

A REVIEW OF EPIDEMIOLOGIC STUDIES AT LOS ALAMOS NATIONAL LABORATORY

G. L. Voelz, G. S. Wilkinson, J. F. Acquavella,  
M. Reyes, & J. F. Mcinroy

Health Division, Epidemiology Group (H-14)  
Los Alamos National Laboratory  
Los Alamos, New Mexico 87545

INTRODUCTION

Epidemiologic studies at Los Alamos are directed toward understanding potential health risks associated with activities pertaining to national energy and defense needs. Currently this research focuses on evaluating the effects of plutonium exposure in man. The major programs consist of 1) epidemiologic studies of the incidence of disease and mortality among plutonium and other workers at six Department of Energy (DoE) contractor facilities (Los Alamos, Rocky Flats, Mound, Savannah River, Hanford, and Oak Ridge), and 2) measurement of plutonium and other radionuclides in human tissues. Currently, investigations of mortality for Pantex workers and the surrounding general population are also being conducted for DoE in support of an Environment Impact Statement. This paper places emphasis on the activities of the national epidemiologic study of plutonium workers.

The purpose of the plutonium workers study is to: 1) investigate whether adverse health effects are associated with exposures to plutonium, 2) explore whether adverse health effects are associated with exposure to transuranic elements, other radioisotopes, and hazardous substances that are found in nuclear facilities making routine use of plutonium, and 3) to describe in detail the nature of such health effects should they be discovered. Since plutonium is such an important radionuclide for the nuclear industry, and since any expansion of the nuclear power and nuclear weapons industries will result in increased use of this transuranic element (as well as other radionuclides), long-term follow-up investigations of the potential health effects in humans that may result from exposures to this substance are of crucial importance to the nation,

Background

Although an extensive literature exists regarding plutonium, it is by and large restricted to laboratory-based studies of animals. Very limited data on humans has only recently become available. However, although biological effects differ, considerable knowledge on human exposures to radium has been developed and is often used to project potential outcomes from plutonium since these nuclides possess some similar characteristics.

The present study grew out of a long-term follow-up clinical study of 26 Manhattan Project Plutonium Workers. This effort was later expanded to a followup of 241 Los Alamos plutonium workers with 10 or more nCi exposure as of 1974. Both of these efforts have resulted in several

reports showing no identifiable health effects associated with plutonium exposures. These populations will continue to be followed as part of the general epidemiologic study.

Autopsy tissue measurements of plutonium in workers have demonstrated that the largest concentrations are present usually in the tracheobronchial lymph nodes followed in decreasing order by the lungs, liver and bones. The primary routes of entry are by means of inhalation of particulates and through contaminated wounds; ingestion accounts for only minimal exposure. Wound intakes, of course, do not involve the lung and tracheobronchial lymph nodes as seen after inhalation exposure. Dissolution of plutonium from the portal of entry throughout the body takes place via the lymphatic and circulatory systems.

These findings, plus the results of studies of radium dial painters and laboratory animal studies suggest that our interest should be directed toward neoplasms and other diseases of the lymphatic and hematopoietic systems (lymphomas and leukemias), respiratory tract (lung cancer and respiratory disease), liver and biliary tract, bone (osteosarcoma) and, to a lesser degree, the gastro-intestinal tract.

The results of studies of chromosome breakage in humans and evidence of some plutonium deposition in the gonads of animals suggest that the mutagenic properties of plutonium exposures is also a topic worthy of future consideration.

## STUDY DESIGN

### The Major Focus

The surveillance of incidence for selected diseases among plutonium workers who have experienced a wide range of exposures, primarily to Pu<sup>238</sup> and Pu<sup>239</sup>, is the major focus. Surveillance activities are expected to continue through 1990-2000 and will comprise a lifetime follow-up for many of the more heavily exposed early workers. Since the data necessary for determining the incidence of most diseases is not readily available, this information must be obtained by means of directly contacting study subjects, seeking their cooperation, and obtaining information regarding their illness histories and other important variables. Similar approaches have been successfully carried out by Los Alamos National Laboratory in the aforementioned studies of Manhattan District workers and workers exposed to 10 or more nCi of plutonium.

The basic data necessary for conducting such an effort is identical to that required for evaluating mortality status with the addition of searches for deceased workers through the Social Security Administration and collection of death certificates. Consequently, it will be possible to investigate mortality and to conduct death certificate based case-control studies before completing any analyses of incidence.

