UNITED STATES TRANSURANIUM REGISTRY REPORT JULY 1, 1974 TO OCTOBER 1, 1975 TO THE ERDA DIVISION OF BIOMEDICAL AND ENVIRONMENTAL RESEARCH

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HANFORD ENVIRONMENTAL HEALTH FOUNDATION

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UNITED STATES TRANSURANIUM REGISTRY SUMMARY REPORT JULY 1, 1974 TO OCTOBER 1, 1975 TO ERDA DIVISION OF BIOMEDICAL AND ENVIRONMENTAL RESEARCH

by

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U. S. TRANSURANIUM REGISTRY (USTR)

INTRODUCTION

This report covers activities of the USTR for the period July 1, 1974 to October 1, 1975.

PURPOSE AND SCOPE OF REGISTRY

As indicated in the original Schedule 189, Request for Operating Costs, the primary purpose of the Registry is to protect the interests of workers, employers and the public by serving as a national focal point for the acquisition and provision of the latest and most precise information about the effects of the transuranic elements on man. This is being done by (a) Establishing the population at risk. To date some 9063 transuranium workers have been so identified. (b) Accumulation at the local projects, on a continuing basis, of the best current estimates of the amount and location of any internal deposition of any of the transuranium elements in employees and improving these determinations by reconciliation with actual burdens found in various organs at autopsy or by alternate methods and (c) Following such employees clinically and by epidemiological methods to determine whether there may be any adverse effects of such deposits on health or longevity.

REGISTRY MANAGEMENT

At the Registry Director's request, efforts have been made to secure a younger physician to direct the Registry activities. Dr. B. D. Breitenstein, Occupational Physician for the Hanford Environmental Health Foundation is working part-time with the U. S. Transuranium Registry (USTR) and is expected to take over the direction of the Registry during the first half of 1976.

The Los Alamos Scientific Laboratory was asked by the Division of Biomedical and Environmental Research (DBER) to submit a plan for the epidemiological portion of the Registry program and to coordinate this study under the aegis of the Registry. Battelle Northwest (BNW) was asked by the Registry to work closely with the Registry, especially in the field of biology, so that animal findings might be rapidly correlated with the human studies. Dr. Roy C. Thompson agreed to direct this liaison.

ADVISORY COMMITTEE MEETING

The Advisory Committee to the USTR met in Richland October 3 and 4, 1974, and the minutes covering this meeting are attached as Appendix A.

EPIDEMIOLOGICAL STUDY DESIGN

A proposed design for an epidemiological study was made. This suggested the method to identify transuranium workers at risk and to compare health, longevity and cause of death of these with controls. The study design is shown as Appendix B. Copies were sent to DBER, key Registry participants and the Registry Advisory Committee for comments and discussion.

EDUCATIONAL ACTIVITIES

(1) Publications by members of the Registry staff. These data are presented in Appendix C.

(2) Information supplied on request to Energy Research and Development Administration or to news media, radio, television and service clubs. Requests varied from simple informal telephone queries about some of the Registry activities to more complex formal requests such as one from the Committee of the Governor of Colorado, appointed to investigate the health and safety aspects of the Rocky Flats Plant. All were answered with care, often after receiving appropriate assistance from ERDA. The nature of these inquiries and answers is indicated below.

(a) Telephone queries and interview with newspaper reporter.

The Registry Director answered telephone queries from Robert E. Gillette, who was preparing articles for Science magazine on the occupational health and safety aspects of the atomic energy program. He asked for detailed information about the USTR and for reprints describing Registry operations. By request, he indicated he would read back to the Director what he wrote before it was published so necessary changes could be made, but this was not done. The articles appeared in Science September 20 and 27, 1974.

USTR activities were discussed in response to a phone call from D. Glickstein, Delaware newspaper writer, who was writing about the du Pont occupational health program.

A telephone call was received from Ms. Barbara Newman of National

Public Radio, Washington, D. C., January 24, 1975, asking for information about the Registry. She was told about the Registry in general nontechnical terms.

Telephone questions from Mr. Richard Langley, Canadian Broadcasting Company, concerning the USTR Director's opinion of the adequacy of methods to protect the public and plutonium workers from hazards of Pu, were answered.

Telephone queries concerning the general purpose and operation of the Registry by Don Wolf of Straight Creek Journal, Denver, were answered.

A talk was prepared and presented to Richland Rotary on Health Protection of Radiation Workers and the Public.

An interview by a Tri-City Herald science writer with the Registry Director resulted in articles in this local newspaper on April 5 and 6, covering Registry activities.

(b) More formal requests for technical information re Registry activities included:

A 200-word summary report to ERDA of the FY 1975 Registry activities. (Appendix D).

A letter from the committee of the Governor of Colorado, appointed to investigate the health and safety aspects of the Rocky Flats plant, asked for specific data on Rocky Flats autopsy cases. The request cited the new law covering "freedom of information." Dr. Marks of DBER-ERDA gave suggestions for answer which was sent indicating that the Registry would send its last annual report (June 1974) and that Rocky Flats had been requested to supply information in answer to specific detailed information requested and that Dr. Mancuso had been requested to send copies of his more recent reports of the AEC Health and Mortality Study.

Mr. Fred Leitz, Westinghouse Hanford, who was preparing data for discussion concerning proposed Washington State law requiring a moratorium on atomic power, was given information and was provided with copies of the Hempelmann* study and Health Physics article (see Appendix C) re Transuranium Registry.

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*L. H. Hempelmann, 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 25:461-479, 1973.

A call from Bruce Hutchins and Michael Kimball, General Electric, Sunnyvale, concerning their efforts to write an article on Pu toxicity was received. The USTR 1974 Annual Report was sent and they were later given a copy of the paper entitled "Health of Hanford Pu Workers" (Appendix C).

A telephone call was received from Mr. W. D. Craig, General Electric Company, Fast Breeder Reactor Department, Sunnyvale, California, requesting information on Pu toxicity. He was to testify in a Congressional investigation (McCormack et al.). He was also supplied a copy of the 1974 Registry Annual Report.

Mr. Kenneth Baker, ERDA Operational Safety, called asking if the Registry could supply information on how many people were at risk in Pu work today among contractors and licensees. He was advised the Registry has complete information only on number of contractor employees with positive deposition. This has been supplied to ERDA (Dr. Marks). He was further advised that there were $\sim$ 4000 with evidence of some Pu deposition divided about equally among those currently employed and those separated. Asked for an estimate as to number of licensee workers at risk to Pu exposures, he was told a few hundred. The question was asked at a Congressional investigation in progress at that time.

Seven Registry cases were discussed with Dr. Marks to assist him in answering queries of the U. S. Environmental Protection Agency re Pu effects.

A call from R. Alexander, ERDA Regulatory Division requested confirmation of the Registry findings that the calculated systemic deposition was .8 to 7 times the autopsy findings in cases to date with 5% or more of maximum permissible systemic burden. He heard the Registry Director's paper at Houston and wished to reconfirm the data before making recommendations regarding Pu standards for ERDA programs.

At the request of Mr. A. G. Fremling, Manager, ERDA Richland Operations Office, he and three of his staff were given a briefing on USTR activities by Dr. W. D. Norwood, Registry Director and Dr. P. A. Fuqua, Medical Director of the Hanford Environmental Health Foundation.

EXCHANGE OF INFORMATION WITH BRITISH
RE THEIR AUTOPSIES AND OUR REGISTRY PROGRAM

Following a request for more data on 10 autopsies on Windscale Plant plutonium deposition cases reported by Dr. G. B. Schofield,* there has been considerable exchange of information. Dr. Schofield and Mr. Ward (also from Windscale) visited to learn about the Registry program, the methods of record keeping and the Hanford work on the Health and Mortality Study. Dr. G. W. Dolphin and Dr. Stewart Rae of the National Radiation Protection Board, England, have been given further information on Registry autopsy cases discussed in Health Physics (Appendix C). They have supplied the Registry with information on 14 autopsies on British plutonium deposition cases. They plan to have a British registry of plutonium deposition cases. Mr. Peter Smith, epidemiologist on Dr. Schofield's staff will visit the Registry in November, 1975. The British trade unions are particularly concerned about the possible relationship of Pu deposition with leukemia in Windscale Pu workers since there was one case with leukemia and another with myeloproliferative disease.

U. S. TRANSURANIUM REGISTRY STATISTICS

From Table 1 it may be seen that a total of 53 autopsies have been reported and 38 of these have had a complete workup as of this date.**

LOS ALAMOS

The major change noted is in numbers of transuranium workers identified at Los Alamos where there was an increase from 259 to 3024. This was due to clarification of the definition of a transuranium worker. The number is expected to be considerably higher, when present studies to carefully scrutinize questionable cases are completed.

Los Alamos reported on the present health status of some 25 employees most heavily exposed to Pu during the early operating days. None have developed malignant disease. A further study of present health, mortality

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*Schofield, G. B. and Dolphin, G. W.: U. K. Experience on the Medical Aspects of Radiological Protection of Workers Handling Plutonium, Ann. Occup. Hyg. Vol. 17, pp. 73 - 83, Pergamon Press, 1974.

**The number of completed autopsies is now 42.

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Table 1

U. S. TRANSURANIUM REGISTRY STATISTICS

1975

	Transuranium Workers Identified			Health Physics and Medical Releases			Authority For Autopsy			Autopsies Obtained			Autopsy Reports Complete		
	Mo. Sep	CY to Date	Total to Date	Mo. Sep	CY to Date	Total to Date	Mo. Sep	CY to Date	Total to Date	Mo. Sep	CY to Date	Total to Date	Mo. Sep	CY to Date	Total to Date
Hanford	2	37	2367	2	37	2174	0	8	533	0	0	14	0	0	8
Rocky Flats	0	40	1772	0	40	1611	0	6	173	1	4	34	0	0	28
Los Alamos	0	2765	3024	0	0	257	0	0	127	0	2	3	0	0	0
Savannah River	0	8	1567	0	0	0	0	0	0	0	0	0	0	0	0
Mound	0	0	333	3	4	8	3	4	9	0	0	1	0	0	1
Oak Ridge	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	2	2850	9063	5	81	4050	3	18	842	1	6	53	0	0	38

and cause of death of some 250 employees at Los Alamos with the largest estimated depositions of plutonium is in progress.

HANFORD

A study of present health, mortality and cause of death of 452 plutonium deposition cases was reported and this report is attached as Appendix E. Identification of Pu workers hired before 1957 and not presently employed is under way.

Arrangements were made with Battelle Northwest to use frozen autopsy specimens instead of formalin treated ones for Hanford autopsy cases.

Arrangements were made with Battelle Northwest that on request uranium analyses as well as Pu will be done on Hanford autopsy specimens when deceased had exposure to both.

Blood and urine were assayed for Pu content on 24 of the Hanford employees who have highest depositions of Pu and efforts made to determine trends. None were found due to difficulties in knowledge re time of deposition, and particle size and chemical composition of the plutonium.

SAVANNAH RIVER

Messrs. B. Rusche, Manager of Environmental Controls and P. Walke, health physicist visited the Registry as part of their program to reassess their position relative to more complete participation in the Registry program.

Dr. Poda has indicated on August 12, 1975 that this plant would completely participate in the Registry program. He indicated also that he and Dr. Sidney Pell, biostatistician, will be available to assist on the epidemiological study.

OAK RIDGE

Dr. J. A. Auxier, Director of the health physics program at Oak Ridge was a USTR visitor this year and indicated that he would see that presently employed and terminated transuranium workers were identified so that information already given to the Health and Mortality Study may be utilized by the Registry.

ROCKY FLATS

This plant was visited shortly before the change of contractors was made and we received assurance from the Deputy Director of Rockwell International, the new operators, that they will give whole-hearted support to the Registry program. Before leaving employment at Rocky Flats Dr. Hylton secured agreement for a willed body of an employee who has an estimated systemic burden of about 26 nCi and about 10 nCi lung burden of plutonium. This will allow bioassay of the total skeleton at time of autopsy.

MOUND LABORATORY

Mound remains the only major laboratory, with depositions of plutonium comparable with those at Hanford, Rocky Flats and Los Alamos, that is not completely participating in the Registry. They have indicated that they will continue to assess the situation and it is hoped that they will join the others in complete participation.

ARGONNE NATIONAL LABORATORY

Argonne is working to try to identify transuranium workers who have worked at Argonne and also those who worked at the Metallurgical Laboratory in the very early days.

Rowland and Durbin reported findings on survival, cause of death and estimated tissue doses in a group of humans who were critically ill and were injected with ^{238}Pu in 1945, 1946 and 1947. Half of the bony skeleton of one case is being examined for ^{238}Pu deposition. The Registry has advised Dr. Rowland of the bones which are of particular interest to the Registry.

LICENSEE PARTICIPATION

Exxon

Exxon (Richland) signed a letter of agreement indicating complete participation in the Registry program and supplied a list of transuranium workers whom they have identified.

Nuclear Fuel Services, Inc. (NFS)

NFS was visited and gave approval for participation of their New York and Tennessee plants. However they wish Registry people to interview their workers at a time when they are not scheduled for work, which will be very difficult to do.

Nuclear Materials and Equipment Corp. (NUMEC)

NUMEC was visited and will participate in the Registry program. They also asked that workers be interviewed by Registry representatives.

Kerr-McGee

Telephone conversations requesting an interview have been held but they requested further time to study the matter before granting a personal interview.

REGULATORY STANDARDS ENDORSEMENT OF USTR

On a four-day trip to the East Coast, Dr. Norwood and Carlos Newton visited Dr. S. Marks and Dr. Jerry Davis. Dr. Davis will endeavor to secure approval for a letter from Regulatory Standards to licensees soliciting their voluntary cooperation with the USTR.

USTR has solicited similar endorsement by Nuclear Energy Liability Property Insurance Association of the Registry and encouragement of insured licensees to cooperate with the Registry as an aid in reducing liability costs arising out of claims of adverse effects due to work exposures to transuranium elements.

DATA COLLECTION AT Pu INHALATION INCIDENT

A meeting was held with members of BNW Departments of Occupational and Environmental Safety and Biology to discuss optimum procedures to follow at time of plutonium inhalation accidents.

SEPARATION OF BONE MARROW FROM BONE

The possibility of leukemia or other blood dyscrasias must be considered in Pu deposition cases. Information concerning methodology was secured from Dr. A. H. Beddoe of England and discussed with Dr. J. F. Park of Battelle Northwest Biology Department. Iral Nelson and Roy Thompson, also of BNW, were sent copies of an article from Health Physics indicating a simple method for separating bone marrow from bone. Appropriate bone will be collected at Hanford autopsies. BNW is to try the proposed methods to separate bone marrow from bone in pigs.

REGISTRY INFORMATION COLLECTION AND TABULATION

An automated system of collection and tabulation is being developed by Boeing, successors to Computer Sciences at Hanford, to assemble data and print periodic reports as an aid in determining whether work with transuranium elements is detrimental to the health of transuranium workers.

DENVER WORKSHOP

A workshop was held in Denver on February 27, 1975, mainly to discuss importance and methodology to be used in executing an epidemiological study of health, mortality and cause of death of transuranium workers. Los Alamos Scientific Laboratory was asked to submit a proposal and to coordinate the execution of such a study. After the details of the protocol are worked out, Dr. George Hutchinson, epidemiologist at Harvard, will be asked for critical comments. This study will operate under the aegis of the Registry.

The need for assessing, defining and where possible increasing the degree of uniformity among major ERDA contractors in the collection, processing and analyses of health physics data was acknowledged. Since significant deviations or interpretations will have a serious adverse effect on proposed or ongoing epidemiological studies, Associate Director C. E. Newton was assigned the responsibility of selecting a panel of contractor health physicists to give attention to this matter.

The minutes of this workshop are attached as Appendix F. They also indicate by Attachment I the estimate, as of February 1975, of the number of current and separated employees, by installation, with positive deposition of transuranium elements.

SUN VALLEY WORKSHOP ON THE BIOLOGICAL EFFECTS AND TOXICITY OF ^{239}Pu AND ^{226}Ra

Numerous papers were presented and in-depth discussions were held concerning ^{239}Pu and ^{226}Ra biology and toxicity. The Registry Director presented a paper entitled "Health of Hanford Plutonium Workers." An abstract of this paper follows, while the complete paper is attached as Appendix E.

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APPENDICES

Appendix A - Minutes of Meeting of Advisory Committee

Appendix B - Epidemiological Study Design

Appendix C - Publications by Members of the Registry Staff

Appendix D - Short Summary of Registry Activities in 1975 to ERDA

Appendix E - Health of Hanford Plutonium Workers

Appendix F - Minutes of Denver Workshop

Appendix G - Detailed Information on Registry Autopsy Cases

U. S. TRANSURANIUM REGISTRY

FOURTH ADVISORY COMMITTEE MEETING

The U. S. Transuranium Registry's Advisory Committee met on Thursday and Friday, October 3 and 4, 1974, in the Hanford Environmental Health Foundation's Conference Room at the Kadlec Medical-Dental Building, Richland, Washington.

MEMBERS PRESENT	R. D. Evans L. H. Hempelmann C. C. Lushbaugh H. M. Parker E. A. Putzier J. H. Sterner, Chairman	
MEMBERS ABSENT	T. F. Mancuso	
OTHER ATTENDEES	P. F. Dunigan P. A. Fuqua S. Marks C. E. Newton W. D. Norwood	AEC-RL HEHF AEC-HQ (DEBR) BNW USTR Acting Director

MINUTES — The minutes of the Third Advisory Committee Meeting were not read.

PROCEEDINGS

POPULATION AT RISK — The revised definition of a TU (transuranium) worker was reviewed. It was agreed (1) that a worker meeting only one of criteria included in the definitions should be classified as a TU worker; (2) that a worker once classified a TU worker should always be classified a TU worker.

The inclusion of nanocurie units rather than microcurie units in the criteria for TU worker classification was questioned since the exclusive use of microcurie units for body depositions had been previously advised and accepted by the committee as preferable to help insure avoiding error. Although there was not unanimous agreement, the consensus was that units used, should generally be such that a huge number of zeroes preceding the decimal are not needed and that body burdens presently should preferably be stated in terms of nanocuries.

The question was raised as to whether or not non-AEC contractor or licensee employees can be included in the USTR. Examples of important cases that should be included such as a parcel handler who spilled Pu from a carboy on his skin, were cited. It was agreed that (1) the USTR should be free to include justified cases (2) that the TU worker definition should allow for inclusion of such cases in the USTR (3) that the USTR should go to the employer of TU workers to include the worker as a registrant (4) that the USTR should accept no self referrals without the consent of the employer if still

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Population at Risk (continued)

in business (5) that in the accident case when there is a question about who the responsible contact is, it should be resolved with whoever owned the plutonium (6) that the USTR should handle licensee cases on an ad hoc basis and (7) that the USTR Acting Director should develop words to cover the medical legal aspects of cases that are not covered as licensees or contractor.

AEC CONTRACTOR PARTICIPATION

AEC contractor participation in the USTR was reviewed by the USTR Acting Director as stated in the USTR Summary Report to June 30, 1974 to USAEC Division of Biomedical and Environmental Research. The following was noted that three of the four projects having the greatest potential exposure are completely cooperating. Those are Hanford, Los Alamos, and Rocky Flats. Monsanto-Mound Laboratory is cooperating in a limited manner.

HANFORD - All contractors are completely cooperating. Because of the automated AEC Health and Mortality Study, much data is available on the control populations (workers not exposed to transuranium work) which has to be collected at the other installations.

ROCKY FLATS - The greatest number of autopsies have been secured. Permission for a willed whole body has also been obtained.

LOS ALAMOS - Some confusion in the past, regarding a basic definition of a transuranium worker, has resulted in only 259 workers being so identified. Jim Lawrence is presently working to identify past and present transuranium workers. Some estimates of systemic Pu deposition based on early urinalysis, are being revised downward as a result of recent autopsy findings. Zia Corporation employees who are past and present transuranium workers, are being so classified and efforts made to secure the participation of Zia in Registry activities. Studies are under way to determine good control groups to compare with the transuranium worker group as to longevity and causes of death.

MONSANTO (MOUND) - No autopsies have been secured by Mound. This seems to indicate that securing autopsies only after death of employees is not very effective. About 25% of the higher deposition cases are at Mound. Updated lists giving names, social security numbers, lung burden and systemic burden estimates have been recently supplied.

SAVANNAH RIVER (duPont) - Savannah River will not permit request for autopsy of either active or separated employees, during the lifetime of the employees and to date no autopsies have been secured. The medical superintendent gets reports of deaths of transuranium workers and may request autopsy. He has sent us 272 summary medical histories and examination findings and we have received social security numbers only on 1,559 workers identified by positive urine and potential exposure history as transuranium workers.

OAK RIDGE - Only transuranium workers estimated to have greater than 10 nCi of plutonium (or 25% of a permissible

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AEC Contractor Participation (continued)

limit for the deposited transuranium isotope) will be identified for the Registry. Workers may not be asked to participate in the Registry activities, though the medical director may request an autopsy following death. However, we may use any of the material collected by the AEC Health and Mortality Study. Oak Ridge National Laboratory is presently identifying transuranium workers for us.

It was concluded that (1) minor inaccuracies in the USTR statistics table should be corrected and (2) cases not now included in the USTR case log should be included. These cases include 70 cases at Los Alamos and other autopsy cases at Hanford performed prior to the organization of the USTR.

The question of how to secure better cooperation of AEC contractors with the USTR was discussed. It was agreed that AEC contractor medical directors and health physicists should become more actively involved. Dr. Sterner suggested that a follow-up meeting with medical and/or health physics representatives is needed and there was general committee agreement. There was not agreement as to the value of recent Science articles on "Plutonium (I): Questions of Health in a New Industry" and Plutonium (II): Watching and Waiting for Adverse Effects." There was not agreement on the desirability for AEC-DEBR and military personnel actions to effect improved contractor-USTR cooperation.

LICENSEE PARTICIPATION IN USTR

How to contact licensees regarding USTR participation was discussed. It was stated that insurance carriers have been interested in licensee-USTR participation and that AEC should participate in informing licensees about USTR operations. Dr. Marks agreed that he would determine the right person in AEC Regulatory for USTR contact. It was noted that Kerr-McGee may have several hundred employees, many of whom are at risk. Dr. Marks asked if the population at risk could be better estimated. It was stated that the 17,000 estimate included future projection. Dr. Norwood was asked by the Chairman, Dr. Sterner, to develop more accurate population at risk figures for both AEC contractor and licensee employees.

