00, subject to change) will be available only from:

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