Should investigations of either mortality or incidence demonstrate excesses of specific diseases among plutonium or other heavily exposed workers, case-control studies entailing the collection of more in-depth

information on important confounding and risk variables will be developed. The attached flow chart depicts in graphic form the general plan of the overall program.

### Mortality

Early study efforts have been devoted to obtaining the cooperation of appropriate officials at the various facilities, defining available sources of data, defining worker populations (populations at risk), compiling rosters of workers, submitting them to the Social Security Administration for ascertainment of mortality status, compiling exposure information, and coding raw, hard copy data into machine readable form.

Several study approaches using various segments of the various populations at risk will be employed. A general analysis of mortality rates at each of the study facilities will comprise a crude investigation of each plant population and, eventually, all six populations together. Investigations of standardized mortality ratios (SMR's) will be completed using expected numbers of deaths obtained from US, state and county rates for age specific causes of death and observed numbers of deaths among workers at each facility. An additional analysis will compare mortality rates for plutonium burdened with nonburdened workers, and external radiation exposed with nonexposed workers at the same facility.

A second approach will employ a proportional hazards model using a Cox regression technique. This technique will allow us to evaluate the effect that plutonium levels and other exogenous variables have on the hazard function; i.e., risk of death.

Finally, should either the SMR or the proportional hazards approach demonstrate higher than expected numbers of deaths for specific causes, detailed death certificate based case-control studies will be conducted in an attempt to discover sources of exposure that may account for such excesses.

Mortality studies are characterized by disadvantages as well as advantages. The advantages are that they can be conducted relatively quickly in comparison to incidence studies, and they are based upon death certificates which are the only form of "hard data" with respect to vital status (other than birth certificates) that are collected in relatively uniform fashion throughout the United States. The disadvantages are that 1) mortality studies are only accurate for diseases that are highly fatal, i.e., that demonstrate high case fatality ratios; and 2) information on important confounding and risk variables, such as smoking and medical x-ray exposures, are not generally available.

### Incidence

Since the data necessary for determining the incidence of most diseases are not readily available, this information must be obtained by means of directly contacting study subjects, seeking their cooperation and obtaining information regarding their illness history and other important variables.

An advantage of incidence compared to mortality studies is the ability to capture information regarding diseases that are not highly fatal as well as data on important confounding and risk variables that can only be obtained through direct contact with individuals.

Approximately 10,000 workers including all of those with positive plutonium body burdens will be identified, traced and interviewed in order to develop incidence rates for specific diseases. Data on important confounding and risk factors such as tobacco use, medical x-ray exposures, occupational exposures, and major illnesses experienced shall be collected. This approach will allow us to not only ascertain incidence rates for selected diseases of interest but also to investigate interrelationships between plutonium exposures, other radionuclides, and hazardous substances as well as risk factors that were just mentioned. Individuals comprising the study cohorts will then be contacted by means of interviews or questionnaires at approximately five-year intervals to update their health status, and to obtain additional data on other variables if necessary.

Analyses of incidence data will include the calculation and comparison of incidence rates for the plutonium exposed and unexposed cohorts, stratified analyses employing Mantel-Haenzel Chi Square techniques, and analyses employing proportional hazards regression model as well as logistic regression techniques. These will allow us to not only compare incidence rates, but to also determine confounding and effect modification, ascertain the simultaneous effects of exogenous variables on cancer incidence, and to determine the probability of developing diseases of interest, such as a particular neoplasm, given specified levels of exposure.

Similar to the mortality effort, a nested design approach will also be used in our studies of incidence. Should incidence rates for specified diseases be found elevated, detailed case-control studies will then be conducted in order to obtain additional detailed data for the purposes of further explaining such excesses.

## RESULTS

These studies have resulted in a number of published papers, some of these are listed at the end of this report. A synopsis of the major findings is given here.

### Medical Followup of Manhattan Project Plutonium Workers

Twenty-six male subjects who worked with plutonium during World War II under extraordinarily crude conditions have been followed medically for a period of 32 years. Inhalation was the primary mode of plutonium exposure. Current estimates of the systemic plutonium depositions in these individuals range from 7 to 230 nCi. Eleven individuals have depositions greater than 40 nCi, the current maximum permissible body burden for workers. Two individuals in the group have died: one due to myocardial infarction and the other due to injuries sustained in an

automobile-pedestrian accident. This mortality rate is about 50% of expected deaths based on United States white male rates. All 24 living subjects were re-examined during the period 1975-78. No cases of cancer were diagnosed in the group except for two skin cancers that have no history or basis that relate them to plutonium exposure. The diseases and physical changes noted in the group are characteristic of a male population in their 50s and 60s. This study yields no evidence suggesting that adverse health effects have resulted from the 32 years of exposure to internally deposited plutonium.