FOLLOW-UP OF SEPARATED AND RETIRED AEC CONTRACTOR AND LICENSEE TU WORKERS

Dr. Marks stated that the USTR should develop a better follow-up program of separated employees with depositions. This would include medical and health physics data. The need to indicate USTR interest in the follow-up of the TU worker was emphasized and stated to be an obligation. Disagreement of this policy was voiced on the basis that (1) this policy has not been carried out by industry in the past, (2) health physics urine assay follow-up has not been found to be practical, (3) there is no present evidence of adverse health effects at permissible levels and (4) all types of cancer cases might be encouraged to infer a radiation cause effect without justifiable scientific support, and initiate legal action.

Dr. Hempelmann was asked to discuss his follow-up on a group of about 250 Los Alamos deposition cases. About 90 cases are still in Los Alamos. He knew all of 26 early cases personally

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Follow Up of Separated and Retired AEC Contractor and Licensee TU Workers (continued)	and 22 out of 26 returned for follow up examination. Dr. Marks stated there is a need to look at examination results and that detailed follow up of some 26 significant deposition cases has done the industry a great deal of good. The practability of limiting TU worker follow up to death certificate data and/or diagnoses was described by Dr. Norwood. C. W. Kirklin (HEHF) was called to come in and further explain to the committee the procedure used by the AEC Health and Mortality Study and the Registry in procuring death certificate information. Dr. Hempelmann stated that death certificate data is fine, if one is looking for leukemia or other diseases with a relatively short life expectancy, but they will not pick up, soon enough, thyroid cancer for example where death may be long delayed. The consensus was that follow up of separated employees should have attention by USTR on all cases with depositions above 10 nanocuries and, random selection follow up for those below this level.
USTR RELATIONSHIPS	Present and anticiapted USTR relationships with the AEC Health and Mortality Study and Battelle Northwest were discussed. There was particular emphasis placed on the value of the complementary nature of the AEC Health and Mortality Study and the USTR and on the increasing broader scope of Battelle scientific interest in USTR operation.
USTR SUMMARY REPORT TO JUNE 30, 1974 TO USAEC DIVISION OF BIOMEDICAL AND ENVIRONMENTAL RESEARCH	Comments were requested on this report. Dr. Marks stated that the report was excellent but that subsequent reports should include greater use of statistician. Tables and forms included in the report were discussed and modifications were recommended for subsequent reports. Cancers found in registrants were discussed. The importance of obtaining more adequate full cross section bone samples was emphasized, also the need for whole bodies for accurate determination of skeletal distribution. It was suggested that more adequate skin samples are best procured from the abdomen rather than from the axilla. The family history should include ethnic background, country of birth of father, mother and grandparents and race. Payments made for autopsies was discussed and concern was expressed for no designation of escrow funds for commitments already made. Copies of the contract forms for autopsies and registrant wallet cards were shown to the committee.
FUTURE OBJECTIVES OF THE USTR	Anticipated bone marrow and autoradiographic studies were described and technical difficulties discussed. The desirability of concurrent USTR bioassay of other isotopes than plutonium to which TU workers are exposed such as uranium and polonium was described. Dr. Marks indicated that he favors this approach and that a proposal should be developed to add other isotope assays to present USTR bioassay procedures. The committee advised go ahead on uranium assay in conjunction with plutonium assay for workers who have been at risk to both uranium and transuranium elements.

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The question was raised as to whether there is cross placental transfer of plutonium in humans. It was suggested that USTR should get data if TU workers get pregnant and have abortions, that products of abortions should be obtained for measurements. A question was raised as to the existence of federal legislation to prevent research on the uterus and contents. It was concluded that AEC contractor Medical Directors should discuss this suggestion. Blood assay results were discussed and it was stated that there should be controls made up of non-TU workers.

FUTURE USTR RELATIONSHIPS

Battelle scientific interest in USTR operations was expanded particularly relating to the Biology Operations plutonium toxicity research.

USTR STUDY DESIGN

Ray Buschbom, Battelle Northwest, was called in to discuss USTR study design. He stated that health, mortality and causes of death of the group at risk are to be compared with non-occupationally exposed groups to determine if there are adverse effects due to occupational exposure to the transuranium elements. TU workers will also be divided into subgroups according to the estimated deposition if autopsy is not obtained and according to autopsy determined deposition if autopsy is obtained. The experience of these subgroups with respect to health, mortality and cause of death may be compared with each other. Also it may be possible to relate the results quantitatively to the degree of deposition. The "A" TU worker autopsy group, the "B" identified TU worker (not autopsied) group and the "C" control groups were described.

Questions were raised regarding (1) control group selection and biases (2) why the 60 autopsies which Los Alamos has from the general population might not be a good control group (3) use of autopsy results (4) statistical treatment of USTR data not epidemiology related and (5) limitation of autopsy sample assays to two or three laboratories. It was stated that due to the present status of the art which is improving, the present use of the number of laboratories participating is a healthy condition.

The importance of following separated workers was further discussed. It was suggested that USTR look into the experience of steel worker follow-up which appears to have been successful. Discussion continued on how body deposition varies over a period of time, the problem being to evaluate what the body burden is or will be and where the depositions are located in the body. Discontent was expressed with the whole problem of expressing body burdens in percent of maximum permissible. The desirability to report body burdens in nanocuries in place of percent of body burden was repeated.

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DESIRABLE DATA TO BE OBTAINED AT PLUTONIUM INHALATION INCIDENTS

Ken Heid, BNW, was called in to discuss the desirable determinations to be made at the time of accidental inhalation of plutonium or other transuranium elements. Improvements in the accuracy of estimated cumulative organ dose, were related to particle collection, particle size, chemical composition, physical composition, particle solubility, in particular, in addition to the more common urine and fecal assays, lung counts, Am/Pu ratios, nasal and skin smears and blood samples. Confidence levels of determinations were discussed. It was stated that nasal smears may be underrated by many people, that 60 case comparisons showed that the nasal smears give initial lung burdens within a factor of five. It was further stated that models are not much better than nasal smears for estimating depositions but that they are the best guess that knowledgeable people have been able to make. Mr. Parker suggested a present rough rule of thumb for pulmonary lavage in Plutonium Industrial Hygiene, Health Physics and Related Aspects, quoted exactly as follows: "Lung lavage for a person over age 50 may well be a poor tradeoff of competing risks. For a person age 20 to 30 after one week for thorough investigation of the deposit, lung lavage for 50 times the MPLB would appear to be a good risk. Others might make this determination at 10 x MPLB." The mortality rate for this procedure is generally that for general anesthesia.

The question was raised as to how to improve better handling of licensee accident cases. It was the consensus that (1) not much could be done at this time with licensees since most licensees are not cooperating with the USTR and (2) that it would be desirable to carry out the discussed additional procedures as indicated in AEC contractor accident cases and that AEC Regulatory personnel should be contacted at the highest levels in order to help effect carrying out these determinations.

USTR DATA PROCESSING PROGRAM

C. W. Kirklin (HEHF) was called in to discuss planning for USTR data collection for automatic data processing systems design. An exhibit was presented to those present illustrating the discussion which included the following: (1) master file (2) death data (3) TU worker work history form (4) TU worker medical history form (includes occupational history) (5) TU worker medical summary forms (6) deposition data (7) internal exposure data (8) external exposure data and (9) autopsy data. Numerous questions from the committee concerning the collection and recording of USTR data were answered. (Copies of this exhibit are to be sent to L. H. Hempelmann and E. A. Putzier.)

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USTR PERSONNEL	The need for planning for the expanded use of statistical personnel was emphasized by Dr. Marks. Procurement of a replacement USTR Director is in process.
USTR BUDGET	It was the consensus that USTR programs and budget should be equated and projected with planned advance reactor programs as they relate to plutonium containing fuels or other transuranium elements.
ADJOURNMENT	Prior to adjournment at 12 Noon, October 4th, appreciations were expressed to Advisory Committee Members for their time, diligent help, support and most valuable advice related to USTR Operations. No definite time was set for the next USTR Advisory Committee meeting.

PAF:jl
11-7-74

DRAFT
8-20-74
WDN:dO

U. S. TRANSURANIUM REGISTRY
STUDY DESIGN

The group to be studied are transuranium workers in AEC contractor and licensee plants. The transuranium worker is defined in Appendix A. Health, mortality and causes of death of the group at risk are compared with non-occupationally exposed groups to determine whether or not there are adverse effects due to occupational exposure to the transuranium elements. Transuranium workers will also be subdivided into subgroups, according to the estimated deposition if autopsy is not obtained and according to autopsy determined deposition, if autopsy is obtained. The experience of these subgroups with respect to health, mortality and causes of death may be compared with each other. Also it may be possible to relate the results quantitatively to the degree of deposition.

"A" TRANSURANIUM WORKER AUTOPSY GROUP

The transuranium (TU) worker group, present and future, who are autopsied are categorized as follows:

(1) Registry number

(2) Social security number

(3) Sex

(4) Race

(5) Date of birth

(6) Date of death

(7) Cause of death

(8) Serious medical conditions during life

(9) Environmental exposures other than radiation

(10) Accumulated external radiation dose at work

(11) Years of potential exposure to TU elements at work (elapsed years between employment on TU element work and leaving TU element work)

(12) Years of actual deposition of TU elements (elapsed years between deposition and death). Dates and estimated depositions at times

of known accidental deposition to be recorded.

(13) TU radioisotopes exposed to at work

(14) Non-TU radioisotopes exposed to at work

(15) Type of TU exposure

(a) Acute or chronic

(b) Via inhalation or wound

(16) Nature of inhaled or injected TU particles - size, shape, chemical composition, solubility

(17) Estimated deposition TU elements during life

(a) Systemic

(b) Lung

(c) Wound

(d) Tracheobronchial lymph nodes

(e) Other organs

(18) Concentration of TU elements in each organ sampled (nCi per gram)

(19) Deposition from autopsy by organs sampled and by systemic and total body. Systemic burden found at autopsy is compared with systemic burden estimated before death. The employee name is helpful to confirm questionable identification by social security number. It is not used in the data processing procedures.

"B" IDENTIFIED TRANSURANIUM WORKERS (NOT AUTOPSIED)

The same information is collected except for data pertaining to autopsy -- items (18) and (19). Non-autopsied TU worker causes of death should not be compared with autopsied groups as to cause of death since malignant disease is often found at autopsy which was not diagnosed as present before death.

"C" CONTROL GROUPS

(1) Hanford Operations

(a) All Hanford non-transuranium workers past, present and future. This would be the primary control group. Data is on tapes prepared by the AEC Health and Mortality Study, and is available to the Registry. Items (13), (15), (16), (17), (18) and (19) would be omitted as not applicable. (11) would be years of employment. Cohorts by year of employment (five-year age interval group vs. year of start on TU work), sex, color.

(b) Siblings - Data from AEC Health and Mortality Study is as follows:

(i) Name and social security number of employees

(ii) Name of sibling (last, first and second name)

(iii) Relationship of sibling (brother, sister, half brother or half sister)

(iv) Age of sibling

(v) Whether deceased

(vi) Address of sibling (City, State or Country)

(vii) Parents (father's last and first name, age and address; mother's maiden name, given name, age and address).

(viii) Year of source record

(c) Subgroups based on amount of deposition of transuranium elements in transuranium workers.

(d) A sample from U. S. mortality statistics broken down by cohorts as to age (five-year group), color, sex.

(e) Possibly use a random sample or whole group of Washington State employed people.

(f) Autopsy studies at Hanford, Los Alamos, etc. to determine organ content of radionuclides including the transuranium elements.

(2) Other Plants

(a) Same items as for C(1)(a) except these would have to be collected for each plant. We would settle for a randomly selected number of non-TU workers from the plant of same age at hire as the TU Registry starter age, same sex, color.

(b) Siblings not available without excessive costs

(c) Same as for Hanford

(d) Same as for Hanford

(e) Omit or substitute whatever local groups may suggest

(f) Same as for Hanford

APPENDIX A

A Transuranic Worker is defined as one:

1) who has a deposition of a transuranic element as a result of occupational exposure as evidenced by:

   a) confirmed positive results in urine, feces, or blood.

   b) confirmed positive results based on in vivo examination.

2) or whose occupational activities present a reasonable opportunity to acquire internal deposition of any of the transuranium elements in quantities greater than might be expected to be found in persons who are not occupationally exposed to transuranic elements. (For plutonium these are total actual depositions greater than 0.4 nCi.)

   These persons can normally be identified by subjective review of the work assignment for the individual. Typical criteria include:

   a) annual or more frequent routine bioassay examinations.

   b) annual or more frequent routine in vivo examinations.

   c) exposed to airborne concentrations in excess of 10 MPC-hours in any one week.

   d) frequently required to wear respiratory protection.

   e) frequently required to wear lapel air sampler.

   f) confirmed positive nasal smears or nose blows.

   Any one of the above positive or inferential criteria is sufficient to identify a worker as a transuranium worker and once a worker is so identified he is always considered a transuranium worker. The Registry should be advised which of the above items were used to classify as TU worker.

10/14/74

APPENDIX B

For cause of death, autopsied individuals in exposed groups would be compared with autopsied individuals in unexposed groups and non-autopsied with non-autopsied groups.

Comparisons as to Cause of Death

For comparison of health and longevity, autopsied and non-autopsied groups may be combined.

	TU Workers		Controls Not TU Workers		
(1)	autopsied	⟷	autopsied)	-(1)	other plant workers
	not autopsied	⟷	not autopsied)		
(2)	autopsied	⟷	autopsied)	-(2)	siblings
	not autopsied	⟷	not autopsied)		
(3)	autopsied	⟷	autopsied)	-(3)	sample of U.S. mortality
	not autopsied	⟷	not autopsied)		

Intercomparison of subgroups of workers, based upon amount of body deposition would also be by comparing the groups with higher deposition with those with lower deposition and further divided into autopsied and non-autopsied groups for cause of death comparisons.

Papers and Publications by Members of the Registry Staff

1. Norwood, W.D. and Newton, C.E., Jr.: U. S. Transuranium Registry Study of Thirty Atuopsies presented at the Annual Meeting of the Health Physics Society July, 1974 and published in Health Physics Vol. 28, 669-675, June, 1975.

2. Norwood,W.D., Newton, C.E., Kirklin, C.W., Heid, K.R. and Breitenstein, B.D.: Health of Hanford Plutonium (Pu) Workers, presented at University of Utah's workshop on The Biological Effects and Toxicity of ^{239}Pu and ^{226}Ra, Sun Valley, Idaho, October 6 - 9, 1975. This paper is included in this report and is to be published in the Proceedings of this meeting early in 1976.

3. Norwood, W.D.: Health Protection of Radiation Workers, published by Charles C. Thomas, Springfield, Illinois, 1975.

SI-SIE-75a

PUBLICATION BY ERDA AUTHORIZED ☐

NOTICE OF RESEARCH PROJECT
SCIENCE INFORMATION EXCHANGE
SMITHSONIAN INSTITUTION

APPENDIX D

SIE NO.

ERDA CONTRACT NO.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SUPPORTING DIV. OR OFFICE

NAME & ADDRESS OF CONTRACTOR OR INSTITUTION: (State the division, department, or professional school, medical, graduate or other, with which this project should be identified.)

Hanford Environmental Health Foundation
P. O. Box 100
Richland, WA 99352

TITLE OF PROJECT:

U. S. Transuranium Registry of AEC, AEC Contractor and Licensee Employees

NAMES, DEPARTMENT, AND OFFICIAL TITLES OF PRINCIPAL INVESTIGATORS AND OTHER PROFESSIONAL SCIENTIFIC PERSONNEL (not including graduate students) engaged on the project, and fraction of man-year devoted to the project by each person

W. D. Norwood, M.D. - Acting Director
C. E. Newton, Jr. - Associate Director
P. A. Fuqua, M.D. - Medical Director, Hanford Environmental Health Foundation

NO. OF GRADUATE STUDENTS ON PROJECT 0 NO. OF GRADUATE STUDENT MAN-YEARS

SUMMARY OF PROPOSED WORK (200-300 words, omit Confidential Data). Summaries are exchanged with government and private agencies supporting research, are supplied to investigators upon request, and may be published in documents. Make summaries substantive, giving initially and for each annual revision the following: OBJECTIVE, SCIENTIFIC BACKGROUND FOR STUDY, PROPOSED PROCEDURE, TEST OBJECTS AND AGENTS.

The U. S. Transuranium Registry (USTR) was established in 1968 to determine if internal depositions of transuranium elements affect the health status, longevity and cause of death of exposed workers. Such answers are essential to the progress of the breeder reactor program for power generation. Comparative health studies are in progress starting initially with 26 Los Alamos workers most heavily exposed to plutonium depositions. At Hanford 425 plutonium deposition cases are being compared to siblings, plutonium workers with no known deposition, other Hanford workers and a one percent matched sample of U. S. workers obtained from Social Security. Health status, longevity and death causes subdivided according to estimated current deposition or that found at autopsy are being compared. Similar studies are contemplated for other sites when the basic epidemiological design is developed and approved.

RESULTS TO DATE: Some 9055 workers at risk to transuranium elements have been identified at the various ERDA sites and are being individually identified and basic information supplied to the USTR for analysis and data processing. Fifty autopsies have been performed and in general show a smaller systemic and a larger lung deposition of plutonium than predicted. A report of present health status, mortality and cause of death of 425 Hanford workers with internal depositions of plutonium subdivided according to the amount of the deposition is expected to be complete and released in October 1975. A committee of health physicists from major ERDA contractors is being sponsored by USTR to define and assure compatibility of health physics data prepared for use in Registry programs.

	PROGRAM CATEGORY NO.
BUDGET	
PRIMARY	
SECONDARY	

Signature of Principal Investigator W. D. Norwood, M.D.

DATE July 30, 1975

INVESTIGATOR DO NOT USE THIS SPACE

1009642

APPENDIX E

NOT FOR PUBLICATION

HEALTH OF HANFORD PLUTONIUM (Pu) WORKERS

W. D. Norwood, C. E. Newton, C. W. Kirklin,
K. R. Heid and B. D. Breitenstein

For presentation at

The University of Utah's
Workshop on the Biological Effects and
Toxicity of ^{239}Pu and ^{226}Ra

Sun Valley, Idaho
October 6-9, 1975

HEALTH OF HANFORD PLUTONIUM (Pu) WORKERS*

PART I OF STUDY

W. D. Norwood,[a] C. E. Newton,[b] C. W. Kirklin,[a]
K. R. Heid[b] and B. D. Breitenstein[a]

ABSTRACT -- Health, mortality and cause of death in 452 Hanford known Pu deposition cases was analyzed for the period 1944 to 1975. Malignant disease as a cause of morbidity and mortality was carefully examined because of its occurrence in laboratory animals subjected to very large doses of plutonium. Other serious diseases were also considered. The average years at risk in these individuals with depositions was 23 (range 2 - 31) years. The average years following deposition in those estimated to have more than 4 nCi was 16.7 (range 6 - 30) years. Using clinical judgment in evaluating severity of malignancy, and other disease, there does not appear to be any meaningful difference between the health and mortality of the employees with low deposition of Pu (≤ 2 nCi) and that of employees with higher systematic depositions (2 nCi to 400 nCi).

INTRODUCTION

This paper presents one facet of a continuing effort to evaluate the health of employees who handle open sources of transuranium elements under conditions found in Energy Research and Development Administration (ERDA) facilities operated by their major contractors and in facilities operated by licensees under the Nuclear Regulatory Commission (NRC). The urgent need for a study of the health of plutonium workers by means of the follow-up of well defined populations has been emphasized by the Advisory Committee of the U. S. Transuranium Registry (USTR) (U. S. Transuranium Registry (USTR) Advisory Committee Meeting, Richland, Washington, October 3-4, 1974) and endorsed at a workshop for medical directors, health physicists of the major ERDA installations handling transuranium elements, and consultants (Workshop convened by USTR, Denver, Colorado, February 27, 1975). Such knowledge is vital to

*This paper is based on work performed under Contract E(45-1)-1837 with the Energy Research and Development Administration.
a. Hanford Environmemtal Health Foundation
b. Battelle Pacific Northwest Laboratories

continually assess the extent of possible adverse effects, if any, that personnel may enounter in participating in the continued development of nuclear energy and in particular the breeder reactor program.

ERDA EPIDEMIOLOGICAL STUDY

The portion of the U. S. Transuranium Registry study at Hanford presented in this paper, is an early evaluation of readily available data and will become part of the over-all epidemiological study which will define a study population consisting of all identified Pu workers with either detectable burdens or burdens above a stated value at the major facilities handling open sources of plutonium. Controls will be employee populations of (1) exposed Pu workers with no detectable burden and (2) employees having no exposure to plutonium. The final decision on the criterion to be used in defining the study population has not been made.

EARLY STUDIES

A study of health of twenty-five (25) heavily exposed plutonium workers at the Los Alamos Scientific Laboratory was published in 1973 (Hempelmann et al. 1973). The conclusion was that "to date, none of the medical findings in the group can be attributed definitely to internally deposited plutonium." A study of health of some 250 Pu workers who have depositions is now in progress at Los Alamos.