#### Mortality Study of Plutonium Workers at Los Alamos

A mortality study of 224 Los Alamos white, male workers with the highest exposures to plutonium (10 nCi or greater depositions) has shown no excess deaths due to any cause compared to adjusted rates of white males in the United States population. Estimates, using risk values developed by scientific committees, such as UNSCEAR and BEIR, suggest that less than 0.5 excess cancer deaths would be expected in the group by 1976, although lifetime experience may carry a potential of one or two excess cancers in the group. The mortality data for such a small group is not adequate to support or question these estimates, although there is no suggestion of any excess deaths to date.

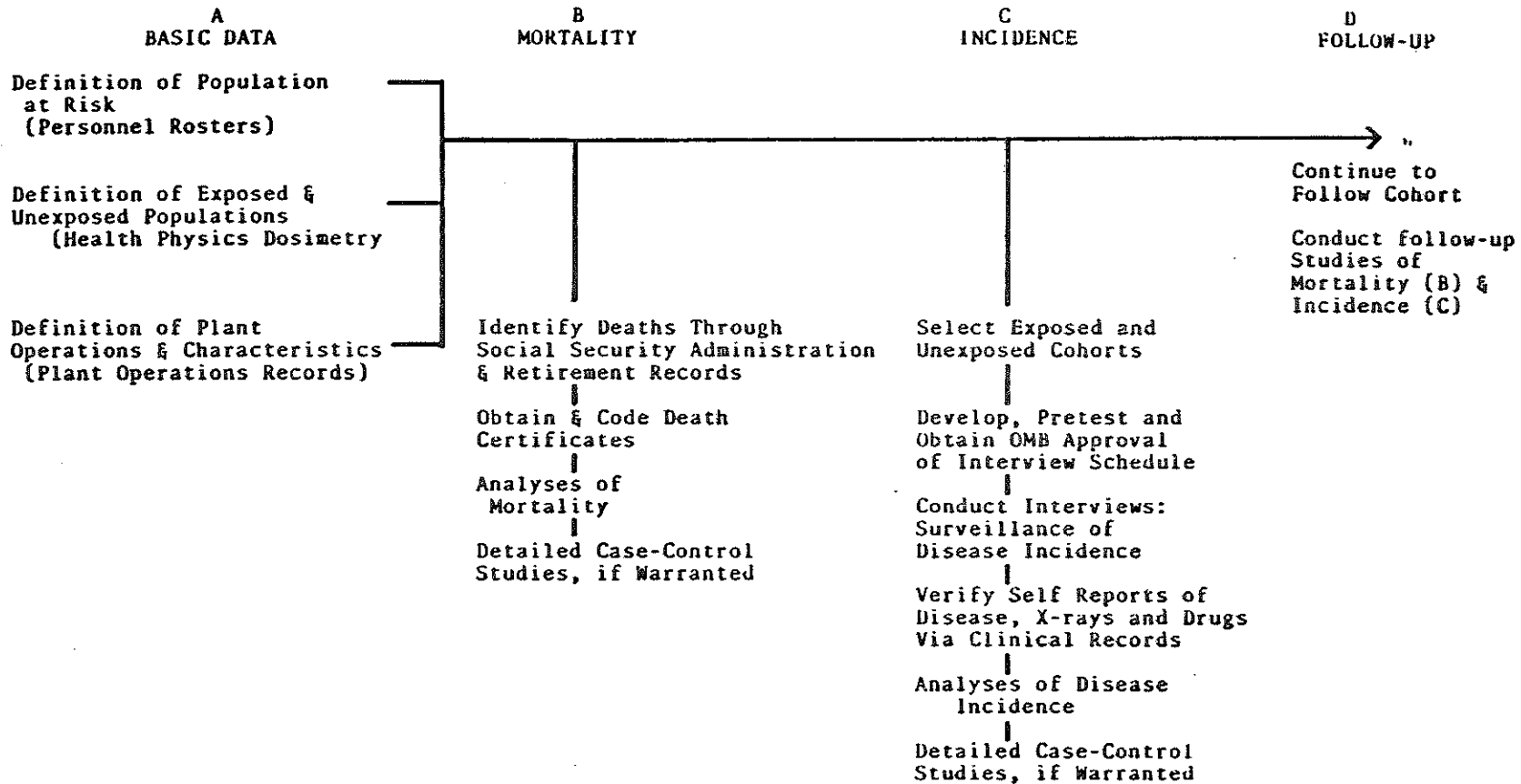
Other hypotheses suggest the risk due to plutonium is much higher. The Gofman risk hypothesis suggests that 52 out of the 244 persons, or more than one out of five, will develop lung cancer. It is noted that the exposures occurred nearly 25 years ago on the average, so a relatively long latent period has already passed without the development of excess lung cancers in the group. The calculation that 15 excess lung cancer deaths should have been noted by 1976 is believed to be a reasonable, conservative interpretation of the Gofman risk hypothesis. The data in this study suggest that this hypothesis seriously overestimates the risk of lung cancer due to plutonium exposure.

In applying risk estimates, it seems reasonable to expect that predicted and observed excess cancers should correlate. Undoubtedly, risk estimates will be adjusted and refined as more information is compiled. Estimates significantly higher than those predicted by the UNSCEAR and BEIR reports are not supported by the human data presented here.

#### Preliminary Mortality Study of Workers at Rocky Flats

A preliminary analysis of mortality was completed for all white males who have worked at the Rocky Flats Plant during the period 1952 to 1979. The 452 observed deaths were significantly fewer than the 831 expected for all causes. The 107 deaths due to all malignant neoplasms were also significantly fewer than the 167 expected from these diseases. Expected deaths were derived from age and calendar-specific death rates for U. S. white males. Deaths reported for benign and unspecified neoplasms numbered eight versus an expected two, a significant elevation. These tumors, all intracranial, are the subject of a case-control study to be

**SURVEILLANCE OF THE INCIDENCE AND MORTALITY FROM  
SELECTED DISEASES AMONG PLUTONIUM WORKERS**



reported later. Subdividing the cohort on the basis of plutonium exposures and external radiation exposures results in similar overall findings. The benign and unspecified neoplasms, however, were not significantly high in the plutonium-exposed group.

#### Morbidity and Mortality Study of Los Alamos County, NM

Cancer among Los Alamos County, New Mexico, male residents, all of whom have worked in or have lived within a few kilometers of a major plutonium plant and other nuclear facilities, has been reviewed with respect to mortality between 1950 and 1969 and incidence between 1969 and 1974. A possible excess of neoplasms of the reticuloendothelial system was detected, but the incidence data suggest that this excess, if real, is no longer occurring. Several potentially causal occupational exposures have existed. Higher than expected incidence for cancers of the colon and rectum appears to be explained better by socioeconomic than occupational factors. Neither mortality nor incidence data suggest an excess of lung cancer in Los Alamos males. Healthy worker and healthy military effects, white ethnicity, and migration are potential intervening variables relevant for interpreting mortality data in counties dominated by a single major facility.

#### A Study of Malignant Melanoma Incidence at the Los Alamos National Laboratory

An analysis of melanoma incidence for 1969-1978 was conducted among 11,300 workers at the Los Alamos National Laboratory in New Mexico. For the total cohort, 6 cases were detected versus 5.69 expected (Standardized Incidence Ratio (SIR) = 105, 90% Confidence Interval (CI) = 51, 198) based on incidence rates for the state of New Mexico, specific for age, sex, and ethnicity. Among Anglo males, 3 cases were detected, while 4.4 were expected. The associated SIR of 68 (90% CI 23, 163) does not suggest excess melanoma incidence in this subcohort. A direct comparison with statewide incidence rates yielded similar results. These results are in conflict with the recently reported threefold excess of malignant melanoma incidence among Anglo male employees at the Lawrence Livermore National Laboratory.

#### An Evaluation of Social Security Followup

Occupational epidemiologic studies often use the Social Security Administration (SSA) for ascertaining mortality among industrial cohorts. However, there have been few reports assessing the completeness of this method. This study reports results of an evaluation of SSA for a mortality search. Correctly ascertained deaths ranged from 76% to 90% among males and from 53% to 77% among females. Duplicate record searches conducted one year later, raised this rate to a range of 88% to 94% for males and 71% to 87% for females. The correct identification of death by the SSA appeared to be independent of ethnicity, cause of death, location of death and decade of death. Age at time of death was related to correct ascertainment. Individuals 65 years of age or over were identified much more accurately than persons less than 65 years of age.