PART I HANFORD STUDY

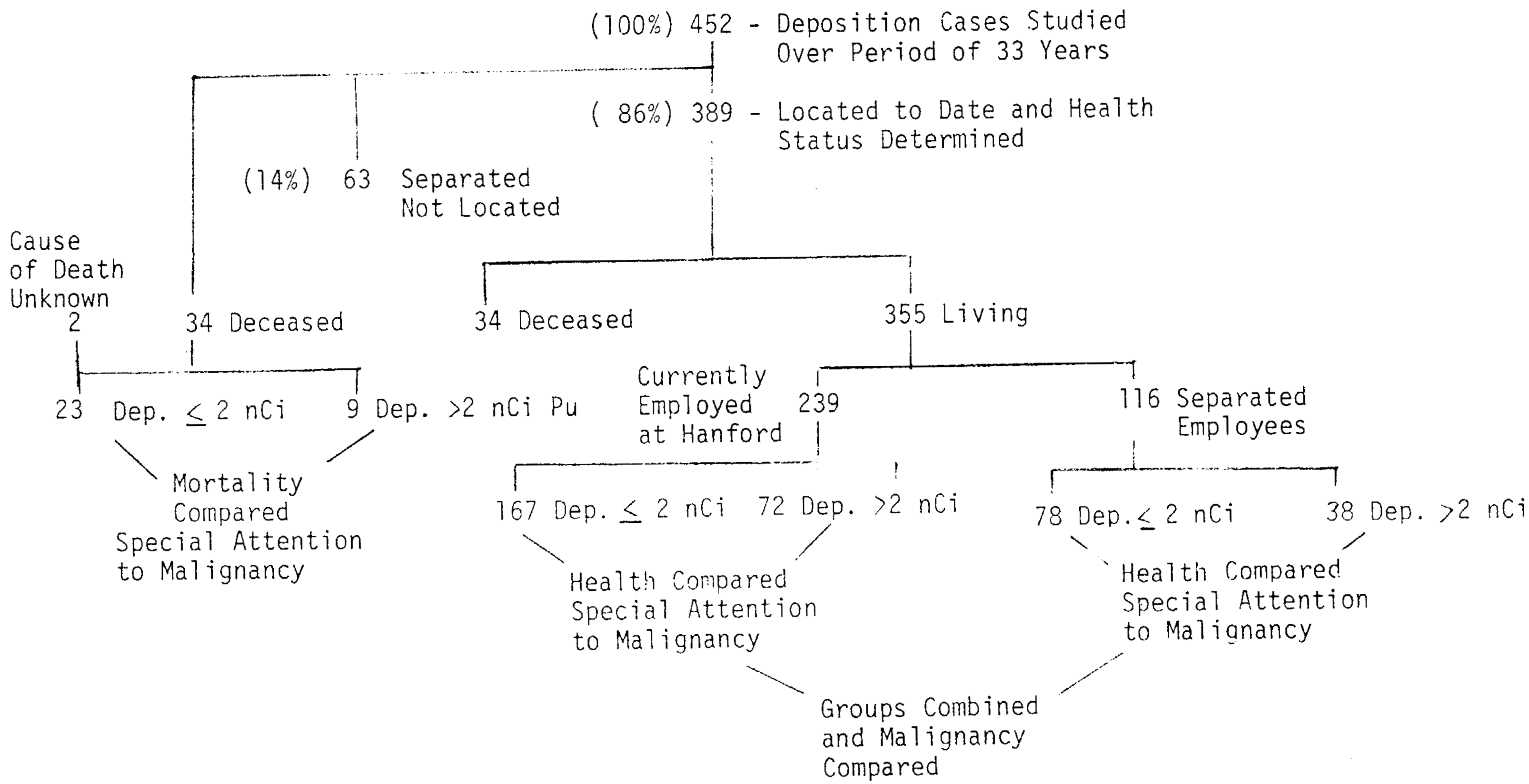
As depicted in Figure 1, this was a study of health, longevity and causes of death, covering a period of about thirty-one years (1944 - 1975), of all Hanford Pu workers (452) identified as having depositions of Pu. As of September 1, 1975, 239 of these were still working at Hanford and 213 had separated by retirement, death or for other reasons. Eighty-six (86) percent or 389 of the 452* workers

*The 63 who could not be contacted are considered to be alive as of 1973 since the Social Security Administration has no evidence of their death.

1009646

Figure 1

DIVISION OF Pu DEPOSITION CASES (HIGH vs. LOW) FOR HEALTH AND MORTALITY COMPARISON



were located and health status or cause of death determined. The 389 were divided into those living (355) and those deceased (34). Causes of death were determined on 32 of the deceased and will be determined on the other two.* Health status of 110 living workers with estimated deposition of Pu greater than 2 nanocuries was compared with that of 245 Pu workers with estimated depositions of 2 or less nCi. In like manner the 34 deceased workers were separated into two groups: 9 with depositions greater than 2 nCi; and 25 with depositions of 2 nCi or less. Employees having depositions of 2 or less nCi of Pu represent persons who have incurred some slight plutonium intake confirmed by positive bioassay samples. However, at this low level of activity many uncertainties exist in the data and it is difficult or even impossible to quantify the deposition. Time constraints in preparing this report prevented the identification of a suitable comparison group outside the Hanford plutonium worker group; therefore the Pu workers with less than 2 nCi were used for an internal comparison. Excluded from the study were all Hanford plutonium workers who had no indication of plutonium deposition by urinalysis.

The present health status of those currently employed at Hanford was determined by a careful review of the Hanford Environmental Health Foundation medical records. Health status of the separated employees was determined by a questionnaire or interview. Death certificates were obtained for those who had died.

HEALTH OF PRESENTLY EMPLOYED HANFORD WORKERS WHO HAVE Pu DEPOSITIONS

At Hanford, carefully executed medical examinations were made at the time of employment and at intervals of twelve (12) to fifteen (15) months on all employees since operations began in 1944 and these records are available for study as are carefully kept health physics records. A wealth of information has been data processed and is available on

*Social Security check of deaths is to 1973. Some deaths may have occurred since then in the 63 separated Pu workers not located.

tapes (Mancuso and Sanders 1975). However, to determine present health status of Pu workers, it was necessary to review and summarize individual health records. Health records covering a period of the last six to ten years were examined and a work sheet was prepared for each employee under study.* Such a sheet is shown in Table I. Microfilms were available for previous years and were utilized as needed. Each employee under study was then characterized by name, social security number, sex, race, birth date, service date, years at risk in Pu work, type of work, work locations, cigarette smoking habits, major work exposures other than radiation, cumulative exposures to external radiation at work, estimated internal deposition of Pu, cumulative dose to organs and incidence and severity of disease.

Medical examinations included pre-employment and follow-up periodic medical histories, physical examination and laboratory and x-ray studies. Chest x-rays were taken at each examination. Urinalyses and complete blood counts were alternated with SMA 12-60 blood chemistry profiles. These included calcium (Ca^{++}), inorganic phosphorus (Inor. Phos.), glucose (Glu), blood urea nitrogen (BUN), uric acid, cholesterol (Chol.), total protein (TP), albumin (Alb.), total bilirubin (T. Bili.), alkaline phosphatase (Alk. Phos.), lactic dehydrogenase (LDH) and serum glutamic oxaloacetic transaminase (SGOT). Single abnormal Alk. Phos., LDH and SGOT abnormalities were recorded in the summaries since Alk. Phos. and LDH were studied to determine if they were possibly affected by Pu depositions.** Single SGOT abnormalities were noted because they may have significance. Blood

*In long-term employees, the original pre-employment and some periodic examinations would not be reviewed. However, occupational physicians repeat the pertinent medical findings on the later medical records.

**Unpublished Studies at Rockwell International Rocky Flats Plant.

TABLE I

TYPICAL WORK SHEET SHOWING HEALTH RÉSUMÉ OF EACH EMPLOYEE PRESENTLY EMPLOYED IN PLUTONIUM (Pu) WORK AT THIS PROJECT
Each Has an Estimated Systemic Deposition of Plutonium

(Abbreviation code shown at bottom of table)

Occupational Medical Examination	
4/7/75 Interim	(name) ____________, SS# ____________, BD 1-25-16, SD 6-3-47 Lead Nuclear Chem. Oper. 200-W, 234-5 Bldg; 5'2" - 141#, (CBC, UA, Ch x-ray) - WNL, IMH - Smoked 1 pkg cgts/day 15 years to 1945
1/24/74 Periodic	Blood sugar 180 mg.% - high, Px - 140/80 BP, IMH - Hypertension (under treatment), prostatic infection. Ca screening questionnaire - mother had Ca of breast. SMA -12-60 - Uric Acid 10.5 (2.5 - 8), Inorg. Phos. 2 (2.5 - 4.5), Ch x-ray - WNL.
10/17/73 return to work	IMH - prostatitis and testiculitis.
9/14/72 Interim	IMH - no change, (CBC, U.A. x-ray - chest) WNL.
5/17/71 Periodic	IMH - joint pains. Px BP - 142/100. SMA - Inor. Phos. 2 (2.5 - 8), Glu. - 140 (65-110).
2/9/70 Interim	(CBC, U.A., chest x-ray) WNL. IMH - post operative urethral stricture.
11/4/68 Periodic	IMH - no change. Px - BP 170/100. SMA - Elev. of glu., Uric A., depression of Inorg. Phos., chest x-ray - WNL.
8/4/67 Interim	IMH - no change. (CBC, UA, chest x-ray) WNL.
5/17/66 Periodic	Pulmonary function test - normal. IMH - no change. Prostate surgery - Nov. 19, 1964 (benign hypertrophy) not malignant. Px - BP 180/90.
Summary	Smoked 1 pkg cgts/d 15 years to 1945 - med. smoker, hypertension, Uric Acid + Inorg. Phos. -, prostate surgery - not malignant.

WNL - within normal limits
IMH - interim medical history, Px - physical examination, BP - blood pressure, Ca - carcinoma, SMA - blood chemistry survey - 12 determinations, BD - birth date, SD - service date for Pu work, CBC - complete blood count, UA - urinalysis, Ch - chest, Cgts - cigarettes, Pkg - package, + = above normal - = below normal

sugar changes were not noted unless a diagnosis of diabetes mellitis or other abnormal diagnosis was made. Other SMA values were noted only if found on repeated examinations. Abnormalities in blood chemistry were reported only as high or low as compared with the normal range in this report and will be considered in more detail in a later study.

CHARACTERIZING HEALTH

Since in laboratory animals, malignant disease especially of lungs, bone, liver, lymph nodes and at sites of local wounds has occurred following large Pu depositions,* incidence of malignant disease and mortality due to malignancy was of major importance. Incidence of other major diseases was also determined. The increased incidence of atherosclerosis in cigarette smokers has been cited as possibly related to alpha emitting polonium associated with cigarette smoke (Martell 1975). Therefore incidence of atherosclerosis was carefully considered.

Diseases were characterized according to nomenclature of the Eighth Revision International Classification of Diseases, Adapted (ICDA). Malignancy was distinguished by the organ of origin, type and maturity of cells noted by pathologist, presence or absence of metastases, type of therapy, years without recurrence following therapy and other factors available. Hypertension was considered to be present if there was a repeated systolic pressure of 175 mm of Hg or greater or a repeated diastolic pressure of 90 or greater or if the employee was receiving therapy for elevated blood pressure from his personal physician. Obesity was noted if the occupational physician had advised the employee to try to reduce. Coronary artery disease was subdivided into (1) that with infarction or severe enough for surgical bypass or (2) that without infarction or requiring surgical corrective action. When such organs as breasts, uteri, prostates, etc. were

*Hundreds of times the equivalent maximum permissible deposition for humans.

noted as having been removed or operated on, the hospital or physician was asked for a clinical and pathological diagnosis. Similar information was secured in situations of known malignancy to learn the type of cell and estimated severity of the condition. Severity of other diseases was estimated, using clinical judgment. For example, peptic ulcer was characterized as requiring medical therapy only or both medical and surgical treatment.

FINDING AND CHARACTERIZING HEALTH AND CAUSE OF DEATH OF SEPARATED EMPLOYEES

Separated employees were often difficult to locate and several methods were used. In recent years, the address of the Pu worker at the time of termination has been recorded and he has been asked to complete a new address form if he moved and to return it to the U. S. Transuranium Registry in a self-addressed envelope. Those who have authorized autopsy are sent a new card annually and a letter to them periodically brings them up-to-date on Registry activities. Their contract with the Registry is renewed at five-year intervals and serves as a further opportunity for contact and exchange of information. If letters to last addresses are returned by the Post Office it has been possible to get a limited number processed annually by the Social Security Administration, who sent a letter to the last known address to indicate that the Registry would like to communicate with the individual. The separated employee may or may not then exercise his option to communicate with the Registry. Social Security also has searched through a limited list of names periodically for the Registry to determine those who have died and where the employee died. By contacting the proper State government department keeping vital statistic records the cause of death was determined.

A current health status questionnaire was sent to former plutonium workers asking for name of spouse and names of two friends or relatives who are most likely to always know his address. Additionally he was asked to answer the following questions: (1) Are you in good health? (2) Have you had any serious illness or operations requiring hospitalization? (3) If yes, what illness? (4) If yes, name of hospital and approximate dates, and (5) Comments. Such a simple questionnaire had proven successful in the Los Alamos study referred to previously. Receipt of letters was verified by certified mail. Occasionally an employee refused to accept the letter but courteously answered the questions when the physician called by phone. When letters were not answered and phone contact could not be made, house calls were made by the physician if the employee lived in the local area. In all such cases satisfactory answers to the same questions were obtained and follow-up information secured from hospitals and physicians, who graciously cooperated in this effort. Even so, location of people who have left the area twenty or thirty years ago has not been easy. Following the relatively few construction workers was more difficult. Continued efforts are being made to locate more separated employees. For uniformity, one physician (WDN) made all contacts with separated employees and all evaluations of health of this group and of the group presently employed at this project. At the time of making such evaluations he was not aware of the estimated deposition of Pu for these employees.

ESTIMATED CUMULATIVE DOSE DUE TO DEPOSITED PLUTONIUM

More important than cumulative years at risk is the estimated cumulated dose to organs based on estimated initial inputs and dates of such inputs by wound or inhalation and subsequent internal transfer and elimination. Bioassay and in vivo data were collected to estimate the resulting deposition for each case involving the accidental intake of plutonium. Bioassay results were fitted to either the Langham model (American Industrial Hygiene Association 1956) for transportable forms of plutonium or to the Healy model (American Industrial Hygiene Association 1957) for non-transportable forms of plutonium to determine the systemic burden commitment. This estimate of the total systemic burden was then used to calculate the dose (in rads) to the bone and liver. When sufficient in vivo measurements were available these lung count data were used to calculate dose to lung. If insufficient lung count data were available, the Task Group Lung Model (Task Group on Lung Dynamics 1966) concepts were applied for use with bioassay results. Organ dose calculations were based on the recommendations of the Advisory Committee to ERDA on Dose from Plutonium (Mancuso and Sanders 1974). Pertinent assumptions recommended by this committee include a 45%-45% partitioning of the activity reaching blood to bone and liver; 100-year half-time clearance from the bone and 40-year half-time clearance from the liver. Since no quality factor was used, the dose was reported in rads. Rem doses can be calculated by multiplying the bone dose in rads by 50 and the lung and liver doses in rads by 10.

Table II lists those cases where the deposition for an individual equals or exceeds 4 nCi plutonium. When the deposition results from more than one intake, only the date for the major intake was identified; however, dose calculations reflect the combined dose from all depositions. This will help to identify the total exposure duration, but could in a few cases be somewhat misleading. The mode of intake was listed for each person. Organ doses received through 1974 and the 50-year dose commitment was listed for each case.

STUDY FINDINGS

Discussion of Comparability of Low Deposition vs. Higher Deposition Cases

The study groups fall into four basic divisions which are characterized in Table III. The internal comparability of the still employed Pu workers and the separated contacted Pu workers is very close. There is some variance in average years at risk in the very low and higher Pu deposition cases in the deceased group and in age in the

TABLE II

ALL HANFORD PLUTONIUM DEPOSITION CASES ≥4 nCi
CALCULATED RAD DOSES TO ORGANS

Case No.	Dep. Year	Years Since Deposition	Types of Intakes	Estimated Systemic Burden (nCi Pu)	Calculated Rad Dose*** to Organs: Through 1974**			50-yr Commitment		
					Lung	Bone	Liver	Lung	Bone	Liver
1	1945	30	I*	25	25	6	15	25	12	25
2	1947	28	I	25	15	6	15	15	11	25
3	1947	28	I	20	15	5	12	15	8	20
4	1947	28	I	7	2	2	5	2	3	8
5	1948	27	I	75	50	18	45	50	32	75
6	1948	27	I	5	3	1	3	3	2	5
7	1950	25	I	5	4	1	3	4	2	5
8(D)	1951	17	I	5	<1	<1	2	1	2	5
9	1951	24	I	8	5	2	4	5	3	8
10	1951	24	I	5	1	1	3	1	2	5
11	1952	23	W*	45	--	10	25	--	20	50
12	1952	23	I	25	15	4	10	15	10	25
13	1952	23	I	8	4	2	4	4	3	8
14	1952	23	I	9	4	2	5	4	4	9
15	1952	23	I	7	2	2	4	2	3	8
16	1952	23	I	4	<1	1	2	<1	2	3
17	1953	22	I,W	7	2	1	3	2	3	7
18(D)	1953	17	I	7	3	<1	2	3	2	4
19(D)	1953	9	I	25	15	1	4	15	10	25
20	1953	22	I,W	6	3	1	3	3	3	6
21	1953	22	I	4	2	1	2	2	2	4
22	1954	21	I	4	<1	1	2	<1	2	4
23	1954	21	I	6	3	1	3	3	3	6
24	1954	21	I	4	2	1	2	2	2	5
25	1954	21	I,W	7	2	1	3	2	3	7
26	1954	21	I,W	7	2	1	3	2	3	6

*I = Inhalation, W = Wound, (D) = Deceased
**Or until death.
***Dose from ^{239}Pu only to conform with practice at other ERDA projects. In all other tables, the deposition estimate is from ^{239}Pu + ^{241}Pu, the practice here.

Case No.	Dep. Year	Years Since Deposition	Intakes	Estimated Systemic Burden (nCi Pu)	Calculated Rad Dose to Organs					
					Through 1974			50-yr Commitment		
					Lung	Bone	Liver	Lung	Bone	Liver
27	1954	21	I	8	2	2	4	2	4	9
28	1955	20	I	4	3	1	2	3	2	3
29	1955	20	I,W	5	1	1	2	1	2	5
30	1955	20	I	10	5	2	4	5	4	10
31	1955	20	I	7	5	1	3	5	3	7
32	1955	20	I	85	15	16	40	15	40	100
33	1955	20	I	4	4	1	2	4	2	4
34	1955	20	I	8	2	2	4	2	4	9
35 (D)	1955	17	I	35	20	5	15	25	16	35
36	1956	19	I	5	5	1	2	5	2	5
37	1956	19	I	8	5	1	3	5	3	8
38	1956	19	I	35	20	5	10	20	15	35
39	1956	19	I,W	50	45	7	20	45	20	50
40	1956	19	I	400	40	80	200	40	200	400
41	1956	19	I,W	6	6	2	6	6	3	9
42	1957	18	I	4	3	<1	1	3	2	4
43	1957	18	I	5	3	<1	2	3	2	5
44	1958	17	W	9	--	2	4	--	4	10
45	1958	17	I	5	4	<1	1	4	2	5
46	1958	17	W	25	--	5	12	--	12	30
47	1958	17	I	10	4	2	4	4	5	10
48 (D)	1959	14	I	10	7	1	3	7	4	10
49	1959	16	I	15	2	2	6	2	6	15
50	1960	15	I,W	7	3	1	2	3	3	8
51	1961	14	I	5	1	<1	1	1	2	5
52 (D)	1961	9	I	8	<1	<1	2	<1	4	9
53	1961	14	I	4	3	<1	1	3	2	4
54	1961	14	I	15	9	2	5	9	6	15
55 (D)	1962	12	I	4	3	<1	1	3	2	4
56 (D)	1962	12	I,W	8	2	1	3	3	4	10
57	1962	13	I	4	<1	<1	1	<1	2	4

Case No.	Dep. Year	Years Since Deposition	Intakes	Estimated Systemic Burden (nCi Pu)	Calculated Rad Dose to Organs: Through 1974 Lung	Through 1974 Bone	Through 1974 Liver	50-yr Commitment Lung	50-yr Commitment Bone	50-yr Commitment Liver
58	1962	13	I	4	3	<1	<1	3	1	3
59	1962	13	W	10	--	2	4	--	5	10
60 (D)	1962	8	I	10	5	1	3	5	4	12
61	1962	13	I,W	4	3	<1	1	3	2	3
62	1962	13	I	15	15	1	3	15	6	15
63	1962	13	I	4	3	<1	2	3	1	4
64	1962	13	I,W	15	7	2	4	7	5	12
65	1963	12	I	4	3	<1	<1	3	1	3
66	1963	12	I,W	4	<1	<1	1	<1	2	3
67	1963	12	I,W	4	2	<1	1	2	1	4
68	1963	12	W	6	--	1	2	--	3	6
69	1964	11	W	6	--	<1	2	--	3	6
70	1964	11	I	8	5	<1	1	5	3	7
71	1964	11	I,W	5	3	<1	1	3	2	5
72	1964	11	I,W	4	2	<1	<1	2	1	3
73	1964	11	W	100	--	11	30	--	50	100
74	1964	11	I,W	6	5	<1	1	5	3	6
75	1966	9	I,W	9	2	1	3	2	4	9
76	1966	9	I	5	4	<1	1	4	2	4
77	1966	9	I,W	20	<1	2	4	<1	8	20
78	1966	9	I,W	5	3	<1	1	3	2	5
79	1967	8	W	15	--	1	4	--	7	25
80	1967	8	I	7	2	<1	1	2	3	6
81	1967	8	I	8	10	1	2	8	5	10
82	1968	7	I	15	9	1	2	10	6	14
83	1969	6	I	20	7	1	3	7	7	15
84	1969	6	I	15	10	1	2	10	6	15

TABLE III

COMPARABILITY OF LOW vs. HIGH DEPOSITION CASES IN THE FOUR DIVISIONS

Div. 1 — 239 Hanford Pu Workers Still Employed	167 with ≤ 5% mpbb* Pu	72 with >5% mpbb* Pu
Male - Number and (%)	160 (96.4%)	71 (98.6%)
Female - Number and (%)	7 (3.6%)	1 (1.4%)
Ave. Age (and range) as of 9-1-75	52 (29-69)	53 (32-65)
Ave. Yrs. (and range) at Risk as Pu Workers	23 (4-31)	25 (1-31)
Number of Nonwhite	0	0
Div. 2 — 116 Separated Pu Employees Who were Contacted	**78 with ≤ 5% mpbb**	**38 with >5% mpbb**
Male - Number and (%)	67 (85.9%)	36 (94.7%)
Female - Number and (%)	11 (14.1%)	2 (5.3%)
Ave. Age (and range) as of 9-1-75	57 (28-80)	59 (41-80)
Ave. Yrs. (and range) at Risk as Pu Workers	23 (4-28)	25 (2-30)
Number of Nonwhite	1	None recorded
Div. 3 — 63 Separated Pu Employees Who Could Not be Contacted **	**49 with ≤ 5% mpbb**	**14 with >5% mpbb**
Male - Number and (%)	34 (69%)	12 (86%)
Female - Number and (%)	15 (31%)	2 (14%)
Ave. Age (and range) as of 9-1-75	51 (25-83)	60 (50-75)
Ave. Yrs. (and range) at Risk as Pu Workers	9 (1-24)	11 (2-22)
Number of Nonwhite	0	0
Div. 4 — 34 Hanford Pu Workers Who are Dead	**25 with ≤ 5% mpbb**	**9 with >5% mpbb**
Male - Number and (%)	22 (88%)	9 (100%)
Female - Number and (%)	3 (12%)	0 (0%)
Ave. Age (and range) at Death	57 (31-81)	60 (43-67)
Ave. Yrs.(and range) at Risk as Pu Workers	15 (2-27)	21 (4-28)
Number of Nonwhite	0	0

* 5% mpbb = 2 nCi
**Probably living

separated not contacted group. There is also a higher percentage of women in the separated not contacted group. This was probably due to name changes with marriage. The ratio of the total number with ≤5% mpbb to those with >5% mpbb was approximately 2 to 1 in the two larger groups and 3 to 1 in the two smaller groups. The socioeconomic status of all these workers is similar since they were doing the same type of work, receiving similar salaries and living and working in the same location.