The age of an industrial facility and of its work force may have a major influence on the adequacy of mortality ascertainment through Social Security. These findings indicate that studies which rely solely upon the SSA for determination of mortality may suffer from underascertainment of death, especially among younger workers and females. Two major problems may result from inadequate identification of deaths: 1) SMRs based on comparisons with mortality rates from general populations could be lowered and the effect misidentified as a "healthy worker effect" and 2) for studies of rare diseases, a very small number of missed deaths may yield totally misleading study results.

#### Plutonium in Autopsy Tissue from Persons in the General U.S. Population

The primary objectives of this study are to determine the baseline concentrations of plutonium in the general population, to monitor for changes that may be related to growth of the nuclear industry, and to obtain data on the long-range time dependence of fallout plutonium incorporation into the body.

The tissues analyzed include lung, tracheobronchial lymph nodes, liver, bone, kidney, and recently, gonads, thyroid, and spleen. The median concentrations observed in the general population (dis/min per kg of tissue wet weight) are: tracheobronchial lymph node (360), 5.8; liver (701), 1.6; vertebrae (325), 0.6; rib (95), 0.6; thyroid (184), 0.6; lung (705), 0.4; gonad (264), 0.3; spleen (325), 0.2; and kidney (631), 0.1. The parenthetical numbers indicate the number of samples analyzed.

The effects of age, sex, date of death, cause of death, and geographic location of residence on the observed plutonium deposition have been evaluated. Because of the different biological turnover times of plutonium in the various organs of the body and the changing concentrations of plutonium in the atmosphere, the plutonium concentration ratios between tissues have changed as a function of time. However, our data indicate that over the past ten years, the highest concentrations in the general population are found in the tracheobronchial lymph nodes and the liver, and the lowest concentrations are in the spleen, gonads, and kidney. The median body burdens of plutonium in the U.S. population are estimated to have reached 12 pCi during the 1960s and have declined to about 2 pCi in 1977. Large errors in estimated skeletal burdens of plutonium may exist because of small specimen sample sizes and a lack of knowledge concerning the relative distribution of plutonium among the various bones of the human body.

#### Plutonium in Autopsy Tissue of Occupationally Exposed Workers

Tissues from 180 autopsy cases of former workers at various nuclear facilities have been analyzed for their plutonium content. Not all the individuals had worked directly with Pu since many were secretaries, clerks, truck drivers and other support personnel. The results indicate that approximately three-fourths of these cases have Pu depositions not much different than fallout levels of Pu in the U.S. general population.



Estimated whole body depositions in the remaining cases range from about 0.05 to 50 nCi. Data from the 20 highest deposition cases are compared with the in vivo estimates from urinalysis data. In general, the urinalysis data give estimates that are high by factors of 2 to 3, or more. The observed variation in the whole body distribution suggests that each exposure incident is unique and must be evaluated on the basis of chemical form, solubility, particle size, mode of entry and duration of exposure.

## STATUS

Efforts in 1981 were devoted to completing the collection of data required for conducting mortality analyses, reducing these data and transforming them into machine readable form, beginning analyses of mortality, and developing an interview schedule that will be used in the surveillance of disease incidence for selected illnesses.

### Rocky Flats

Preliminary analyses of worker mortality for Rocky Flats have been completed and published as reported above. Additional and more detailed analyses are now being conducted with more refined data.

As a result of the excess in intracranial tumors that was observed and in response to allegations of elevated rates for brain cancer among Rocky Flats workers, a case-control study of workers who have been identified as having died of an intracranial tumor is also being conducted. In this study, cases with intracranial tumors are being compared with several types of controls. The purpose is to investigate the hypothesis that brain cancer victims experienced more internal and/or external radiation exposure than did controls. Credence is lent to this effort when primary intracranial tumors are evaluated in terms of the 7th rather than the 8th revision of the ICDA. The 7th allows one to look at categories and combinations of intracranial tumors. Thus, upon analyzing the previous data, but according to the 7th rather than the 8th ICDA, we obtain SMR's of 1.39 (95% CI:.74, 2.41) for malignant tumors, 2.44 (95% CI:.12, 10.003) for benign intracranial tumors, and 5.22 (95% CI:2.5, 9.8) for unspecified tumors. When all intracranial tumors, are examined, an SMR of 2.12 (95% CI:1.35, 3.18) is demonstrated. Further analyses comparing cases and controls on radiation exposures and other variables are currently being conducted.

### Los Alamos

In addition to the melanoma study, several additional research activities involving Los Alamos workers are to be completed in 1982. The roster of Los Alamos employees was searched for deaths through the Social Security Administration and the ORAU Death Certificate Retrieval Office during 1981. These data are being entered into a data base containing Los Alamos National Laboratory, Zia Company, and DOE/Albuquerque Operations Office employees.

Clinical studies for the current five-year followup of the Manhattan Project plutonium workers was begun in 1981. All but 4 of the 24 living Manhattan District plutonium workers returned to Los Alamos for follow-up clinical evaluations. The others are scheduled to undergo examinations later in 1982.

With few exceptions, smoking data have been obtained and entered into the data base for the 241 Los Alamos subjects with 10 or more nCi exposure to plutonium. Still remaining are a number of deceased individuals whose next of kin have changed addresses and, as a consequence, require tracing. Another analysis of the data on these individuals will begin shortly.

### Savannah River

Data collection activities were for the most part completed at Savannah River with the filming of personnel record cards. This facility had posed a problem since personnel files for terminated workers were periodically purged except for the terminating interview form which contains little useful information. However, it was discovered that a personnel record card for terminated workers was maintained in the payroll office. These have been filmed and are being readied for use by our coders for transformation into machine readable form. Objections by DuPont management to the filming of salaried employee records, because of privileged salary information, necessitated obtaining a computer printout containing minimal data, such as hire and termination dates, on these individuals. A similar objection regarding salary information on Social Security 941 A forms has impeded our efforts to obtain this information which is the only means available to validate the Savannah River cohort. Coded death certificates have been obtained from the ORAU Death Certificate Retrieval Office for 84% of those known to be deceased. These data are in the process of being entered into a data base.

### Mound

Data collection activities at the Mound facility have been completed for all personnel data. The routine procedures for submitting a cohort roster to the Social Security Administration (SSA) for vital status reporting and the abstracting of demographic data from personnel records for data base creation have been completed for the cohort which is comprised of approximately 6500 employees. Of the 762 Mound employees reported as dead by Social Security, 75% of the death certificates have been obtained and coded according to the 8th ICDA. An additional 50 death certificates have been obtained for employees not reported as deceased by the SSA. 941A forms, necessary for cohort ascertainment, are being forwarded from Mound to Los Alamos. Upon receipt of these data, the information will be examined to verify the completeness of the cohort before analyses begin.

An additional effort to incorporate the previously coded personnel information with death certificate and detailed work history information for each member of the cohort was successfully accomplished in late 1981.

Unfortunately, because the entire computer network at Mound is in the process of renovation, we have been unable to obtain some of the health physics data mandatory for our analyses. The data should be received in a few months, thus allowing the completion of the initial mortality analysis by the end of 1982.

### Survey of Incidence

Considerable effort has been expended toward developing an interview schedule that can be used by both LANL and ORAU for a survey of disease incidence among plutonium workers, workers included in the 5-Rem study, and other DOE-funded investigations if desired. Several drafts have been reviewed by both parties and a final draft is nearing completion. Efforts toward securing Office of Management and Budget (OMB) approval of the instrument will proceed during 1982.

### FUTURE RESEARCH DIRECTIONS

Ultimately, this long-term follow-up study will be able to answer questions regarding health effects in general, and cancer in particular, that may be associated with exposure to plutonium, other radionuclides, and external penetrating radiation.

Analyses of Rocky Flats workers will continue as increasingly refined data are obtained. Directly adjusted comparisons between exposed and unexposed segments of the cohort are planned, as are analyses employing logistic regression and proportional hazards techniques, if warranted. A more indepth look at risks in terms of occupation has begun and will continue for some time, in an attempt to evaluate whether occupational hazards influence mortality. Finally, quality control and methodologic studies, such as an evaluation of the quality of health physics data or estimation of the effect on end results that is exerted by persons lost to followup, will be completed.