Discussion of Health Status
of 167 Hanford Employed Pu Workers with ≤2 nCi Pu
(Low Deposition Cases) Compared to that of 72 Workers
with >2 nCi Deposition of Pu (Higher Deposition Cases)

Comparison of the low deposition cases (≤2 nCi Pu) with those with a higher deposition (>2 nCi Pu) gave the following results:

As shown in Table IV, three (3) employees with low depositions and two (2) with higher depositions had malignant disease. The two higher deposition cases were both of low severity and did not involve potentially critical organs. One of the malignancy cases with low deposition was of great, one of moderate and one of low severity. One of great severity involved the colon and metastases had occurred while one of moderate severity involved retroperitoneal abdominal lymph nodes (lymphosarcoma from diaphragm to pelvis). The lymph gland is considered a potential critical organ. Considering all factors, the higher deposition cases fared better.

There was little difference in the total incidence of other disease in the two groups as shown in Section B of Table IV. One measure of this was the number with no disease which was expressed in actual numbers and shown in parentheses as percent of the subgroup having no disease. Those with no disease comprised 57% of the cases with ≤2 nCi and 47% of the cases having depositions >2 nCi Pu. Incidence of some individual diseases was exceptional. For example, incidence of peptic ulcer and arthritis was 4.7 and 3 times as high respectively in lower depositions as compared with higher deposition cases. Incidence of

TABLE IV

INCIDENCE OF DISEASE IN 239 CURRENTLY EMPLOYED HANFORD DEPOSITION CASES

Malignant Disease and Estimated Severity*	167 Cases Estimated ≤ 5% MPBB**		72 Cases Estimated > 5% MPBB**		
	No. Cases	% of Cases	No. Cases	% of Cases	%MPBB
Colon					
a) With metastases, surgery less than 5 years ago. Severity = G.	1	0.6	0	---	
Thyroid					
a) Surgery 1951, no recurrence. Severity = L.	1	0.6	0	---	
Abdominal Lymph Nodes					
a) Lymphosarcoma. Surgery 1966. No recurrence. Severity = M.	1	0.6	0	---	
Parotid					
a) Surgery 1948. No recurrence. Severity = L.	0	---	1	1.4	15
Tongue					
a) Surgery 1965. No recurrence. Severity = L.	0	---	1	1.4	8
Skin (superficial and easily removed). No melanomas.	5	3.0	3	4.2	8,15,80
Other Diseases					
Hypertension	20	12.0	8	11.1	7,7,7,8,9, 9,15,15
Arthritis, unspecified	14	8.4	2	2.8	6,1350
Peptic Ulcer	11	6.6	1	1.4	20
Obesity	11	6.6	8	11.1	7,8,10,15, 17,20,150, 290

*Severity is an estimate of the seriousness of the malignancy based on cell type, location, metastases and years of arrest.
Low (L), Medium (M), Great (G)

** MPBB = 40 nCi

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TABLE IV (Cont'd)

Other Diseases	167 Cases Estimated ≤5% MPBB		72 Cases Estimated >5% MPBB		
	No. Cases	% of Cases	No. Cases	% of Cases	% MPBB
Ischemic Heart Disease with Infarction or Bypass Surgery	5 } 7	3.0 } 4.2	5 } 6	7.0 } 8.4	7,8,15,20, 55
Ischemic Heart Disease without Infarction or Bypass Surgery	2	1.2	1	1.4	270
Hyperplasia of the Prostate	6	3.6	1	1.4	290
Emphysema	2	1.2	4	5.6	8,9,30,30
Diabetes Mellitus	4	2.4	1	1.4	7
Diseases of Lungs and Lymphatics	1	0.6	1	1.4	7
Pulmonary Tuberculosis	0	---	1	1.4	7
Liver Disease Unspecified	1	0.6	0	---	
Simple Anemia	1	0.6	1	1.4	8
Asthma	1	0.6	1	1.4	25
Thyroiditis	1	0.6	0	---	
Nontoxic Nodular Goiter	1	0.6	0	---	
Acute Pericarditis, nonrheumatic	1	0.6	0	---	
Diarrhea, Intestinal	0		1	1.4	10
Rheumatic Heart Disease	1	0.6	0	---	
Abdominal Aortic Aneurysm	0		1	1.4	20
Diverticulitis	1	0.6	0	---	
Nephrosis	1	0.6	0	---	
Spontaneous Pneumothorax	1	0.6	0	---	
No Evident Disease	95	(57.0) *	34	(47.0) *	

*Does not add to 100% when added to the percentage of those with identified disease because some with disease had more than one disease process.

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TABLE IV (Cont'd)

Smoking History, etc.	167 Cases Estimated ≤ 5% MPBB	72 Cases Estimated > 5% MPBB
	GROUP CHARACTERISTICS	
Average age (1975)	52 years, range (29-69)	53 years, range (32-65)
Average years at risk as a Pu worker	23 years, range (4-31)	25 years, range (1-31)
Individuals with one or more diseases reported with positive tobacco smoking history	71%	76%

coronary artery disease was twice as great in the higher deposition cases. Numbers of individuals with each disease were small, however.

Discussion of Blood Chemistry Tests

Results of blood chemistry - SMA 12-60 tests are shown in Table V. Considering the relatively small number of individuals with abnormal findings and the variety of conditions which influence the parameters of major interest Alk. Phos. and LDH, the values do not appear to be unusual. In a separate study to be reported later total serum alkaline phosphatase values are divided into those for bone, liver and intestine while LDH is divided into 5 isoenzyme fractions.

TABLE V

RESULTS OF BLOOD CHEMISTRY TESTS IN 239 CURRENTLY EMPLOYED HANFORD PLUTONIUM DEPOSITION CASES

Results SMA-12-60 ↑ = Elevated ↓ = Depressed	Number and Percentage of 167 with Depositions ≤2 nCi (≤5% mpbb) with Given Finding		Number and Percentage of 72 with Depositions >2 nCi (>5% mpbb) with Given Finding	
Alk. Phos.	↑11 (6.6%)	↓1 (0.6%)	↑4 (5.6%)	↓0 (0%)
LDH	↑2 (1.2%)	↓2 (1.2%)	↑3 (4.2%)	↓0 (0%)
SGOT	↑9 (5.4%)	↓0 (0%)	↑7 (9.8%)	↓0 (0%)
BUN	↑1 (0.6%)	↓1 (0.6%)	↑2 (7.8%)	↓0 (0%)
Uric Acid	↑4 (2.4%)	↓0 (0%)	↑1 (1.4%)	↓0 (0%)
T Bili	↑2 (1.2%)	↓0 (0%)	↑1 (1.4%)	↓0 (0%)
Inorg. Phos.	↑0 (0%)	↓1 (0.6%)	↑0 (0%)	↓0 (0%)
Cholesterol	↑1 (0.6%)	↓0 (0%)	↑0 (0%)	↓0 (0%)

Discussion of Health of Terminated Living Deposition Cases

As indicated in Table VI, six (6) low deposition cases (≤2 nCi) Pu (7.7%) were suffering from malignant disease while none of the higher deposition cases (>2 nCi) had malignancy. There was little difference in the number with no serious disease; 64% of the low deposition cases and 70% of the higher deposition cases reported no serious disease. Incidence of reported ischemic coronary disease was 5.1% in the low

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TABLE VI

INCIDENCE OF DISEASE IN 116 HANFORD TERMINATED LIVING Pu DEPOSITION CASES

Malignant Disease - Organ and Estimated Severity*		78 Cases Estimated ≤5% MPBB**- Pu: No. Cases	78 Cases Estimated ≤5% MPBB**- Pu: % of Cases	38 Cases Estimated > 5% MPBB** - Pu: No. Cases	38 Cases Estimated > 5% MPBB** - Pu: % of Cases	% MPBB
Prostate		1	1.3	0	0	
Poorly differentiated round celled adeno Ca. with extension to bladder - Operation 1/27/75	G					
Colon and Kidney and Ureter		1	1.3	0	0	
Two separate primary cancers, (1) adeno Ca colon, (2) papillary transitional cell Ca of kidney and ureter and left ureter, operation in 1972	G					
Lung		1	1.3	0	0	
Undifferentiated large celled bronchogenic Ca. Operated - partial lung removal 1973. Heavy smoker.	G					
Prostate		1	1.3	0	0	
Adeno Ca - 5-yr remission	L					
Prostate		1	1.3	0	0	
Adeno Ca - Mod. differentiated. Operated 4/16/75	M					
Peroneal Nerve Sheath		1	1.3	0	0	
Neurofibroma (Schwannoma). Surgical re-removal and cobalt 7/19/72	M					
Total		6	7.7	0	0	
Skin - removed - no recurrence in many years	L	1	1.3	0	0	
Other Diseases						
Diabetes Mellitis		1	3.9	1	2.6	15
Neurosis		1	1.3	0	0	
Coccidiomycosis		1	1.3	0	0	
Rheumatic Heart Disease		1	1.3	0	0	

*Severity is an estimate of the seriousness of the malignancy based on cell type, location, metastases, years of arrest following therapy and other factors. Low (L), Medium (M), Great (G)

**MPBB = 40 nCi

TABLE VI (Cont'd)

Other Diseases	78 Cases Estimated ≤5% MPBB - Pu: No. Cases	78 Cases Estimated ≤5% MPBB - Pu: % of Cases	38 Cases Estimated >5% MPBB - Pu: No. Cases	38 Cases Estimated >5% MPBB - Pu: % of Cases	% MPBB
Hypertension	2	2.6	0	0	
Ischemic Coronary Heart Disease					
(a) with infarction I or surgical bypass B	3 }-4	3.9 }-5.1	I and B-1 I-2 Total 3	7.9	9,[illegible].16
Ischemic Heart Disease	1	1.3	0		
Serious Atherosclerosis with surgical arterial replacement - abdomen 1 - legs 2	3 }-4	3.9 }-5.1	0	0	
Cerebral Atherosclerosis with stroke	1	1.3			
Low Pressure Hydrocephalus	0	0	1	0	9
Emphysema	0	0	1	0	35
Hydronephrosis (stricture ureter)	1	1.3	0	0	
Asthma	1	1.3	0	0	
Peptic Ulcer	2	2.6	1 w/surgery	2.6	7
Enteritis	1	1.3	0	0	
Hepatitis	1	1.3	0	0	
Prostatic Hypertrophy	1	1.3	1	2.6	15
Arthritis	3	3.9	1	2.6	10
No Disease	50	64*	27	70*	
White Males	66	86	36	95	
White Females	11	14	2	5	

*Does not add to 100% when added to the percentage of those with identified disease because some with disease had more than one disease process.

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deposition group. 5.1% of the low deposition cases had serious atherosclerosis of extremities or brain while none of the high deposition cases had such troubles. For serious atherosclerosis for all organs the incidence was 7.9% for high deposition cases and 10% for low deposition cases.

Summarizing: There was little difference in health of the two groups considering all diseases other than malignancy. However the incidence of malignant disease was conspicuously lower in terminated employees with the higher depositions.

Discussion of 34 Deaths in Employees Who were Plutonium Workers

There are 34 known deaths among the 452 Hanford Pu workers with any measurable plutonium deposition. A detailed breakdown is given in Table VII. There were three deaths from malignant disease in the group, with one malignant neoplasm of the brain in the $\leq$2 nCi Pu deposition group and one malignant neoplasm of the tongue and one malignant neoplasm of the bronchus and lung in the >2 nCi Pu deposition group. The estimated dose from Pu to lung in the case of bronchogenic carcinoma was one (1) rad. The smoking history is not known in this group.

Ischemic heart disease with or without infarction was the most significant cause of death, accounting for 18 of the 32 deaths having known causes (56%), with 67% in the high exposure group and 48% in the lower exposure group. The higher exposure group was slightly older at death (61 years versus 57 years) which would account for some of this difference.

The incidence of deaths due to malignancy in 32 deaths, in which cause is known (9.4%), is lower than that expected based upon that in a 10% sample of causes of all deaths in 1974 in the United States (Monthly Vital Statistics Report, 1975). The incidence of death due to malignancy was even lower in the lower deposition cases where the incidence was 4.3%. Using a different type of comparison, the incidence of known deaths due to malignancy in all 26,946 male Hanford employees other than those with Pu depositions, 1944 through

TABLE VII

ALL (34) DECEASED HANFORD PLUTONIUM DEPOSITION CASES

Cause of Death	25 Cases Estimated ≤ 5% MPBB		9 Cases Estimated > 5% MPBB*		
	No. Cases	% of Cases	No. Cases	% of Cases	% MPBB ( )**
Malignant Disease					
Malignant Neoplasm of Brain	1	4	0	0	
Malignant Neoplasm of Tongue	0	0	1	11	20 (52)
Malignant Neoplasm of Bronchus and Lung	0	0	1	11	15 (8)
Other Diseases					
Ischemic Heart Disease with Infarction	10	40	5	56	10,20,25,20,65 (55),(18),(60),(56),(19)
Ischemic Heart Disease without Infarction	2	8	1	11	90 (35)
Disease of the Aortic Valve, Rheumatic	1	4	0	0	
Disease of the Aortic Valve, Nonrheumatic	1	4	0	0	
Cerebral Thrombosis	1	4	0	0	
Cerebral Hemorrhage	1	4	0	0	
Generalized Arteriosclerosis	1	4	0	0	
Cirrhosis of the Liver, Alcoholic	1	4	0	0	
Asthma	1	4	0	0	
Amyotrophic Lateral Sclerosis	0	0	1	11	25 (48)
Motor Vehicle Accident	1	4	0	0	
Gunshot Wound to Head	2	8	0	0	
Unknown (at this time)	2	8	0	0	
Total***	25	100	9	100	--
Males	22	88	9	100	
Females	3	12	0	0	

*MPBB = 40 nCi
**( ) Case Reference No. on Table II
***All White

1974, omitting employees with known Pu deposition was 2.43% (654 deaths due to cancer). The incidence of malignancy in 409 male employees with depositions for the same period was 3/409=.73%.

Among the 32 known causes of death in 452 deposition cases, 9 (28%) occurred in cases with > 2 nCi deposition. The 133 deposition cases with >2 nCi represent $\frac{133}{452}$ = 29.4% of the total group. So the incidence of death as compared with the group with ≤2 nCi is slightly less than expected.

Except for one case of amyotrophic lateral sclerosis, no really unusual causes of death were noted.

Discussion of Malignant Disease in Presently Employed, Terminated and Deceased Pu Deposition Cases
See Table VIII

When the living Pu deposition cases are consolidated into one group the incidence of malignant disease is found to be twice as high in the low deposition group as it is in the higher deposition group. More striking is the fact that the severity in 7 of the 9 low deposition cases was great or medium, while that in the higher deposition cases was all low.

The number of deaths (34) is small so that the number of malignancies as cause of death would have to be very high in one or both of the comparison groups to be significant. This was not the case. In fact the total, three deaths due to malignancy in 32 deaths in which cause of death is known (9.4%) is lower than might be expected. Malignancy as a cause of death in a 10% sample of causes of all deaths in 1974 in the United States was 18.5% - unadjusted for age and sex (Monthly Vital Statistics Report 1975). There were only three deaths due to malignancy which is too few to place much credibility on a comparison of the low and higher deposition cases.

PART II OF STUDY - OTHER COMPARISON GROUPS

The present study has been limited to a comparison of present health and mortality of 452 Hanford deposition cases. Those with

TABLE VIII

INCIDENCE AND SEVERITY OF MALIGNANT DISEASE
(OTHER THAN SKIN CANCER) IN ALL CONTACTED (389)
HANFORD EMPLOYEES WHO HAVE A DEPOSITION OF PLUTONIUM

A. 239 Presently Employed at Hanford

Severity of Malignant Disease	167 with ≤5% mpbb	72 with >5% mpbb*
Little	1	2
Medium	1	
Great	1	
	Subtotal 3 (1.8%)	2 (2.8%)

B. 116 Hanford Terminated Living Employees

Severity	78 with ≤ 5% mpbb*	38 with >5% mpbb*
Little	1	0
Medium	2	0
Great	3	0
	Subtotal 6 (7.7%)	0 (0%)
	Total 9 (3.7%)	2 (1.8%)

C. Incidence of Malignancy as Cause of Death in 32 Deaths in Which Cause of Death is Known Among 452 Deposition Cases

	23 with ≤ 5% mpbb*	9 with >5% mpbb*
Number of Deaths	1 (4%)	2 (22%)

*5% mpbb = 2 nCi Pu

depositions of Pu $\leq$2 nCi are compared to those with depositions $>$2 nCi. There remain for study some 1900 Hanford Pu workers who have no positive evidence of deposition. A continuing study will identify more of these. Other comparison groups may be (1) Hanford workers never exposed to Pu (2) brothers of male workers having Pu depositions or sisters of female workers having Pu depositions. These have been identified in the ERDA Health and Mortality Study (Mancuso T.F. and Sanders B.S., 1975). Another comparison may be with 1% of the U. S. working population taken from the social security list. These comparative studies will depend upon findings and recommendations of epidemiological consultants.

DISCUSSION

With the expected greater use of Pu as a fuel in the breeder reactor, there is considerable interest in the hazard of plutonium to the general public. The study group in the report comprises a specific population class which should have the greatest opportunity to be affected by plutonium. It is noteworthy that the highest deposition case in this study (400 nCi) is 200 times the highest in the low deposition cases (2 nCi) and 1000 times the highest observed in autopsy studies of the general population (0.4 nCi)* to our knowledge. Assuming linearity in the dose response curve, the results of this study should be reassuring to the general public who have been told by a few sources that a very substantial increase in cancer might be expected from Pu in fallout from atomic bomb testing. Special emphasis has been placed on the incidence and severity of malignant disease in deposition cases, since this has been the major finding in laboratory animals. However, all types of illness were considered.

This study will serve to emphasize the difficulty of evaluating morbidity and in locating separated employees and the importance of starting such studies early.

*Iral C. Nelson, Battelle Pacific Northwest Laboratories, personal communication.

It was not specifically reported, but comparison of dose to organs due to accumulated external radiation with that due to internal Pu deposition shows that the former adds relatively little to the total dose to relevant organs in most cases.

It is expected that following review by epidemiologists and suggested improvement of this rapidly executed report, it may serve as a pilot for the study covering all major ERDA projects where unencapsulated Pu is handled.

Acknowledgments

We are grateful to a number of people for assistance. Dr. T. F. Mancuso and Dr. B. S. Sanders cooperated in the design of that part of the study dealing with the health of workers presently employed at the Hanford Project and indicated the need of such a study to supplement their continuing study (Mancuso T.F. and Sanders B.S. 1975). J. R. Houston developed the computer program that was used to calculate the dose to organ tissue and provided assistance in assembling the Health Physics data used. Many people; occupational physicians, health physicists, technicians, clerical personnel and others did the actual work over a 31-year period, which made the data collection possible. Hospitals, especially Kadlec Hospital in Richland and many practicing physicians were most obliging in furnishing clinical and pathological diagnoses. Dr. P. A. Fuqua, President of the Hanford Environmental Health Foundation and Dr. S. Marks, Division of Biomedical and Environmental Research, ERDA, furnished long-term guidance.

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U. S. TRANSURANIUM REGISTRY WORKSHOP

Hilton Inn Airport, Denver, Colorado
February 27, 1975

FOR PHYSICIANS   Chairman - S. Marks (ERDA)

PRESENT

Fuqua, P. A., Hanford Environmental Health Foundation
Hempelmann, L. H., University of Rochester
Hutchison, G. B., Harvard
Lincoln, T. A., Oak Ridge National Laboratory
Lushbaugh, C. C., Oak Ridge National Laboratory
Miller, B. L., Jr., Rocky Flats
Marks, S., Division of Biomedical & Environmental Research (ERDA)
Norwood, W. D., U. S. Transuranium Registry
Poda, G. A., Savannah River
Putzier, E. A., Rocky Flats
Reagan, E. J., Mound Laboratory
Sterner, J. H., USTR Advisory Committee
Thompson, R. C., Battelle Northwest
Voelz, G. L., Los Alamos Scientific Laboratory
Wachholz, B. L., Division of Biomedical & Environmental Research (ERDA)

USTR PURPOSE AND OPERATION

The general purpose and operation of the USTR was stated by the chairman, Dr. Marks, and discussed by others as follows. The USTR is made up of transuranium workers, defined as workers who have a body deposition as a result of occupational exposure or whose occupational activities present a reasonable opportunity to acquire internal deposition of any of the transuranium elements. The USTR has effected (1) identification of these workers, (2) collection of health physics and medical information data and (3) secured authority for autopsy and autopsies on deceased transuranium workers. Effort has been made to enlist contractor cooperation. Families have been alerted to the autopsy study and the procurement of autopsy tissue samples. The families or estates of transuranium workers have been compensated following actual autopsy and procurement of autopsy tissue samples. The samples are assayed at Battelle Northwest, Los Alamos or Rocky Flats Laboratories and results are accumulated by USTR.

PARTICIPATING GROUPS MAKE UP USTR

It was emphasized that the USTR is a combination of participating groups, that each group makes its own study and publishes its own results. The USTR responsibility is for the over-all collection and evaluation of the data secured from all groups. This permits the pooling of autopsy tissue samples for more definitive assay; for example, a study of the location of plutonium in bone. It also effects some necessary uniformity in the procedures of the cooperating laboratories. One Los Alamos case was cited to illustrate that final assay results may be held up in order to make plutonium lung distribution and lymph node studies. It was agreed that tissue banking can be highly desirable.

BROADENING USTR SCOPE

The chairman described the USTR discussions with the Battelle Biology Laboratory for effecting special studies on USTR human autopsy material and data. He then stated that the other direction for broadening the USTR scope is epidemiology. The usual cancer incidence expected in the population was discussed and stated to be about one-third of all deaths. Dr. Lushbaugh emphasized that, when a person dies of cancer, families of the deceased are more interested in having an autopsy performed than if the person dies of a less interesting disease such as cirrhosis of the liver. The occurrence of cancer in TU workers and the relationship to plutonium deposition was discussed.

THE PLANNED EPIDEMIOLOGY STUDY

Autopsy studies do not answer questions about incidence. Incidence of mortality in autopsied individuals should not be compared with incidence in nonautopsied cases due to the bias occasioned by selection of autopsy cases. A carefully conceived epidemiology study with follow-up is now planned, and it is believed that the climate is now strong enough for support at all management levels. LASL is a likely candidate to serve under the Registry semi-autonomously as the coordinating center of the epidemiology study. A good epidemiology study requires a well defined population. The contractors have good records with health physics data.

Dr. Norwood stated that he believed that the best epidemiology study is done with all the population at risk. Dr. Marks stated that he did not agree in that smaller groups can be defined which will be adequate for a good study. There must be controls which can be a variety of well defined groups.

CHEMICAL EXPOSURES

Questions were raised about other hazards involved such as neutron radiation, solvents such as carbon tetrachloride, and other chemicals and as to whether data will be good for human chemical exposures. It was pointed out by Dr. Sterner that generally there is little or no quantified data on these exposures.

DEFINITION OF CLASSES OF WORKERS

Dr. Marks stated that a few classes of workers can be well defined. They are (1) active workers (easiest), (2) separated workers (not retirees), (3) retirees and (4) deceased workers. A good epidemiology study establishes the incidence of disease and length of life from morbidity and death data, and the study population must be fully tracked down. A good study can be done with a study population of a few thousand. One is better off working with smaller well defined groups than large poorly defined populations. (Attachments I and II)

THE IMPORTANCE OF HIGH YIELD ON FOLLOW-UP

Dr. Hutchison emphasized the importance of high yield on follow-up. One should go after 100%. If you can't get 60%, do not bother with the population group. It appears that in this situation you will get 90% at least. Dr. Sterner asked whether one would add significant deposition cases to the study groups. Dr. Hutchison stated that he would not, that this addition would result in bias. Original employment lists should be obtained as the base. The reliability of urine assay was questioned by Drs. Voelz and Hempelmann. Dr. Lushbaugh asked how you predict in advance that you can get more than 60%. Dr. Hutchison stated that in the present proposed study we have good information. Dr. Lushbaugh disagreed while Dr. Marks supported Dr. Hutchison's contention.

FUNDING OF EPIDEMIOLOGY STUDY

The question of sufficient funding for the study was raised by Dr. Norwood. He indicated that a prospective rather than a retrospective study would be expected to cost less. Dr. Marks stated that ERDA was expected to fund the study and that we cannot wait for a prospective study. Questions about relative costs were discussed, and Dr. Hempelmann stated that he located 76% of cases without much effort at Los Alamos. Dr. Wachholz raised the question of the availability of information on how body burdens were received. He was assured that such information was sometimes available, but it was agreed that in some cases this information is not known and is not obtainable.

APPROACHES FOR EPIDEMIOLOGY STUDY

Desirable approaches for an epidemiology study were summarized by Dr. Marks as follows:

1. Mortality
   - (a) Cause of death obtained
   - (b) Social Security processing
2. Morbidity
   - (a) Data available from personnel files of active workers
   - (b) Have clinical and health physics examination (plutonium body burden from urine analysis).

CONTROL GROUPS

At this point, a general discussion of desirable control groups began. The first group considered were siblings of the same sex. Also, all employees other than TU workers, state populations, applicants medically cleared for employment but who never started to work and a fraction of the national population were mentioned. In answer to Dr. Lushbaugh about persons who do not have brothers and sisters, Dr. Hutchison replied that this situation would cut down the size of the group but that he would not worry about internal bias since this would be a small group. He also said that the Mancuso Study (ERDA Health Study) looked at this situation both ways, leaving this group in and out. Dr. Marks stated that this planned epidemiology study will not use siblings for controls but will probably use other plant employees. He also stated that it is hoped to have Mancuso Health Study data eventually from all major plants prospectively. Discussion of methods of clinical follow-up and the value of obtaining health physics data continued.

CLINICAL EXAMINATION

Dr. Marks concluded that controls should be matched for mortality analysis and raised the questions of what to do for clinical follow-up and the feasibility of matching in view of potential difficulties in obtaining clinical examinations of persons without depositions. The use of vital statistics incidence information was thought to be of little or no value. The use of a questionnaire for follow-up was discussed.

Dr. Marks concluded that an epidemiology study is necessary and that it should include morbidity data.

USE OF QUESTIONNAIRE IN LIEU OF CLINICAL EXAMINATION

Dr. Hutchison discussed the use of a questionnaire as the most effective and best for use with separated personnel rather than clinical examination. Dr. Hempelmann described mail surveys as inexpensive and said that he had obtained a good response in Los Alamos case follow-up. If there is no response, he has found great success with follow-up telephone calls carried out by medical students. Dr. Lincoln raised the question of remuneration for filling out questionnaires. The consensus appeared to be that this was not necessary. Dr. Norwood cautioned that when you concentrate on small numbers of workers with expanded clinical examination you create unjustifiable liabilities and that expanded uses of questionnaires could significantly decrease this potential and greatly reduce costs incurred.

LASL PLUTONIUM WORKER STUDY

Dr. Voelz concluded the morning session for physicians with a current summary (Attachment III) of the clinical follow-up of LASL separated employees who have transuranium element burdens. He stated that, of 26 reported, there has been one additional death recently. Attempts are being made to expand the study. Nearly 200 of 260 persons have been located. They have 4 people with tumors, two are terminal and are expected to die within a year. In 11 cases who are deceased there have been no malignancies.

REPRINTS

Dr. Marks provided reprints to all attendees as follows: (1) "Basic Considerations in the Assessment of the Cancer Risks and Standards for Internal Alpha Emitters" by Edward A. Martell (statement presented at the public hearings on plutonium standards sponsored by EPA, Denver, Colorado, January 10, 1975 and (2) Plutonium (II) "Watching and Waiting for Adverse Effects" by Robert Gillette, Science, Vol. 185, September 1974. See Attachment V for (2). Dr. Martell's article is long and will be sent on request.

This concluded the morning session for physicians.

FOR HEALTH PHYSICISTS Chairman - C. E. Newton (USTR)

PRESENT

Auxier, J. A., Oak Ridge National Laboratory
Bisline, R., Rocky Flats
Campbell, Charles, ERDA
Crain, Sue, Mound Laboratory
Lagerquist, C. R., Rocky Flats
Lawrence, J. N. P., Los Alamos Scientific Laboratory
McInroy, J. F., Los Alamos Scientific Laboratory
Newton, C. E., Hanford
Walke, Pat, Savannah River Plant

PROCUREMENT AND TISSUE SAMPLE PREPARATION

Following a general introduction and review of the attached agenda of the one-day USTR workshop, Mr. Lagerquist centered attention on procurement of autopsy tissue samples. He pointed out that they had moderately good success in obtaining pre-death autopsy releases. Of about 1500 employees interviewed they had obtained 156 signups, or about 10%. In spite of this success he noted that of their 30 recent autopsy cases only one resulted from a pre-death release. He noted, however, that the degree of success in obtaining the tissues at autopsy relied heavily upon the interest shown by the plant personnel, particularly the plant physician and health physicist. Additionally, the money paid the next of kin ($350.00) appears to be of great interest and plays a more important part than they initially realized. There are two additional areas that help them in securing the release and these are the interaction of the employees with the plant personnel department which provides timely notice of the employee's death. Generally this department is notified almost immediately because of reimbursements regarding insurance and past wages. The other point was that the USTR, acting as a third party, helps in the interview with the next of kin in obtaining the release as the USTR is represented as national in scope and the cooperation is not just for the benefit of Rocky Flats or the immediate locale.

In addition to the forms used and predescribed by the Registry, Rocky Flats has introduced a form submitted to the next of kin for signature which not only describes the specific organs that they are interested in but informs the next of kin that they intend to take entire organs such as lung, liver and heart. They have also found that it is an advantage to have prepared a briefcase containing all of the supplies necessary to label and package the tissue samples and literature describing the size and list of tissues desired for the use of the pathologist. If the organ samples are not to be analyzed immediately, for example, if obtained on Friday evening, the samples are then quick frozen, except for the lungs, until such time as personnel are ready to begin the laboratory analyses. The lungs are not frozen but perfused and stored in formaldehyde. When the lung is processed there is some question in the minds of the personnel at Rocky Flats that lymph node separation is sufficiently complete and they are uncertain as to the reliability of data based on the separation. Mr. Lagerquist displayed a number of slides for the purpose of showing the great variability in the distribution of plutonium in the tissue samples that have been processed so far. It was quite evident from the slides, that almost any major organ can be the preferred site of deposition, depending upon the vast number of variables associated with the deposition cases.

TISSUE ANALYSIS

The subject of tissue analysis was discussed by Mr. McInroy of Los Alamos and he indicated that they are placing more and more emphasis on looking at Pu 238 as well as Pu 239 and suggested that perhaps other contractors should also look at this isotope more closely. In the laboratory he discussed the use of Pu 242 as an internal spike to determine the efficiency of Pu recovery from autopsy specimens. Plutonium 242 was judged superior to Pu 236 tracer, since the lower energy portion of the Pu 236 spectrum complicated evaluation of the lower energy isotopes of plutonium. Plutonium 242 having an alpha energy lower than either Pu 239 or Pu 238 did not interfere with the spectrometer analysis of these isotopes.

The matter of establishing the weight of the organs sampled was discussed and as is well known, the lung weight at death does not normally reflect the normal weight of the lung and the possibility of establishing a basis of using the dry weight was explored. It was noted, however, that the various laboratories may or may not ash the sample to complete dryness and thus difficulties would be encountered in trying to use this approach. It was noted that the various laboratories have stored the tissues as formalin fixed and frozen tissue specimens, although currently LASL prefers the formalin fixed procedure as the anatomical relationships in the tissue are not destroyed. Additionally when samples of the entire lung are obtained it is possible to inflate the lungs and examine them in a lung counter for a determination of the Pu content prior to laboratory procedures. A subject of particular interest to the USTR was possible procedures to separate bone marrow from the bone and LASL indicated that they did not do this and that if they were to attempt it they would probably need larger bone specimens, probably from other anatomical locations than the rib, vertebrae and sternum that they are now getting. This brought up the discussion of the homogeneity of the Pu distribution in the various samples and bone and lung remain the organs which are suspected to have the most heterogeneous distribution. The distribution in human bone has not been pursued by

LASL, although they have had some interaction with Dr. Jee, as has Hanford. Dr. Auxier of Oak Ridge indicated that he would be happy to accept the bone samples for the Registry and work with Dr. Jee in obtaining spectrum and flux necessary to obtain the fission tracks necessary for analyses.

ESTIMATES OF ORGAN DOSE

In addition to the material that follows, which was presented by Dr. Auxier, he presented to the group a draft of "Comments on Dosimetry of Plutonium for the Transuranium Registry Workshop" prepared by ORNL Health Physics Division. This draft document rather than a summary has been attached for the convenience of those interested in the details of this subject. (Attachment IV)

The preponderance of animal research and human experience has been with plutonium. Therefore, use should be made of the results from plutonium research to indicate the influence of the time factor on the distribution of transuranium elements in the body and the relation between the body burden and transuranics in the urine. Chronic, long-term intakes of these elements will be through inhalation incidents. Single intakes lead to translocation and excretion conforming to established models. (a) A single inhalation gives clear rates described by the Task Group Lung Model. (b) The rapid, early excretion of inhaled soluble compounds has been calculated by Beach and Dolphin, and Healy has modified Langham's equation to account for the slow clearance of insoluble material from lung to blood. Heid et al., have reviewed the perturbation of chelating agents and conclude that enhanced excretion persists for as long as 100 days after termination of treatment.

For highly soluble materials which clear rapidly from the lung, major differences in distribution and effects would not be predicted for acute and long-term, chronic intakes. Some difference in ratios of deposition in liver to bone might be anticipated in the two cases because of the slower clearance of transuranics from bone.

For inhalation of insoluble material, the slow clearance from the deep lung could lead to differences in retained material at autopsy in the two cases of acute and chronic exposure. Clearance half-times of 500 days or greater are suggested in the Task Group Lung Model. Thus - (a) radiation to the lung could be different in the two modes of exposure and (b) the ratios of transuranic concentrations in lung and liver to that in bone would be expected to differ in chronic and acute exposures.

The isotopic composition of the transuranic depends on the materials, methods and conditions of preparation. The elements in greatest abundance will be those formed in nuclear reactors by neutron reactions with uranium isotopes and with the products of these reactions. For example, the plutonium formed in a brief reactor exposure of uranium reactor fuel is 99 weight % ^{239}Pu; in an exposure of 13,000 MWD/T, is 79% ^{239}Pu, 15% ^{240}Pu and 1% ^{242}Pu. In a heavy exposure (33,000 MWD/T) the ^{239}Pu is down to 56% while ^{242}Pu has increased to 5%

The modes of decay and half-lives of the various isotopes of the transuranics differ and will determine biological hazard and methods of analysis and measurement. Most, but not all, of the isotopes decay by alpha emission. A notable exception is ^{241}Pu, decaying by β emission to make it considerably less hazardous than the other isotopes of Pu. The relatively short half-life (13 yr.) of this isotope means that any plutonium containing an appreciable fraction of ^{241}Pu will undergo ingrowth of ^{241}Am to permit convenient detection by means of the penetrating 60 keV gamma ray of this radionuclide.

The great differences in specific activity (half-life) among the various isotopes mean that there will be large mass and concentration differences for a given activity administered or in an organ. There are indications that the distribution and organ retention differ for ^{239}Pu and the isotopes ^{237}Pu and ^{238}Pu. Obviously, dose and body burden as a function of time depend on half-lives. Apparently the dependence of organ distribution on specific activity results from two factors: high cell mortality and redistribution with isotopes of high specific activity, and concentration effects on rates of polymerization of soluble compounds.

Regarding dependence of distribution on chemical solubility (it is assumed "solubility" for the USTR means solubility of ingested materials and not of autopsy samples) the latter can be handled by appropriate dissolution procedures for the various tissues as described in laboratory manuals of standard analytical methods. Soluble actinide compounds, especially plutonium, quickly hydrolyze in the neutral (pH ~7) media of the body and unless Pu^{+4}, the common form, is found in a complex, the hydrolyzed ion polymerizes to form suspended, colloidal particles. Polymeric actinides deposit largely in liver rather than bone; monomeric (or dissolved) actinides deposit preferentially in bone. The excretion patterns depend on this distribution between liver and bone. Elimination from the liver is primarily through the bile and gastrointestinal tract. Elimination from bone and most soft tissues other than liver is via blood to urine. From the standpoint of the USTR, it is important to correlate organ distribution and excretion patterns with chemical solubility of the ingested material.

The Task Group Lung Model has classified inhaled materials on the basis of clearance times as determined by solubility. Only highly complexed actinide ions (e.g., citrate, DTPA complex) remain soluble enough in neutral media to clear the lung within days (Class D). Nitrates, chlorides and probably sulfates and carbonates of the actinide elements are sufficiently soluble to clear within weeks (Class W). The insoluble compounds, notably including the oxides (the most common material in exposure cases), clear with half-times of the order of a year (Class Y).

As indicated, complexed actinides distribute in the pattern characteristic of "monomeric" ions, i.e., 75 - 90% skeletal. The soluble but hydrolyzable compounds (nitrates, chlorides, carbonates, etc.) will either hydrolyze and polymerize or will complex with the blood protein transferrin if enough reserve acidity accompanies the actinide. Then, as above, polymeric to liver, complexed monomeric to bone. The insoluble compounds deposited in the pulmonary region clear by cellular engulfment (phagocytosis) part going to lymph, part to blood and the balance up the tracheobronchial tree to the GI tract. These processes are slow (years) and the partition between process probably depends on particle size and radioactivity. Here phagocyte mortality plays a part and is influenced by specific activity (isotopic composition). Obviously, for the common situation of long-term exposure to oxide dusts, the lymph nodes will be a major repository and as much as 70 - 90% of the body burden has been reported in the pulmonary lymph nodes.

The complexed compounds mentioned above will penetrate the gut wall readily and will be largely deposited in the bone. The soluble but hydrolyzable compounds will polymerize. There will be very little transport through the intestinal lining. The small amount of polymeric actinide entering the blood stream will deposit preferentially in the liver. Oxides and other insoluble compounds (hydroxides, carbides, etc.) will be excreted with even less uptake than with the hydrolyzable compounds. How the material penetrating the gut wall is distributed is "still the subject of debate."

Behavior of the various actinide compounds will follow the scheme laid out above for wound injection: (a) complexed actinide ions via blood to bone, (b) hydrolyzable compounds polymerize, are transported to lymph nodes and to liver, the distribution and rates depending probably on reserve acidity which retards hydrolysis. In any case, movement by lymph is slow and limited to nearby nodes. (c) Excretion patterns of ^{241}Am in baboons have been found heavily dependent on division between liver and skeleton. Fecal to urine ratio was changed by a factor of two by decreasing the pore size through which the injected citrate was filtered from 0.45 μm to 0.22.

Injected oxides, metals or other insolubles will be transported to lymph nodes at slow rates depending on particle size. For particles of appreciable size, there will be no movement and the insoluble material will be enclosed in fibrous scar tissue which may become cancerous.

DATA COLLECTION

Mr. K. R. Heid discussed the following data that would be useful for early assessment of probable severity of an intake: (1) concentration of Pu aerosol, (2) duration of exposure, (3) nasal smears, (4) contamination spread, and (5) type of accident. Data that would be directly useful for evaluation of intake was discussed as: (1) bioassay data, (2) in vivo examination data, (3) particle size, (4) isotopic composition, (5) chemical form of aerosol and (6) solubility of aerosol.

It was pointed out that there was a lack of uniformity in practices to the extent that comparison of evaluation of intakes was questionable. Standardization is definitely needed in the following areas of health physics evaluations: (1) Particle Size: both in the source of particles and in sizing techniques. (2) Solubility: In what material? Over what time reference, etc. (3) Chemical Form: Oxides -- are they high fired? Air oxidized or what? (4) Mathematical models to be used for evaluation. (5) Dose calculations to organs, etc.

Input from Hanford to the ERDA Health and Mortality Study was described including exposure to toxic environments, medical exposure, occupational radiation exposure (external and internal, including calculation of dose to lungs, liver, bone, and lymph node). In all cases, raw data should be collected and retained indefinitely.

UNIFORMITY IN DATA

The need as mentioned above for assessing, defining and where possible increasing the degree of uniformity among major ERDA contractors in the collection, processing and analyses of health physics data was acknowledged by all present. Since significant deviations or interpretations will have a serious adverse effect on proposed or ongoing epidemiological studies, Carlos Newton has been assigned the responsibility of selecting a panel of contractor health physicists to meet soon to give attention to this matter.

FOR ALL ATTENDEES Chairman - W. D. Norwood, M.D. (USTR)

PRESENT — Attendees of both physicician and Health Physics sessions.

AUTOPSY AT ROCKY FLATS — The chairman for Health Physicists, C. E. Newton, Jr., USTR, summarized the Health Physics meeting. He stated that at Rocky Flats the majority of releases for autopsy are obtained after death. Success is dependent on interest of physician and his contacts. Money to next of kin has been an important item. When a TU worker dies the personnel department is generally notified and is a good source of prompt information that death has occurred. The medical department uses a separate release (other than prescribed by USTR) to describe each sample and the sample size taken for autopsy.

LABORATORY ANALYSIS OF AUTOPSY TISSUE SAMPLES — Autopsy tissue samples are assayed at three different laboratories - Battelle Northwest, Los Alamos and Rocky Flats. Although all do not use the different techniques and tracer, a program is well underway to determine the degree and significance of any variations so that intercomparisons of lab results are meaningful. The autoradiography of bone and other tissues is desirable in high deposition cases. The problem is not a simple one. Dr. Webster Jee used neutron activation on some bone. John Auxier at Oak Ridge has volunteered to do this. Bone samples are to be sent to him and he will cooperate with Webster Jee. Long bone is needed. Dr. Lushbaugh pointed out that when the need is to get the bone marrow, the head of the femur not the shaft, should be used. The sternum, pelvis, and long wedges of vertebral bodies are also good sources of red bone marrow. He further stated that autopsy lung weights are not scientific, that with terminal illness the lung is distorted by pneumonia or cancer or fluid and that normal weights of lungs should be used to determine plutonium per gram content.

HEALTH PHYSICS DATA COLLECTION — The chairman continued and reported that health physicists do agree on not using rem units for autopsy samples. He stated that Ken Heid reported on data collection at Hanford to assist in the evaluation of a plutonium intake via inhalation as follows:

A. Data useful for early assessment of probable severity

1. concentration of plutonium aerosol
2. duration of exposure
3. nasal smears
4. contamination spread
5. type of accident

B. Data directly useful for evaluation of intake:

1. bioassay sampling
2. in vivo examination
3. particle size
4. isotopic composition
5. chemical form of aerosol
6. solubility

This data should be obtained and maintained. The feeling of the group was that USTR should approach all problems in a standard manner. There were not major technical differences. There was no agreement on solubility determinations or particle size determinations. A way is needed to relate data to a model. The consensus was to ask USTR (C. E. Newton) to form a small task group of health physicists to work on this task soon. Why do isotopes vary in body distribution? There may be more reasons than effect of mass.