Similar analyses are also planned for Mound and Savannah River workers. Furthermore, it will be possible, as data for each new cohort becomes available for analysis, to combine study populations. Since the number of subjects with significant body burdens at each individual facility is small, this tactic will increase chances of finding rare health effects that may be associated with exposures to plutonium or other radionuclides.

A variety of activities will be completed for Los Alamos workers. Analyses of the results of the clinical followup for former Manhattan District workers will be completed. This will complete about 37 years of follow-up experience on a group that is among the most heavily plutonium-exposed individuals known. Also, another analysis of 241 workers exposed to 10 or more nCi, which incorporates added years of followup as well as additional information on smoking habits, will be conducted. Together, the above two investigations are the only prospective efforts encompassing plutonium-exposed workers that have been or are being conducted anywhere in the world.

Mortality analyses of the entire cohort of Los Alamos workers is dependent upon the transformation of personnel data into machine readable form. Because of the size of the Los Alamos cohort and the number of plutonium-exposed individuals, follow-up analyses of these workers are of considerable interest. Because of the condition of personnel data and the effort required to transform them into a form suitable for analysis, it will be 1983 before such analyses can be completed.

Detailed incidence studies will begin shortly, assuming that OMB approval of the survey instrument is obtained. Locating respondents and conducting interviews will require several years before meaningful analyses can be completed.

All of the above studies are designed to provide information on the incidence of disease and the mortality experience among plutonium workers. The data base will also contain considerable information on external radiation exposures at low doses and dose rates. In many cases, these exposures may include a significant neutron component. Although these exposures are a complex mixture, it is intended that the analyses shall include a study of interaction between internal and external exposures. The combined effect may influence health outcomes among this interesting set of radiation-exposed individuals. This study should be applicable to several low dose radiation questions.

An ancillary benefit of the overall study effort will be the assembly of records for a sizeable group of workers followed over a long period with what we intend to be a high follow-up rate. These records of work histories, smoking histories, medical information, and verified death records should constitute a unique resource to address other possible health questions, particularly as they relate to occupational exposures.

#### PUBLICATIONS

1. "Studies on Persons Exposed to Plutonium," G. L. Voelz, J. H. Stebbings, Jr., L. H. Hempelmann, L. K. Haxton, and D. A. York, p. 353 in Late Biological Effects of Ionizing Radiation, Vol. 1, ST1/Pub/489, (International Atomic Energy Agency, Vienna, 1978).
2. "A 32-year Medical Follow-up of Plutonium of Manhattan Project Plutonium Workers," G. L. Voelz, L. H. Hempelmann, J.N.P. Lawrence, and W. D. Moss, Health Physics, 37, 445, 1979.
3. "Studies on Health Risks to Persons Exposed to Plutonium," G. L. Voelz, J. H. Stebbings, Jr., J. W. Healy, and L. H. Hempelmann, p. 419 in The Medical Basis for Radiation Accident Preparedness, Eds., K. F. Hubner and S. A. Fry (Elsevier North Holland, Inc., New York, 1980).
4. "An Update of Epidemiologic Studies of Plutonium Workers," G. L. Voelz, G. S. Wilkinson, J. Acquavella, G. Tietjen, R. Brackbill, M. Reyes, and L. Wiggs, Proceedings of the Symposium on the Radiobiology of Radium and the Actinides in Man, Lake Geneva, Wisconsin, October 12-16, 1981 (to be published in Health Physics).

5. "Evaluation of Social Security Follow-up of Some Southwestern Populations," M. Reyes, J. H. Stebbings, Jr, and G. L. Voelz (to be published in JOM, March 1982).
6. "Morbidity and Mortality in Los Alamos County, New Mexico, 1. Methodological Issues and Preliminary Results," J. H. Stebbings, Jr., and G. L. Voelz, Environmental Research, 25, 86, 1981.
7. "A Study of Malignant Melanoma Incidence at the Los Alamos National Laboratory," J. F. Acquavella, G. L. Tietjen, G. S. Wilkinson, C. R. Key, and G. L. Voelz, (accepted by Lancet for publication).
8. "Plutonium in Autopsy Tissue: A Revision and Updating of Data Reported in LA-4875," J. F. McInroy, E. E. Campbell, W. D. Moss, G. L. Tietjen, B. C. Eutsler, and H. A. Boyd, Health Physics 37, 1, 1979.
9. "Statistical Analysis of a Los Alamos Scientific Laboratory Study of Plutonium in U.S. Autopsy Tissue", T. Fox, G. L. Tietjen, and J. F. McInroy, Health Physics, 39, 877, 1980.
10. "Deposition and Retention of Plutonium in the United States General Population," J. F. McInroy, H. A. Boyd, and B. C. Eutsler, page 161 in Actinides in Man and Animals, Ed., M. E. Wrenn (RD Press, Salt Lake City, Utah, 1981).
11. "Determination of Americium and Plutonium in Autopsy Tissue: Methods and Problems," H. A. Boyd, B. C. Eutsler, and J. F. McInroy, p. 43 in Actinides in Man and Animals, Ed., M. E. Wrenn (RD Press, Salt Lake City, Utah, 1981).
12. "Correlation Between a Subject's Body Burden of Plutonium and Uranium and the Subject's History of Exposure 30 Years Before," J. F. McInroy, C. J. Maletskos, D. C. Bogen, N. Cohen, and R. A. Wessman, Proceedings of the Symposium on the Radiobiology of Radium and the Actinides in Man, Lake Geneva, Wisconsin, October 12-16, 1981 (to be published in Health Physics).
13. "The U.S. Transuranium Registry Report on the  $^{241}\text{Am}$  Content of Whole Body, Part III. Preparation and Analyses of the Tissue Samples," J. F. McInroy, H. A. Boyd, B. C. Eutsler, R. Manning, and D. Romero, Proceedings of the Symposium on the Radiobiology of Radium and the Actinides in Man, Lake Geneva, Wisconsin, October 12-16, 1981 (to be published in Health Physics).
14. "Concentration of  $^{239-240}\text{Pu}$  in Human Tissue, (I) Preliminary Report of a Comparative Study on Different Populations," H. Kawamura, G. Tanaka, J. F. McInroy, and B. C. Eutsler, (to be published in Journal of Radiation Research, Tokyo).
15. "Plutonium Concentrations in Tissues of Occupationally Exposed Nuclear Workers," J. F. McInroy, H. A. Boyd, B. C. Eutsler, B. C. Moss, (to be published in Health Physics).

PAPERS IN REVIEW OR IN PREPARATION

1. "Cancer Mortality Among Plutonium and Other Nuclear Workers," G. S. Wilkinson, J. F. Acquavella, M. Reyes, R. Brackbill, G. L. Tietjen, L. Wiggs and G. L. Voelz, LAUR-81-3593 (abstract).
2. "History of Epidemiologic Studies of Persons Exposed To Ionizing Radiation," G. L. Voelz, LAUR-82-393 (Abstract).
3. "Autopsy-Based Studies of Plutonium and Other Nuclide Concentrations in Human Tissue," J. F. McInroy, LAUR-82-392 (Abstract).
4. "Mortality Among Plutonium and Other Radiation Workers," G. S. Wilkinson, G. L. Voelz, R. M. Brackbill, J. F. Acquavella, M. Reyes, G. Tietjen and L. Wiggs, LAUR-82-413 (Abstract).
5. "A Study of Malignant Melanoma Among Employees at the Los Alamos National Laboratory," J. F. Acquavella, G. S. Wilkinson, G. L. Tietjen, C. r. Key and G. L. Voelz, LAUR-82-412 (Abstract).
6. "A Comparison of County Cancer Mortality Rates in the Region Surrounding the Pantex Plant Nuclear Weapons Facility," L. A. Wiggs, G. S. Wilkinson, G. L. Tietjen, LAUR-82-411 (Abstract).
7. "Quality Control Activities In Support of the Plutonium Workers Study I. Assessment of Coding Consistency for Personal Data Collected at Rocky Flats and Mound," M. Reyes and G. S. Wilkinson, (in review).
8. "A Melanoma Case-Control Study at the Los Alamos National Laboratory," J. F. Acquavella, G. S. Wilkinson, G. L. Tietjen, C. R. Key and G. L. Voelz (in review).
9. "A Quantitative Consideration of Employees Lost-To-Followup In An Occupational Mortality Analysis," J. F. Acquavella, G. L. Tietjen and G. S. Wilkinson (in review).
10. "A Case-Control Study of Intracranial Tumors Among A Cohort of Nuclear Workers," M. Reyes, G. S. Wilkinson, G. L. Tietjen, R. Brackbill, and G. L. Voelz (in preparation).