BODY ORGAN DEPOSITIONS

Slides were shown by Clayton Lagerquist to illustrate the variables (% differences) that are occurring that affect health physics determinations for bone, liver, lung and remaining depositions. The emphasis was that every case is different in deposition results.

BODY BURDEN FROM URINE ANALYSIS

When we base deposition determinations on urine assay, the estimates of body burden may be on the high side by a factor of 2 or 3 when compared to tissue analysis. Plutonium 238 is an item of interest. Studies are in progress for study of the half time of transfer of plutonium from the lung.

15 days	500 days	1000 days
most sol.	less sol.	least sol.

PLANNED USTR EPIDEMIOLOGICAL STUDY

Dr. Marks, Chairman for physicians, discussed the planned epidemiological study. He stated that there was not complete agreement at the medical meeting. He stated that this study is a component of the broadening of USTR scope and that the autopsy study is also being broadened by bringing in Battelle Northwest, with Roy Thompson, for more definitive study of human autopsy data.

WHY DO EPIDEMIOLOGY STUDY

Autopsies are not a good source of cases for an epidemiologic study because they introduce biases. Management cooperation will be needed for the study. The study will involve defining a population for study, either the entire population at risk or workers who have burdens at different levels. Categories of workers may include those who are still employed, separated but not retired workers, retirees and deceased workers.

STUDY NEEDS

The study will obtain mortality and morbidity data. There is need to get a high yield of follow-up. If only 60% follow-up is obtained the study should not be carried out. Morbidity data appears easy enough to get on current employees but when employees have separated you run into a different problem. Bringing persons back for clinical and health physics examination was discussed. The consensus was that this procedure would be expensive and would not be sufficiently beneficial to justify the expense. The best system is to use questionnaires.

CONTROL GROUPS

Matching within plants seems to be best. Maximum effort is needed by all groups to conform to some basic protocol. Staff personnel from the coordinating center may need to go out to collect or train people.

USTR PURPOSE

Dr. Norwood stated that the purpose of the USTR is to try to determine if TU work is detrimental to worker health. Is there an increased incidence of disease during life? Where are plutonium body depositions? Where is plutonium deposited in bone? 10^9 curies of TU elements may be produced by the nuclear power industry by the year 2000. Am-241 and Cm are expected to be resulting from future nuclear power generation. Mound Laboratory data is important for plutonium 238 data and Savannah River data for ^{241}Am and Cm. Is the linear threshold applicable to plutonium? In the radium study the practical threshold appears to be 1000 rads. We cannot extrapolate animal data to man but we must get all possible data. Little attention has been given to controls to date by participating projects in human studies except for the Health and Mortality Study, which makes such data available on Hanford workers. Licensees expected to participate in the USTR include Nuclear Fuel Services, Inc. (NFS), Nuclear Materials and Equipment Corporation (NUMEC) and Kerr-McGee. Exxon is beginning to handle Pu and we are beginning to get authorizations for autopsies. Windscale will fill out USTR data sheets on their autopsy cases. Windscale has requests to compensate for leukemia and for extra hazard pay. Dr. Norwood concluded with slides illustrating methods for USTR data collection.

REPORTS OF MEDICAL DIRECTORS ON USTR DATA COLLECTION

Dr. Fuqua reported that starting USTR activity at Hanford may have been easier since they had followed employee death rates long before the Health Study was begun. To date Hanford has identified 2330 transuranium workers of whom 92% have authorized procurement of medical and health physics data. Obtaining authorizations for autopsy prior to death was new to them and some were not optimistic about a high percent of acceptance. However, 22% or 526 of those identified as TU workers have signed autopsy releases on the basis of participation in a scientific study and the expectation of a certain payment of $350 to their estates. Pre-planning autopsy before death and authorizing USTR procurement of tissue samples has eliminated untimely urgency at the time of death and is believed to be the preferred practice for higher autopsy authorization before death. They do have morbidity data on accident and health insurance claims after seven days. Dr. Voelz at Los Alamos has identified 250 TU workers and has solicited USTR participation and autopsies at time of dispensary visits. Dr. Lincoln at Oak Ridge stated that they believe plutonium there is a relatively small problem. They have had one autopsy. They have a cancer registry and morbidity data is available from examination results.

USTR STATISTICS AND DATA COLLECTION

Dr. Norwood handed out a table of USTR statistics and discussed USTR study design. He then illustrated with slides some forms used for USTR data collection. These included forms used for medical history, physical examination, x-ray and laboratory work and health physics screening forms.

USTR AUTOPSY STUDY

Dr. Norwood asked Dr. Hutchison to comment on study of USTR data. Dr. Hutchison stated that USTR registration and analysis activity should be distinguished from each other. One should not use all registrants for study. The day-to-day and year-to-year operation is a different activity from the analytical. The most suitable groups to compare are burden groups vs. other employed. There may be other interesting groups. Detailed protocols should be prepared. Sibling controls have been used. One should consider other industrial groups and general population mortality data, morbidity, tumor registry, or other cancer incidence data. There is no cancer data for the whole country. Outside of cancer data, the situation is worse. There are no general figures available for other diseases. Outcome measurements may include total morbidity, cancer mortality, hemopoietic findings, cancer suspects, bone tumors. We do not need to include chronic leukemias.

Dr. Sterner stated that OSHA (and ERDA has OSHA responsibilities) stipulates the kind of records required for arsenic workers because arsenic is now thought of as a carcinogen. The use of forms for data collection might be the factor that would break us all apart. We may drag our heels with forms now but we must agree on what data to collect and then get what is collected in usable form for study.

LICENSEE PARTICIPATION

Dr. Wachholz raised the question of licensee participation. Dr. Norwood replied that none have said no but those with Pu workers are only partially participating to date. They do not like to ask employees to participate for fear of charge of coercion and would prefer that USTR ask.

USTR AUTOPSY STUDY INFORMATION

Dr. Norwood continued with illustrations for USTR data collection. Dr. Marks said that this extensive data may not be needed for the epidemiology study. There has to be a compromise as to what we now need with what the need is for the future. Dr. Lushbaugh commented that the data collected may determine the epidemiology study and vice versa. Dr. Hutchison stated that the analytical system will focus on a much smaller amount of data. Dr. Norwood stated that the objective is to carry out studies in industrial plants with USTR correlation of the data. The USTR Advisory Committee has been most helpful in developing guidelines for USTR operation. Dr. Hutchison said that a protocol should state when results can be expected and when they will be reported. If, for example, we have 400 people in a study and one-half are separated, then we already have a large number of malignancy cases. We can tell if there was a doubling of the incidence. One should be able to tell that in a short time. This is something that one can report. A discussion on answering questions about health effects and providing information continued.

CONCLUDING REMARKS

Dr. Norwood asked Dr. Sterner, Chairman of the USTR Advisory Committee, for concluding comments. Dr. Sterner stated that the Advisory Committee had been concerned with USTR progress but he now feels that important work will be accomplished with ERDA support. He indicated that he particularly hoped that this meeting had whetted the appetite of Dr. Hutchison and that we can obtain his further assistance.

Dr. Norwood expressed his thanks to Mr. Ed Putzier for the meeting arrangements and Mr. Putzier gave credit to his secretary.

Dr. Marks concluded that he thought that this was a very fruitful meeting, that he regretted that physicians could not have been also present at the health physics session. He thanked Dr. Norwood for getting the meeting together and for his continued enthusiasm in the USTR.

PAF:dp
5-6-75

ATTACHMENT I

February 1975

PRESENT ESTIMATE OF
NUMBERS OF CURRENT AND SEPARATED EMPLOYEES WITH
POSITIVE DEPOSITION OF TRANSURANIUM ELEMENTS

HANFORD PLUTONIUM DEPOSITION CASES - 1973 Summary

Percent M.P. Deposition	*Current	**Separated	Total
< 5	137	144	281
5 - 10	31	29	60
10 - 25	26	19	45
25 - 50	4	6	10
50 - 100	1	6	7
100 & over	5	1	6
Totals	204	205	409

Percent Deposition	*Current	**Separated	Total
10 & greater	36	32	68
25 & greater	10	13	23
50 & greater	6	7	13
100 & greater	5	1	6

* Supplied from Personnel Dosimetry Section BNW
** Terminated and Retired

SAVANNAH RIVER PLUTONIUM DEPOSITIONS

Percent M.P. Deposition	Current	Separated	Total
< 5	149	86	235
5 - 10	47	21	68
10 - 20	23	5	28
20 - 50	15	1	16
50 - 100	3	0	3
> 100	0	0	0
Totals	237	113	350

Percent Deposition	Current	Separated
10 & greater	41	6
20 & greater	18	1
50 & greater	3	0
100 & greater	0	0

SAVANNAH RIVER Am Cm Cf-53

	Current (44)					Separated (9)	
MPBB	Am	AmCm	Cm	CF	Total	Cm	Total
< 5%	1	1	34	0	36	7	7
5 - 10 %	0	0	4	1	5	0	0
10 - 20%	0	0	0	0	0	1	1
20 - 50%	0	0	1	1	2	1	1
50 - 100%	0	1	0	0	1	0	0
> 100%	0	0	0	0	0	0	0

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ROCKY FLATS PLUTONIUM DEPOSITIONS

Percent M.P. Deposition	Current	Separated	Total	Percent Deposition	Current	Separated	Total
10 - 25	225	86	311	10 & greater	285	108	393
25 - 50	43	15	58	25 & greater	60	22	82
50 - 100	10	2	12	50 & greater	17	7	24
100	7	5	12	100 & greater	7	5	12
Totals	285	108	393				

LOS ALAMOS PLUTONIUM DEPOSITIONS

Percent M.P. Deposition	Current	Separated	Total	Percent Deposition	Current	Separated	Total
< 5	895	1025	1920	10 & greater	273	394	667
5 - 10	210	227	437	20 & greater	154	188	342
10 - 20	119	206	325	50 & greater	49	37	86
20 - 50	105	151	256	100 & greater	24	7	31
50 - 100	25	30	55				
>100	24	7	31				
Totals	1378	1646	3024				

MOUND LABORATORY PLUTONIUM ^{238}Pu DEPOSITIONS

Percent Syst. Body Burden 238Pu	Current	Separated	Percent Syst. B.B.	Current	Separated
< 10	- 2 lung deps.			2	
10 - 20	26	28	10 & greater	71	59
20 - 30	16 + 1 lung dep.	11	20 & greater	43	31
30 - 40	9	7	30 & greater	36	20
40 - 50	5	3	40 & greater	27	13
50 - 75	10	5	50 & greater	22	10
75 - 100	3	0	75 & greater	12	5
> 100	9	5	100 & greater	9	5
Total	68 + 3 lung deps	59			

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PRESENTLY EMPLOYED Pu WORKERS WITH DEPOSITIONS GREATER THAN
THE INDICATED % OF MAXIMUM PERMISSIBLE Pu DEPOSITION
APPROXIMATE TOTALS, HANFORD, S.R., R.F., L.A., MOUND

Currently Employed (Active)

Percent Deposition	Hanford	Savannah River	Rocky Flats	Los Alamos	Mound	Total
10 & greater	36	41	285	273	79	714
25 & greater	10	18	60	154	53	295
50 & greater	6	8	17	49	22	97
100 & greater	5	0	7	24	9	45

Separated Employees (Inactive)

Percent Deposition	Hanford	Savannah River	Rocky Flats	Los Alamos	Mound	Total
10 & greater	32	6	108	394	59	599
25 & greater	13	1	22	188	31	255
50 & greater	7	0	7	37	10	61
100 & greater	1	0	5	7	5	18

NUMBERS OF EMPLOYEES WITH + DEPOSITIONS OF Pu
DIVIDED INTO GROUPS ACCORDING TO % M.P.B.B.

Currently Employed

% M.P.B.B.	Hanford	Savannah River	Rocky Flats	Los Alamos	Mound	Total
< 5	137	149		895		1181
5 - 10	31	47		210	2	290
10 - 25	26	23	225	119	26	319
25 - 50	4	15	43	105	31	198
50 - 100	1	3	10	25	13	52
> 100	5	0	7	24	9	45
Total c̄ + Burden	204	237	285	1378	81	2085

Separated Employees

% M.P.B.B.	Hanford	Savannah River	Rocky Flats	Los Alamos	Mound	Total
< 5	144	86		1025		1255
5 - 10	29	21		227		277
10 - 25	19	5	86	206	28	344
25 - 50	6	1	15	151	21	194
50 - 100	6	0	2	30	5	43
> 100	1	0	5	7	5	18
Total	205	113	108	1646	59	2131

TOTAL NUMBER OF TRANSURANIUM WORKERS WITH EVIDENCE OF Pu DEPOSITION CATEGORIZED AS HAVING GREATER THAN A CERTAIN PERCENT OF M.P.B.B.

% M.P.B.B.	Current Employees	Terminated Employees	Total
10 & greater	716	599	1315
25 & greater	285	255	540
50 & greater	97	61	158
100 & greater	45	18	63

"A" Estimated number of current and separated employees with identifiable Pu deposition equals 2085 (current) + 2131 (separated) = 4216 (total)

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ATTACHMENT II

U. S. TRANSURANIUM REGISTRY STATISTICS

1975

	Transuranium Workers Identified			Health Physics and Medical Releases			Authority For Autopsy			Autopsies Obtained			Autopsy Reports Complete		
	Mo. Feb.	CY to Date	Total to Date	Mo. Feb.	CY to Date	Total to Date	Mo. Feb.	CY to Date	Total to Date	Mo. Feb.	CY to Date	Total to Date	Mo. Feb.	CY to Date	Total to Date
Hanford	3	8	2338	3	8	2149	-1	1	526	0	0	14	0	0	8
Rocky Flats	11	15	1747	11	15	1587	0	0	168	0	0	30	0	0	28
Los Alamos	0	2765	3024	0	0	257	0	0	127	1	1	2	0	0	0
Savannah River	0	0	1559	0	0	0	0	0	0	0	0	0	0	0	0
Mound	0	0	333	0	0	4	0	0	5	0	0	1	0	0	1
Oak Ridge	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	14	2788	9001	14	23	3997	-1	1	826	1	1	48	0	0	38

ATTACHMENT III

CURRENT SUMMARY OF LASL PLUTONIUM WORKER STUDY

L. HEMPELMANN, M.D. AND G. L. VOELZ, M.D.

FEBRUARY 1975

LASL PLUTONIUM WORKERS STUDY

Fraction of MPBB	Original Study	Expanded Study	Currently Located (%)	
5-10	3	3	3	(100)
3-5	5	6	6	(100)
1-3	10	19	18	(95)
0.1-1	6	227	167	(74)
	24	255	194	(76)
Deceased	2	9		
	26	264		

Death, Causes of. (Not all verified yet)

Accidental Trauma	3
Alcoholism Related	2
Coronary Heart Disease	1
Post-operative CV Surgery	1
Radiation - Criticality	1
Suicide	1
Epilepsy (grand mal)	1
Unknown (to us)	1

Malignancies Reported To Date

Carcinoma of Bladder
Lymphoma
Carcinoma of Colon
Carcinoma of Lip

Medical Studies on LASL Plutonium Workers

Medical History
Physical Examination
Complete Blood Count
Urinalysis (Clinical)
Radiological Urinalysis
Body Burden Estimate (PUQFUA CODE)
Chest Counts for Pu
Monitoring of Old Wound Sites
Lung Cytology
Chromosome Analysis

Blood Chemistry Profile
- Alkaline Phosphatase
- Cholesterol
- Total Bilirubin
- Total Protein
- Albumen, Globulin and A/G Ratio
- Total Lipid
- Transaminase (SGOT)
- Lactic dehydrogenase (LDH)
- Creatinine
- Glucose
- Urea Nitrogen (BUN)
- Urea

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TABLE [illegible]

Plutonium Concentration in Urine Samples Collected from Early Plutonium Workers

Employee Identification	1946	1957-58	1971			1974
	(dis/min per sample collected)		(dis/min per 24 hr)			
	Termination Single Sample	Single Sample	Multiple Analysis of Several Samples n	mean	±1 Sigma	Single Sample
3	5.1	0.46	7	5.06	1.08	4.54
4	8.2[b]	1.28	10	2.61	0.30	2.54
1	8.5 (1945)	1.00	5	1.99	0.34	1.76
7	7.5	1.03	6	1.57	0.88	1.89
9	11.7	0.46	6	1.53	0.47	1.03
5	1.4	0.71	3	1.53	0.70	--
18	4.9	1.14	3	1.09	0.53	0.82
8	4.6	0.13	6	1.04	0.10	1.10
17	4.6	--	2	0.92	0.17	0.78
6	10.2	0.63	4	0.91	0.18	0.78
12	3.2	--	2	0.63	0.77	--
10	14.6 (1945)	0.39	4	0.57	0.26	0.50
16	0.0	0.20	6	0.54	0.18	--
2	--	--	4	0.52	0.14	0.10
20	2.0	0.34	2	0.49	0.07	0.45
22	5.4	0.08	4	0.44	0.24	0.18
23	9.3	0.22	2	0.35	0.01	0.21
26	3.1[b]	0.83	8	0.26	0.03	0.24
27	12.0	0.17	7	0.30	0.13	0.09
24	0.5	0.70	2	0.22	0.08	0.44
21	2.2	0.14	2	0.22	0.05	--
25	2.1[b]	0.08	5	0.12	0.02	0.09
13	6.1	0.08	4	0.11	0.06	0.07
26	0.8	0.00	6	0.08	0.08	0.07
19	2.0	0.27	-	--	--	0.49

a Presently employed at LASL
b Mean of 1945 results

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CURRENT HEALTH STATUS QUESTIONNAIRE

FORMER PLUTONIUM WORKERS

LOS ALAMOS SCIENTIFIC LABORATORY

LOS ALAMOS, NEW MEXICO

NAME: ______________________ WIFE'S NAME: ______________________

ADDRESS: ____

BIRTHDATE: ______________________ SOC. SECURITY NO: ______________

CHILDREN'S NAMES AND ADDRESSES:

NAMES AND ADDRESSES OF TWO FRIENDS OR RELATIVES WHO WILL ALWAYS KNOW WHERE YOU LIVE:

(1) Are you in good health?

(2) Have you had any serious illness or operations requiring hospitalization?

(3) If yes, what illness?

(4) If yes, name of hospitals and approximate dates:

______________________ ______________________

Date Signature

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ATTACHMENT IV

COMMENTS ON DOSIMETRY OF PLUTONIUM FOR THE TRANSURANIUM REGISTRY WORKSHOP*

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Health Physics Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

The dosimetry of Pu-239 or Pu-238 is relatively uncomplicated since the average dose to body organs is due almost entirely to alpha radiation, and these radionuclides decay to isotopes of uranium of such long half-life that they can be considered as stable in terms of a human life span. However, there are problems enough as soon as one begins to probe a bit deeper.

The Lungs

Activity is deposited in various amounts in regions of the respiratory tract according to the AMAD of the aerosol. Clearance from these regions depends on many factors -- the chemical form of the aerosol, its physical form, etc. -- but in the current lung model it does not vary with particle size. This is undoubtedly an oversimplification as is being validated by Lovelace. In fact, the Lung Task Group tried to construct models which would reasonably represent the ranges of values, and the long-term clearance values chosen are expected together to encompass the range of values usually encountered for particulates within a factor of three on either side. Thus, the long-term clearance half-time value of 500 days should be considered as representing the range of values from 170 days to 1500 days. The short-term clearance value of 50 days represents the range from 17 days to 150 days, etc.

*Research sponsored by the Energy Research and Development Administration under contract with Union Carbide Corporation.

**Consultant.

The distribution of this activity in the various compartments of the lung is known not to be uniform, but no one has, as yet, suggested a model for the distribution; in effect, the crude dosimetry of the present assumes uniformity.

With such an assumption, the dosimetry of the lung proper would be relatively straight forward except for movement of a portion of the activity, either to thoracic lymph nodes or to other sites within the lung. The clearance to the lymph nodes is by the clearance half-time which is longest; from the lymph nodes the clearance is even slower. Thus, the lymph nodes build up a considerable amount of activity which remains for long times in the case of an insoluable aerosol of long radioactive half-life. Something of this kind really occurs in man as many of the autopsy cases indicate.

The solution would seem to be simple -- namely, recommend an appropriate MPD (Maximum Permissible Dose) value for these lymph nodes. But these lymph nodes appear to be rather resistant to radiation so far as tumorogenesis is concerned, although many of the lymph nodes from experimental animals have shown fibrosis following inhalation of Pu-239, etc. The sparse biological data on involvement of the lymph nodes makes it difficult to decide what MPD might be appropriate. The biological data do indicate that exposure of the lymph nodes hardly changes the production of tumors so far as present data are concerned, and thus the ICRP has announced the intention of not computing doses to lymph nodes for purposes of radiation protection - that is, the number of tumors produced in lungs far outweighs those involving lymph nodes in data now available. Thus, the Commission recommends that dose in the respiratory system be limited by the dose averaged throughout the lungs. Meanwhile, the Commission will continue to keep the entire question under review as further data are obtained.

Committee 2 has decided it will consider beta and gamma activity emitted in the lymph nodes since this would contribute to the dose to the lungs in most cases. However, it will not compute a separate dose to the lymph nodes and, in particular, alpha radiation emitted in the lymph nodes will be assumed to be absorbed there. The Committee is currently trying to decide whether it would be better to:

I. Ask ICRP to select an MPD since many people feel that the Commission is remiss in ignoring the question of the significance of this dose.

II. Continue as at present, giving no dose to lymph nodes.

III. Include the pulmonary nodes as a part of the lungs so dose is averaged over lungs and pulmonary nodes. An argument for this is that those measuring so called lung burdens cannot distinguish activity in lungs and that in the pulmonary lymph nodes. Of course, in other cases one could by the same argument include a gamma emitter deposited in the ribs!

This third alternative would somewhat affect the dose estimate since the lymph nodes accumulate practically the same number of μCi-days as does the rest of the lung for insoluble Pu-239 and the same is true for Pu-238. However, the dose to lungs would only be increased by a factor of $\sim$ 2.

The doses to bone and liver are highly uncertain since the deposition in these organs varies greatly according to the degree of polymerization and complexing of the Pu. Biological data can be cited showing deposition in bone and liver may be as much as $\sim$80% and $\sim$10% of the activity entering blood, respectively, and these percentages can be reversed for other experimental data. Some autopsy values show practically the same range. The missing piece of the puzzle is that often the health physicist can get only a meager indication of the state of the material when taken into the body. ICRP is currently assuming 45% deposition for both bone and liver, but it is recognized that this might well be in error by 50% or so in either direction.

The ICRP has designated the endosteal cells near bone surfaces as the likely targets for dose to bone although (a) their distribution in depth from the surface is not accurately known, and (b) the thickness of the layer in which the Pu deposits and the time scale for remodeling of the bone are not well known even for experimental animals. Some recent work of Marshall and his colleagues indicates that the layer may be very thin, approximately 1 μm. Using this and allowing for various degrees of overlay, he calculates the dose received from a surface distribution of Pu-239 in relation to the average dose received by bone. He obtains numbers in the range of 20 to 30. Mays and Tueller have calculated a similar result. In fact, they have calculated these doses, or dose rations, for a number of radionuclides, including Ra-224 and Ra-226, and the results do support the fact that, on a per rad basis, Ra-224 is considerably more carcinogenic than is Ra-226. This is understandable if the endosteal cells are truly the cells at risk, since Ra-224 will largely decay while on the bone surface, while much of the energy of the Ra-226 and daughter particles is wasted. For the present, Committee 2 of ICRP intends to continue the use of the former methods; that is, average bone dose calculated assuming complete absorption of alpha energy, weighting this with a quality factor of Q = 10 and, for Pu and for Ra-224, including an additional factor of five where this last, the n-factor, applies only for bone. For dose to liver, only the factor Q = 10 would be used.

Finally, for dose to gonads, May and Richmond have suggested that uptake by ovaries be taken as about a factor of 10 lower than the uptake by testes. The best values are probably those of the autopsy cases of Pu workers who have accumulated a significant body burden and may be summarized as 10^{-5} for males and 10^{-4} for females as the fraction of activity reaching blood that deposits in the gonads.

It is apparent that the Pu and Actinide Registry can do much to help clarify this puzzle. The data accumulated by the Registry on the concentrations -- not the amounts unless accompanied by estimates of the mass -- in the pulmonary lymph nodes and in the lungs should analyzed by exposure history, that is, chemical and physical data on the aerosol, by the time of the exposure and time of death. Of course, any pathological findings would be noted also, I am sure.

The same type of analysis needs to be applied to the data on bone and liver estimates and I think it would be desirable to collect a few samples of gonads even if it is difficult to measure the activity in them. Whether the Registry can go further -- say in documenting the degree to which Pu in bone has been overlayed by new bone or not -- is questionable. However, I believe if it can be done at all, it should be tried in some cases since an enormous amount of animal data will hardly give us the equivalent data on man.

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ICRP Draft Dosimetric Data on Plutonium.

generator in the base of the cell shoots the cone-shaped rocket out through the flying shards of the cell cover and, a few feet clear of the ground, the rocket motor ignites. Almost simultaneously the missile pitches over on its set course, aimed by a split second injection of Freon into its rocket exhaust, and becomes a distant streak in the sky almost before onlookers realize it has left its cell.

Sprint is controlled at each instant of its flight by Central Logic and Control, a computer designed by Bell Laboratories, the research arm of the Bell telephone system. The unique feature of the machine is that to handle its rather elaborate task in real time it contains not one but a tandem of 10 central processors, with a capacity of performing about 10 million operations a second.

Besides its 10 central processors, Central Logic and Control consists of 12 program stores, each with a capacity of 16,000 words, 15 variable stores constituting a "scratch-pad memory" for radar data that need only be held a short time, two input/output controls, and two timing and status units. The system can be divided into formally equal "green" and "amber" partitions, which check each other in real time for malfunction. The green partition components are the ones that fight the battle, the amber are for testing and maintenance. If the amber side detects any malfunction in the green, it instantly switches in one of its own corresponding components in place of the faulty green component. As with the radars, redundancy is cultivated to a high degree to ensure the equipment stays on line when needed.

The essence of the Safeguard system is the system design and its embodiment in the software, written by Bell Laboratories with IBM as a subcontractor. According to Shea, Bell has performed the software job in an "exemplary fashion," notably by designing in a significant performance margin.

Bell Laboratories, with its production arm Western Electric, is the prime contractor for the whole Safeguard system, a job which it undertook at the request of the Army. Unlike other defense contractors, Bell's main business is not dependent on Defense Department contracts, which may make for greater objectivity in rendering advice. "Bell Labs has dealt very candidly with the government and has never overstated what they felt could be accomplished," says Shea. By all accounts the Bell design team has played its part in putting Safeguard together with remarkable efficiency—all performance specifications have been met or exceeded, and the North Dakota site is being completed on [illegible] Attachment V [illegible] however, has been greatly exceeded—running some $1.3 billion above the 1969 estimate for Safeguard—but for reasons largely beyond Bell's control, such as inflation and schedule changes. The story of Bell's achievements in designing Safeguard cannot, however, be told, since the company declines to discuss this ultimate service to its subscribers.

When completed the Safeguard site in North Dakota will be operated for a year and a half to gain operational experience and may then be reduced to working a 40-hour week. The critics may be right in doubting its strategic effectiveness—"Technically it's a fine thing, but it's like a train that doesn't go anywhere," says one opponent—yet anyone visiting the pyramid in the North Dakota wheatfields crammed with its powerful and elegant machinery cannot help absorbing a sense that it will work, and that the Soviet Union was well advised to bargain for its limitation. It is, if nothing else, a notable monument to Western technology and preoccupations, one which, like the funerary pyramids of ancient Egypt, will move future generations to marvel equally at the civilization's extraordinary technical skills and at its unswerving devotion to the mortuary arts.

—Nicholas Wade

Plutonium (II): Watching and Waiting for Adverse Effects

If any of you have a pet beagle, guinea pig, or hamster that is involved in a plutonium spill, we can make a fairly accurate prognosis and outline an adequate course of treatment. [But] at best, the practice of extrapolating animal data to man is of questionable validity, and the extent to which this may be done with confidence should be established by human data as soon as possible.—John A. Norcross, former director of the United States Transuranium Registry, 1972

Almost from the time of its discovery in 1940, and certainly by the late 1940's, radiological health researchers were well aware that plutonium's great potential value was fully matched by its enormous biological hazard. Studies with laboratory animals 25 years ago, for example, quickly established that internal doses of plutonium measured in micrograms were an even more potent carcinogen than radium.

A great deal more has been learned since then about the behavior of plutonium in animals, as the above quotation suggests. But even though plutonium has become an increasingly important and abundant industrial substance, the effects of small internal doses on workers exposed to this strange metal remain uncomfortably uncertain. "The record so far is pretty good," says Walter S. Snyder, an authority on the subject and for many years a leading health physicist at Oak Ridge National Laboratory. But, Snyder adds, "we are still on edge about this."

Faced with this uncertainty—and with the rising prospect that plutonium would begin to spawn a commercial nuclear fuel industry in the mid- or late 1970's—the Atomic Energy Commission (AEC) began in the summer of 1968 to set up a medical data bank to monitor the health of thousands of men occupationally exposed to plutonium. It was hoped that the data bank, which the AEC now calls the United States Transuranium Registry, would serve as a medical trip wire—an early warning system—that would either confirm by its silence that exposure limits adopted in the late 1940's were adequate for workers, or sound an alarm soon enough to head off the kind of occupational health disaster that befell radium workers in the early part of the century, some of whom are still developing malignancies traceable to their jobs.

Today, the Transuranium Registry has passed beyond many of its initial organizational difficulties and has settled into what promises to be a long, quiet watch for signs of adverse health effects. Centered at the AEC's Hanford Reservation in eastern Washington state, the registry has become the repository for medical data on some 6000 nuclear workers, almost all in plutonium operations. And it has begun to report the results of autopsies on plutonium workers as the information becomes available. About 40 autopsies have been performed thus far.

Peaceful as its existence is, the registry is not without its problems and its critics. For one thing, selling industry on the concept of a medical data bank has not been easy, and the job is not yet finished. It also happens that medical data collected so far comes almost entirely from those men most recently exposed to plutonium and other radionuclides, and who are therefore least likely to show any adverse effects in the near future—if such effects are ever to be found at exposure levels currently encountered by nuclear workers.

Whatever its shortcomings, though, the registry represents an innovation in preventive medicine and, in a sense, a novel experiment in technology assessment. As such, it serves to illustrate the difficulties—both social and scientific—of guarding against future catastrophes of occupational health.

Officially, the Transuranium Registry is part of the Hanford Environmental Health Foundation, a private organization that the AEC has contracted to provide medical services for the nearly 7100 employees at the 570-square-mile Hanford Reservation. With an annual budget that fluctuates between $80,000 and $105,000, the registry employs one full-time administrative assistant, a part-time consultant, and a part-time director, William D. Norwood. A physician and researcher at Hanford for many years, Norwood, at the age of 72, says that he's looking for a younger man to take over but hasn't yet found a replacement.

The registry's basic approach has been one of classic epidemiology. It seeks to collect medical records of as many plutonium workers as possible and then to find correlations, if any, between "body burdens" of plutonium or other radioactive elements and any changes in longevity or patterns of disease that develop. The registry is especially—but not exclusively—interested in men known to have absorbed relatively large amounts of plutonium either through inhalation or through contaminated skin wounds, the two main routes of intake. Most careful watch is kept for workers who may develop malignancies of the bone, lung, liver, or tracheobronchial lymph nodes, where plutonium tends to concentrate.

Those workers who sign authorization forms for autopsies are given a special identity card to carry, and if they leave the nuclear industry before they die, the registry pays for them to have periodic physical exams and "body burden" measurements. When the worker dies, the registry pays the family $350 toward funeral expenses. Other deceased enrollees can be traced, and their death certificates located, through their social security numbers.

Problems of Privacy

All of this brushes up against sticky questions about an individual's right to privacy. To avoid problems in this area, the AEC has made cooperation with the registry—both by companies and by their individual employees—entirely voluntary. In addition, all medical data, which is stored on computer tapes, is numerically coded by the registry to protect each worker's identity. Even so, Norwood said in a recent telephone conversation, "We've really had to sell the idea to industry." Besides questions of privacy, he said, "Some companies are afraid that we'll scare their employees by talking about the hazards of plutonium. So we have gotten varying degrees of cooperation."

After some initial resistance the national laboratories and the big nuclear weapons plants handling large amounts of plutonium have all begun cooperating fully, with the exception of the Savannah River production plants run by DuPont at Aiken, South Carolina.*

In contrast with AEC's own facilities and those run by its contractors, the registry has encountered a stonewall of resistance from some of the smaller private companies in the vanguard of a new and potentially major new segment of the nuclear industry—the manufacture of "mixed" uranium and plutonium oxide fuel for conventional nuclear power plants. The AEC is expected to move toward encouraging production of this new fuel within the next year (*Science*, 20 September).

Two companies that intend to make plutonium fuel on a large scale—Westinghouse and Exxon Nuclear—have agreed to cooperate fully with the registry, once production begins in about 3 years.

But two other companies in the plutonium fuel business have balked. These are Nuclear Fuel Services, Inc. (NFS), whose spent fuel reprocessing plant near Buffalo, New York, is closed pending AEC approval of a major enlargement; and the Nuclear Materials and Equipment Corporation (NUMEC), whose plutonium plant at Leechburg, Pennsylvania, near Pittsburgh, is producing fuel for the AEC's breeder reactor program. Together, and when fully operating, the two companies employ only about 200 persons "at risk" of exposure. But both plants have suffered a number of leaks and spills of plutonium that have led to contamination of workers, seemingly in disproportionately high numbers.

Norwood said that NUMEC "hasn't said yes and they haven't said no," but that NFS seemed to have stopped answering his letters. "They haven't responded to my last two or three."

A spokesman for NFS told *Science* that he wasn't familiar with the letters, but that the company's management at present regards participation in the Transuranium Registry as "inappropriate," although no final decision has been made. The spokesman, vice president Claude E. Fountain, said that the company's position was that even inviting employees to participate in the registry voluntarily might be construed as "coercion."

Did the company invite employees to contribute to United Fund and local blood banks? "Of course," said Fountain, "But we view that differently."

A spokesman for a third private plutonium plant, located near Cimarron, Oklahoma, and owned by Kerr-McGee, said the company does not yet know enough about the registry to give it a "blanket endorsement" but that Kerr-McGee "welcomes added information."

In Norwood's view, the noncooperating companies are more likely to hurt themselves than the registry and its goals, although their resistance does deny the registry access to a number of persons exposed to plutonium oxide, a form of the element considered by some authorities to be particularly hazardous. He notes that, "If some former employee comes along and sues these companies for compensation, it might look to the people trying the case that

* DuPont gives the registry data only on workers known to have taken in more than 5 percent of the maximum permissible body burden of 40 nanocuries, a determination that is often difficult to make. The company replaces workers' names with coded numbers.

the company did not do everything it possibly could to protect employee health."

Norwood said that he had been informed that the Nuclear Energy Liability Property Insurance Association, the national insurance pool that underwrites private nuclear facilities, had strongly urged the noncooperating companies to change their position.

How successful has the registry's recruitment been? No accurate figures are available, but upwards of [illegible] 8000 persons may now be [illegible] employed as plutonium operators [illegible] registry has signed up about [illegible] these workers and some 850 of [illegible] have agreed to autopsies.

According to [illegible] estimate supplied to *Science* by the AEC, however, about 17,000 persons are thought to have worked in plutonium operations from the beginning of the Manhattan project to the present [illegible] that means the registry is monitoring only the most recent one-third of the population considered to have been occupationally "at risk" to exposure to plutonium. But finding and enlisting the cooperation of the first two-thirds has so far not been practical, Norwood said, explaining that, for one thing, early employment records are far from complete.

Even so, the apparent loss of the first 11,000 plutonium workers would seem

Briefing

NAS Okays Auto Emission Standards

The health-related auto emission standards embodied in the 1970 Clean Air Act are basically on target and there is "no substantial basis for changing the standards," according to a recently completed report by the National Academy of Sciences-National Academy of Engineering. Presumably the report will help buttress the act against weakening amendments when it comes up for review and overhaul next year. The act was supposed to be up for renewal this year, but it has been carried over with an interim appropriation.

The half-million dollar study was ordered by the Senate Public Works Committee last year following extensive hearings at which auto makers took issue with the standards saying they were too strict and the required emission control devices were not cost-effective.

The academy committee disagrees with both contentions. While data are still inadequate, it says, the evidence that has accumulated since the standards were promulgated tends to confirm their desirability, and the safety margins are indeed "relatively modest." What's more, the report says the standards are justifiable in cost-benefit terms. It estimates the annual cost of reaching statutory emission standards at $5 to $[illegible] billion, and assesses the benefits of clean air at between $2.5 and $10 billion a year.

The study was structured in three parts to analyze the effects on human health of specified pollutants, the relation of auto emissions to ambient air quality, and the costs and benefits associated with auto emission control.

The report estimates that air pollution can be said to be implicated in about 1 percent of all U.S. deaths each year and that automobiles contribute up to one-fourth of this pollution. So automobile exhaust fumes may send as many as 4000 people over the edge each year.—C.H.

Weather Mod Research Under a Cloud

The U.S. government has been trying to mount successful weather modification research programs since the late 1940's, but "an effective national weather modification research program has not been established," according to a recent report of the General Accounting Office (GAO).

If successful, such research could help [illegible] alleviate drought, reduce the destructive forces of hurricanes, suppress lightning [illegible] dissipate fog, the study says. But the country lacks the capability to do these things, presumably in part because the research has been conducted in a fragmented way by seven federal agencies and departments, the report [illegible].

In fiscal 1974 the government spent $17.4 million on this research, but GAO concludes that the money could have been better used if all weather modification research programs were consolidated into a single agency.

The GAO employed unusually crisp language to describe the failure of the Interdepartmental Committee for Atmospheric Sciences (ICAS) in coordinating these programs. ICAS was set up in 1959 as a reaction to the problem of fragmentation among agencies which was apparent even then. But now "ICAS apparently has had little or no impact on increasing coordination and accelerating progress in weather modification research."

As an example of the inability of agencies to sacrifice their priorities to joint endeavors, GAO looked at the 5-year National Hail Research Experiment, begun in 1972, for which the National Science Foundation is chiefly responsible. After several agencies agreed on a plan, the following defections occurred: the Agriculture Department decided not to study the economic benefits of hail suppression (so NSF did) and did not make a study of lightning which was considered "imperative" to the project. The National Oceanic and Atmospheric Administration supplied one airplane for 1 year only, instead of the three pledged for the life of the project. The Atomic Energy Commission did not measure hailstones and make planned tracer studies. And the Department of Defense, instead of supplying two helicopters, told NSF it could have one, provided that NSF paid the bill—which NSF couldn't. GAO did not say whether the truncated project has been a scientific success: ". . . we found, comparing the planned efforts with the actual efforts that, for the most part, agencies could not and did not meet all their obligations."

Most of the federal agencies asked to comment on the study criticized it. The Agriculture Department's comment said GAO had not substantiated its premise that existing research programs were defective. Like most of the comments, it fought the proposed unified program. "I would not wish to defend a budget request on the basis that it enabled us to participate in a national weather modification program," the author said.—D.S.

to represent a considerable handicap. In addition, some scientists who are especially worried about the health effects of plutonium question the registry's heavy emphasis on long-term epidemiology. Among them is Donald P. Geesaman, a biophysicist at the University of Minnesota's School of Public Affairs.

"If all they're looking at is body burdens and the cause of death, this may be next to useless," Geesaman says. "God only knows what else plutonium workers are exposed to—tritium, other radionuclides, hydrocarbons you never dreamed of. For meaningful results you have to look on a fine scale for pathology near local depositions in tissues."

Norwood replies that a few close examinations of autopsied bone have been done, but that techniques need refinement and uncommonly large depositions are necessary now.

In large measure the Transuranium Registry's sensitivity as an early warning system depends upon the nature of the effects, if any, to be discovered. The appearance of a rare malignancy—bone sarcoma, for example—among the first few dozen autopsies would be a clear signal that something was amiss. But hundreds of deaths among the registry's enrollees might be required to detect a statistical increase in garden variety lung cancer.

In the meantime, there is a growing urgency to the central question. Are current occupational standards for plutonium, set in 1949, adequate? As the nation moves toward the commercialization of plutonium, the standards have become an issue between environmentalists on one side and the proponents of nuclear power and the radiation standards community on the other. Earlier this year, for instance, the Natural Resources Defense Council, a respected environmental law group, contended in a lengthy technical paper that current exposure limits for airborne plutonium were too high by a factor of at least 100,000. Others, like Karl Z. Morgan, an eminent health physicist at the Georgia Institute of Technology, believe that a solid biological case exists for reducing the present maximum permissible body burden of plutonium by a factor of 40 or 50. This limit is now set at 40 nanocuries—an amount of material about equal to a pencil point dot on a piece of paper.

Many health physicists, however, believe that no change in the standards, or only a small one, is warranted. Frequently cited as a reason for reassurance is the lack of apparent effect in a group of 25 GI's who were heavily contaminated by plutonium during the Manhattan Project and who have been monitored carefully ever since by researchers at Los Alamos. Chester Richmond, for many years a leader in plutonium effects work at Los Alamos, notes that the only signs of pathology in these men so far are "metaplastic changes found in the sputum" of some of the men. Such changes, though a possible precursor of malignancy, are not uncommon in middle-aged men who smoke.

Even though their number is small, Richmond continues, "I feel very reassured that our standards are not way out of line as some have suggested. If they were—by orders of magnitude—you would have seen something in this group, perhaps a bone sarcoma. They would have raised a red flag."

Walter S. Snyder, a member of the internal exposure committee of the International Commission on Radiological Protection, the leading standards organization, is similarly sanguine but cautious. No adverse effects have been seen thus far, he notes, but if there was one lesson learned from the radium workers a half century ago it is that radiation-caused malignancies may take decades to manifest themselves.

"We are still on edge about this," Snyder says of plutonium. "We're playing a game with very little human data."

—ROBERT GILLETTE

Erratum: In the first of this two-part series on 20 September the Nuclear Materials and Equipment Corporation was incorrectly identified as the Nuclear Materials and Engineering Corp.

UN Conferences: Topping Any Agenda Is the Question of Development

The World Population Conference ended on 30 August in Bucharest without producing explicit agreement that there was a world population problem, and the United Nations Law of the Sea Conference in Caracas wound up a day earlier without doing any legislating. What both the UN sponsored meetings did contribute was sharper definition of the division between the developing countries and the Western industrialized countries, particularly the United States. Does this mean that the conferences were failures—perhaps that the world conference is likelier to produce confrontation than cooperation? Or does it simply mean that the problems addressed at Bucharest and Caracas are of such magnitude and complexity that it is naive to expect instant results?

The question is a timely one since the world conference format is very much in vogue. A cycle that began with the Conference on the Human Environment in Stockholm in 1972 and continued with this summer's meetings and will continue with a World Food Conference from 5-16 November in Rome, an International Women's Year Conference in Bogotá next summer, and a World Conference on Human Settlements in Vancouver in 1976.

The UN Conference on the Law of the Sea, which is the third of its kind, was, in effect, recessed and is scheduled to resume in Geneva from 17 March to 3 April next year and, with good luck, to conclude with a treaty-signing session back in Venezuela next summer.

Not all world conferences are the same, of course. The Law of the Sea Conference differs significantly in aim and in dynamics from the population and food conferences, for example. Its object is a major revision of maritime law, with the stormiest issues involving territorial limits, fishing rights, and the exploitation of minerals beneath the seas. The conferences on environment, population, and food do not focus on specific questions of international law but, to make progress, require the accommodation of social and cultural differences as well as the reconciliation of conflicting economic and political interests. The issues under discussion can all be viewed as different aspects of the problems of underdevelopment.

A familiar phenomenon at the conferences has been the bitter, often ritualistic criticism of the United States by the developing countries and socialist

1009705

DECEASED TRANSURANIUM WORKERS - DATA SHEET #1

Registry No.	Date of Birth / Date of Death	Sex and Race	years: At Risk	years: 1st Positive Urine to Death	years: Definite Exposures to Death	Hospital and Autopsy Protocol Received	Probable Primary Cause of Death	Probable Contributing Causes of Death	Serious Medical Conditions During Life	Cigarettes	Environmental Exposure, Estimated Amount and/or Duration: Craft, Chemicals, Physical, etc.	Ext. Rad. Measured m rem	Inhalation Exposure Composition, Size, Shape, Solubility, Treatment
[illegible]	11/19/0[illegible] / 12/9/71	M [illegible]	[illegible]	* 11 neg. urine assays-HAPO	[illegible]	Swedish Med. Center Seattle 12/10/71	1. Aneurysm of Aorta-Ruptured 2. Multiple Infarcts brain, lung, spleen, kidney	Hypertensive cardio-vasc. dis. Broncho Pneumonia Arterio-nephrosclerosis	Hypertensive Cardiovascular Disease	No Inquiry	Usual at HAPO Sep. 7 yrs R.F.-20 yrs HAPO-224b-3 yrs 231-2 yrs., 221-2	396 m rem R.F. 440 m rem HAPO	^{239}Pu metal, nitrate, oxide at HAPO R.F. - ?
[illegible]	[illegible]/96 / 9/14/71	M [illegible]	--	[illegible]	[illegible]	9/15/71 Dr. Ovitz Penrose Memorial Hospital Denver	Acute Lymphoblastic Leukemia	Cardiomegaly Atherosclerosis, Nephrosclerosis, Pleurisy Emphysema	Hypertension	n.i.	Toolmaker	98 m rem	^{239}Pu Metal, Oxide
[illegible]	[illegible] / [illegible]	M [illegible]	--	[illegible]	[illegible]	Dr. Herr-[illegible] St. Anthony Hospital Denver [illegible]/72	1. Adenocarcinoma [illegible] (primary), well differentiated metastases to heart, lungs, liver, brain, adrenal and lymph nodes. 2. AdenoCa Bronchus, also primary poorly differentiated	Thrombo-embolism	[illegible] mass in chest x-ray	[illegible] cigs per day to 1970	Machinist	[illegible]	[illegible]
0001 0022	5/30/22 / 1/20/72	M [illegible]	--	n	[illegible]	Howe Mortuary Boulder Memorial Hospital 1/20/72	Melanoma (primary site not established). Metastases to lung, brain, small intestine, lymph nodes	Bronchopneumonia	none	No inquiry	Laborer Service Truck Driver	38	^{230}Pu Metal, Oxide

*No positive urine

1009706

DECEASED TRANSURANIUM WORKERS - DATA SHEET #2

Registry No.	Individual Exposures - Radiation: Radiation Isotope NonTr.Ur.	Occupational Cum. Ext. Rad. in m rem: Penetrating	Non-Pen.	Rad. for Dia. & Ther.	Type TU-dep Acute-A or Chronic-C Inhal. or Wound	Estimated Deposition Before Death - nCi (Note if Pu, Am, Cm, Other Tr.Ur.El. s- if soluble, i- if not soluble): Systemic	Lung	Wound	Deposition from Autopsy - nCi Whole Organ or Extrapolation (nCi per Sample / Wt. in Grams of Sample x Wt. in Gms of Organ (weighed if possible)): Systemic	Lung	Bone	Liver	Tr.Br. L.N.	Wound	All Other	Total Body Deposition - nCi: Pre-Death Estimate	From Autopsy	Remarks
02AE 0006					C I	0	0	0	$2.0x10^{-1}$	$0.3x10^{-1}$	$1.6x10^{-2}$	$7.8x10^{-2}$	$6x10^{-4}$	0	Spleen $5x10^{-4}$ Kidney $2.4x10^{-3}$	0	0.23 nCi 0.5%	Worked at Hanford 7, R.F.
02D0 0444					0	0	0	0	$7.1x10^{-2}$	$7x10^{-6}$	$5.2x10^{-2}$	$7x10^{-6}$	$7.2x10^{-4}$	-	Spleen $1.3x10^{-2}$ Kidney $1.4x10^{-3}$ Heart $4.1x10^{-3}$ Trach. $3.8x10^{-4}$	0	$7.1x10^{-2}$	
02D0 0449					0	0	0	0	neg.	neg.	neg.	$5.3x10^{-3}$	$4x10^{-4}$	-	Neg. except Kidney $1.4x10^{-3}$ Pul. Nodes $2.4x10^{-4}$	0	Neg.	Some samples very small.
02[illegible] [illegible]	--		--	--	--	0	Bkgr.	---	neg.	$5.6x10^{-3}$	neg.	--	$2.3x10^{-3}$		neg.	0	$8x10^{-3}$	All dep. in chest

1009707

DECEASED TRANSURANIUM WORKERS - DATA SHEET #3

Registry No.	Concentration of Pu in Organs - dpm per gram: Lung	T.B.L.N.	Liver	Skeleton	Kidney	Spleen	Muscle	Heart	Wound	Other (Specify)	Organ Conc. dpm/gm: Lowest	Highest	Remarks
02AE 0006	0.077	0.086	0.104	.004	0.018	.006					Bone 0.004	Liver 0.104	
0200 0444	$3x10^{-6}$	$3.4x10^{-2}$	$1x10^{-5}$	$1.1x10^{-2}$	$7.7x10^{-3}$	$5.0x10^{-2}$	--	$1.6x10^{-2}$	--	Trachea $3.4x10^{-3}$	Lung	Spleen	
0200 0449	neg.	0.13	$7.3x10^{-3}$	neg.	$9.7x10^{-3}$	neg.	--	neg.		Trachea $5.9x10^{-3}$ Brain neg. Thyroid $7.4x10^{-2}$	Lung, Skel., Spleen, Heart	Pul. Nodes	Essentially negative
0200 0622	$1.51x10^{-2}$	$6.34x10^{-1}$	--	neg.	neg.	neg.	--	neg.		Thyroid neg.	--	TB Nodes	All samples except chest neg.

DECEASED TRANSURANIUM WORKERS - DATA SHEET #1

Registry No.	Date of Birth / Date of Death / Age at Death	Sex and Race	years: At Risk	years: 1st Positive Urine to Death	years: Definite Exposures to Death	Hospital and Date Autopsy Protocol Received	Probable Primary Cause of Death	Probable Contributing Causes of Death	Serious Medical Conditions During Life	Environmental Exposure, Estimated Amount and/or Duration: Cigarettes	Craft Chemicals Physical, etc.		Inhalation Exposure Composition, Size, Shape, Solubility, Treatment
02D0 0627	12/21/46 1/16/72 25	M W	-	0	0	Jefferson County Coroner's Office John R. Hunt, M.D.	Shock and exposure	Immersion	Possible congenital heart disease. Grade 2 rough ejection systolic murmer.	n.i.	Semiskilled waste handler. Decontamination worker.		High fired PuO_2
02D0 0317	6/7/16 3/7/73 56	M W	-	11	11	St. Anthony Hospital Denver 4/7/73	Coronary infarction - acute c̄ cardiac arrest	Pulmonary edema. Chronic passive congestion - liver.	Pleochronocytoma Sclerosis of aorta - marked coronary infarction 9/28/72	n.i.	Process Op. Chem. Op.		$^{239}PuO_2$

1009108

1009709

DECEASED TRANSURANIUM WORKERS - DATA SHEET #2

Reg-istry No.	Environmental Exposures - Radiation: Radiation Isotope NonTr.Ur.	Occupational Cum. Ext. Rad. in m rem: Pene-trat-ing	Occupational Cum. Ext. Rad. in m rem: Non-Pen.	Rad. for Dia. & Ther.	Type TU-dep Acute-A or Chronic-C Inhal. or Wound	Estimated Deposition Before Death - nCi (Note if Pu,Am,Cm,Other Tr.Ur.El. s- if soluble, i- if not soluble): Systemic	Lung	Wound	Deposition from Autopsy - nCi, Whole Organ or Extrapolation (nCi per Sample / Wt. in Grams of Sample x Wt. in Gms (weighed if possible) of Organ): Systemic	Lung	Bone	Liver	Tr.Br. L.N.	Wound	All Other	Total Body Deposition - nCi: Pre-Death Estimate	From Autopsy	Remarks
02D0 0627		8			A-W	0	Bkg.	0	2.0×10^{-2}	9.8×10^{-2}	7.1×10^{-3}	5.1×10^{-3}	1.6×10^{-3} Incl. Pul. nodes	--	Spleen 4.1×10^{-4} Kidney 2.0×10^{-4} Heart 7.2×10^{-3}	0	0.11	
02D0 0317		54, 029	76, 933		A-W	9.2	Positive amount unknown	0	2.6	3.50	0.148	2.02	0.25		Spleen 6.0×10^{-3} Kidney 3.0×10^{-3} Heart 15×10^{-3} Test. 0.2×10^{-3} Trachea 4×10^{-3} Aorta 5×10^{-3} Bladder 0.2×10^{-3} Fat 23×10^{-3} Muscle 338×10^{-3} All other 37×10^{-3}	9.2	6.35	All Pu
									1.6	0.38	1.2	0.13	0.08		Spleen 4.5×10^{-5} Kidney 2.0×10^{-3} Heart 18×10^{-3} Test. 63×10^{-3} Trachea 99×10^{-3} Aorta 8.2×10^{-6} Bladder 63×10^{-4} Fat 76×10^{-3} Muscle 170×10^{-3} All other 3.8×10^{-3}		2.1	All Am

1009710

DECEASED TRANSURANIUM WORKERS - DATA SHEET #3

Reg-istry No.	Concentration of Pu in Organs - dpm per gram										Organ Conc. dpm/gm		Remarks
	Lung	T.B.L.N.	Liver	Skeleton	Kidney	Spleen	Muscle	Heart	Wound	Other (Specify)	Lowest	Highest	
0200 0627	0.26	0.43 incl. Pul. Nodes	7.7×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	7.1×10^{-3}	--	4.8×10^{-2}	--	Thyroid - neg.	Kidney	TBLN and Pul. Nodes	
0200 0317	7.179	31.97	3.085	0.0328	0.0224	0.0684	0.0250	0.0931		Testicle 0.00941 Trachea 0.06720 Aorta 0.1318 Bladder 0.00510 Fat 0.00509	Fat	Nodes	All Pu
	0.7687	10.79	0.1943	0.2770	0.0144	0.0005	0.0125	0.1154		Testicle 0.0329 Trachea 0.0164 Aorta 0.0181 Bladder 0.0178 Fat 0.0169	Spleen	Nodes	All Am

1009711

DECEASED TRANSURANIUM WORKERS - DATA SHEET #1

Registry No.	Date of Birth / Date of Death	Sex and Race	years: At Risk	years: 1st Positive Urine to Death	years: Definite Exposures to Death	Hospital and Date Autopsy Protocol Received	Probable Primary Cause of Death	Probable Contributing Causes of Death	Serious Medical Conditions During Life	Environmental Exposure, Estimated Amount and/or Duration: Cigarettes	Craft Chemicals Physical, etc.	Ext. Rad. Measured m rem	Inhalation Exposure Composition, Size, Shape, Solubility, Treatment
02D0 0629	1912 1972	M	-	0	None		Coronary Infarction	Unknown	Unknown	n.i.	Construction work for Dow. Not a Dow employee S&W Carpenter	0	$^{239}PuO_2$
02D0 0690	2/22/25 2/2/72	M W	-	0	None	Lutheran Hosp. Wheat Ridge, Colorado 2/22/72	Adenocarcinoma Kidney (L) Metastases to adrenal, lungs, lymph nodes and duodenal anastomosis breakdown	Small bowel infarction resected and pneumonia followed kidney resection. Erosive esophagitis	Splenomegaly - Passive congestion liver Ca of kidney	n.i.	Operations clerk. General clerk. Staff clerk - 6.	5,291 m rem total	$^{239}PuO_2$
02D0 0745	12/9/20 2/10/72	M W	-	0	None		Automobile accident Cerebral edema		Diabetes mellitus - controlled c̄ diabineses	n.i.	Semiskilled process operator	8353 m rem total	$^{239}PuO_2$
02D0 1395	1935 1973 3/26/35 10/3/73	M W	-	0	9	Metropolitan Pathologists St. Anthony Hospital Denver 10/4/73	Severe Coronary Art. Disease. Sudden collapse while performing judo and never recovered.	Severe atherosclerosis of heart. Arteriosclerosis of Aorta and pulmonary arteries	Severe atherosclerosis - generalized. Chronic passive congestion lungs, liver. Fractures of ribs due to resuscitation	n.i.	Inspection clerk. Electronic Tech.	6,910	$^{239}PuO_2$

1009712

DECEASED TRANSURANIUM WORKERS - DATA SHEET #2

Reg-istry No.	Radiation Isotope NonTr.Ur.	Exposure Miscellaneous	Acute-A or Chronic-C Inhalation or Wound Exposures	Estimated Deposition Before Death - nCi (Note if Pu,Am,Cm,Other Tr.Ur.El. s- if soluble, i- if not soluble): Systemic	Lung	Wound	Deposition from Autopsy - nCi, Whole Organ or Extrapolation ($\frac{\text{nCi per Sample}}{\text{Wt. in Grams of Sample}}$ x Wt. in Gms of Organ (weighed if possible)): Systemic	Lung	Bone	Liver	Tr.Br. L.N.	Wound	All Other	Total Body Deposition - nCi: Pre-Death Estimate	From Autopsy	Remarks
0200 0629	U nat.	Plant C	C I	0	0	0	$1.0x10^{-2}$	$3.2x10^{-2}$	neg.	$8.7x10^{-3}$	neg.		Kidney $1.4x10^{-3}$ Heart neg. Pul. Nodes $2.7x10^{-3}$	0	$45x10^{-3}$	B.B=0.1% of MPBB Body wt.=that at death
0200 0690	---	---		0	0	0	$0.93x10^{-1}$	$1.84x10^{-1}$	$6.80x10^{-2}$	$2.28x10^{-2}$	$2.61x10^{-2}$ incl. Pul. nodes	--	Spleen $6.7x10^{-4}$ Kidney $1.8x10^{-4}$ Heart $5.9x10^{-4}$ Trachea $9.2x10^{-4}$	0	$3.03x10^{-1}$	
0200 0745	---	---		1.24	0	0	$3.57x10^{-1}$	$1.95x10^{-1}$	$2.14x10^{-1}$	$1.39x10^{-1}$	$4.91x10^{-3}$		Spleen $2.52x10^{-3}$ Heart - neg. Kidney - neg. Thyroid $1.22x10^{-3}$	1.24	$5.6x10^{-1}$	
0200 1395	---	---		<0.4	<0.32		$9.64x10^{-3}$	$2.26x10^{-2}$	$3.9x10^{-3}$	$4.4x10^{-3}$	$3.74x10^{-3}$	--	Kidney $6.3x10^{-5}$ Larynx & Thyroid $4.5x10^{-5}$ Spleen $4.5x10^{-5}$ Brain $2.7x10^{-4}$ TB Tubes $7.2x10^{-5}$ Adipose Tissue $8.1x10^{-4}$	<0.72	$3.56x10^{-2}$	

1009713

DECEASED TRANSURANIUM WORKERS - DATA SHEET #3

Registry No.	Concentration of Pu in Organs - dpm per gram: Lung	T.B.L.N.	Liver	Skeleton	Kidney	Spleen	Muscle	Heart	Wound	Other (Specify)	Organ Conc. dpm/gm: Lowest	Highest	Remarks
02D0 0629	R 7.4×10^{-2} L 9.3×10^{-2}	neg.	1.1×10^{-2}	neg.	7.2×10^{-3}	neg.	--	neg.	--	Pul. nodes 8.6×10^{-1}	Spleen Skeleton Heart TBLN	Pulmonary L.N.	
02D0 0690	4.13×10^{-1}	3.615	3.98×10^{-2}	1.509×10^{-2}	1.739×10^{-3}	4.07×10^{-3}	--	4.711×10^{-3}	--	Trachea 1.95×10^{-2}	Kidney	Nodes	Of the bone the Rib highest conc Vert. next Stern. lowest
02D0 0745	1.70	0.11	0.15	.048	neg.	0.03		neg.		Thyroid 0.154	Kidney Heart	Lung	
02D0 1395	4.59×10^{-2}	5.97×10^{-1}	5.5×10^{-3}	8.73×10^{-4}	3.1×10^{-4}	4.9×10^{-4}	--	--		Larynx & thyroid 5.6×10^{-4} Brain 4.1×10^{-4} TB tubes 8.8×10^{-4} Adipose tissue 1.23×10^{-2}	Kidney	TB and Pul. nodes	

DECEASED TRANSURANIUM WORKERS - DATA SHEET #1

Registry No.	Date of Birth / Date of Death	Sex and Race	Years: At Risk	Years: 1st Positive Urine to Death	Years: Definite Exposures to Death	Hospital and Date Autopsy Protocol Received	Probable Primary Cause of Death	Probable Contributing Causes of Death	Serious Medical Conditions During Life	Environmental Exposure Estimated Amount and/or Duration: Cigarettes	Craft Chemicals Physical, etc.		Inhalation Exposure Composition, Size, Shape, Solubility, Treatment
02D0 0792	5/5/18 12/2/73	M W	-	0	6	Howe Mortuary Boulder 12/3/73	Automobile Accident. Extensive mass trauma, head c̄ deep lacerations and multiple fractures frontal parietal & occipital.	---	Essential hypertension. On medication.	n.i.	Machinist		^{239}Pu Metal Oxide
02D0 0928	1922 2/19/74 Wt at death 165 lbs.	M W	-	0	0	St. Anthony Hospital Denver 2/20/74	Cerebral Hemorrhage due to rupture of an A-V malformation in lateral ventricle of brain. Hemorrhage I.V., cerebral, cerebellum and pituitary subarachnoid.	Arteriosclerosis (generalized) of arteries of heart, kidneys, arteriolonephrosclerosis	Myocardial Infarction 8/18/70 Atherosclerosis generalized	n.i.	Machinist		$^{239}PuO_2$
02D0 1382	10/28/22 8/23/73	M W	-	0	0	St. Anthony Hospital Denver 8/24/73	Glioblastoma Multiforme of Cerebrum	Bronchopneumonia (extensive) immediate cause of death	Arteriosclerotic heart disease. Accessory spleen probably not serious.	n.i.	Machinist		$^{239}PuO_2$

1009714

1009715

DECEASED TRANSURANIUM WORKERS - DATA SHEET #3

Registry No.	Concentration of Pu in Organs - dpm per gram										Organ Conc. dpm/gm		Remarks
	Lung	T.B.L.N.	Liver	Skeleton	Kidney	Spleen	Muscle	Heart	Wound	Other (Specify)	Lowest	Highest	
04UC 0244	0.375	10.352	0.538	0.085 (vertebrae)	0.010 (L) <MRL (R)	0.116	<MRL			Gonad 0.025 Sternum 0.024 Thyroid MRL Blood 0.76 Rib 0.024 Femur 0.047	Thyroid & muscle = <MRL	TBLN 10.35 dpm/g	MRL=min. reporting level (0.03 dis/min per sample analyzed)

1009716

DECEASED TRANSURANIUM WORKERS - DATA SHEET #1

Registry No.	Date of Birth / Date of Death	Sex and Race	years: At Risk	years: 1st Positive Urine to Death	years: Definite Exposures to Death	Hospital and Autopsy Protocol Received	Probable Primary Cause of Death	Probable Contributing Causes of Death	Serious Medical Conditions During Life	Environmental Exposure, Estimated Amount and/or Duration — Nonradiation: Cigarettes	Nonradiation: Craft, Hazards-Chemicals, Dusts, Metals, Solvents, Gases, etc., Asbestos, Physical Agents	Radiation: Tr.Ur. Isotopes, Particle Size, Phys. & Chem. Comp., Sol., Isotopic Comp., Pu/Am Ratio, Treatment
04UC 0207	5/20/26 3/19/73	M W	24.58 y 1948-1973	24.08 y 1949-1973	18.25 y 1955-1973 nasal smear 2500 dis/min		Crushed chest - auto accident		Mild to moderate atheromatous changes noted at autopsy	Intermittently, up to two packs per day since 1945.	Brief exposure to beryllium; various acids and solvents since 1948.	^{239}Pu, ^{240}Pu, ^{241}Am since 1948. ^{238}Pu (slight) since 1971. Weapons grade Pu primarily, in various chemical forms, via inhalation and in wounds which were excised. Particle size unknown.

1009711

DECEASED TRANSURANIUM WORKERS - DATA SHEET #2

Registry No.	Radiation Isotope Non-Tr.Ur.	Exposure Miscellaneous	Acute-A or Chronic-C Inhalation or Wound Exposures	Estimated Deposition Before Death - nCi (Note if Pu,Am,Cm,Other Tr.Ur.El. s- if soluble, i- if not soluble): Systemic	Lung	Wound	Deposition from Autopsy - nCi, Whole Organ or Extrapolation (nCi per Sample / Wt. in Grams of Sample x Wt. in Gms (weighed if possible) of Organ): Systemic	Lung	Bone	Liver	Tr.Br. L.N.	Wound	All Other	Total Body Deposition - nCi: Pre-Death Estimate	From Autopsy	Remarks
[illegible]	[illegible] for lung scan [illegible], bone scan [illegible]		[illegible]	22.0 ^{239}Pu	--	--	7.3	0.76	0.87	5.16	--	--	Aorta 0.014 Pancreas 0.002 Kidney 0.018 Thyroid 0.001 Muscle 0.918 Spleen 0.023 Fat 0.119 Prostate 0.001	22.0±11	9.1	

1009718

DECEASED TRANSURANIUM WORKERS - DATA SHEET #3

Registry No.	Lung	T.B.L.N.	Liver	Skeleton	Kidney	Spleen	Muscle	Heart	Wound	Other (Specify)	Organ Conc. dpm/gm Lowest	Highest	Remarks
	Concentration of Pu in Organs - dpm per gram												
[illegible]	[illegible]		5.17	0.19 Sternum 0.[illegible]7 Vert. 0.[illegible]6 Long Bone (Femur) 0.97	0.1[illegible]	0.23	[illegible].06			Aorta 0.25 Pancreas 0.03 Thyroid 0.06 Fat 0.02 Prostate [illegible]	Fat	Liver	