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ANNUAL REPORT
OCTOBER 1, 1994 - SEPTEMBER 30, 1995

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Dedication

Since the inception of the Registries in 1968, more than 350 men and women have participated in this research through postmortem donation of tissues. The faculty and staff of the Registries recognize these generous and anonymous contributors to science and dedicate this 1996 Annual Report to their memory. So too is this report dedicated to the memory of two of our scientific colleagues, Dr. Roy C. Thompson (1920-1995) and Professor Robley D. Evans (1907-1995), who during their many years of service as members of the USTUR Advisory Committee provided guidance and support, and who throughout the entire existence of the program, served as colleague, mentor, and friend to the entire faculty and staff. These contributors to this research have earned the respect and admiration of all of us within the Registries family. Through their contributions, our understanding of the biological and health physics aspects of the actinide elements has been greatly facilitated, and we moved closer to achieving a primary goal of the Registries - providing a sound scientific basis for radiation protection standards, thereby assuring their adequacy for the protection of people and the environment.

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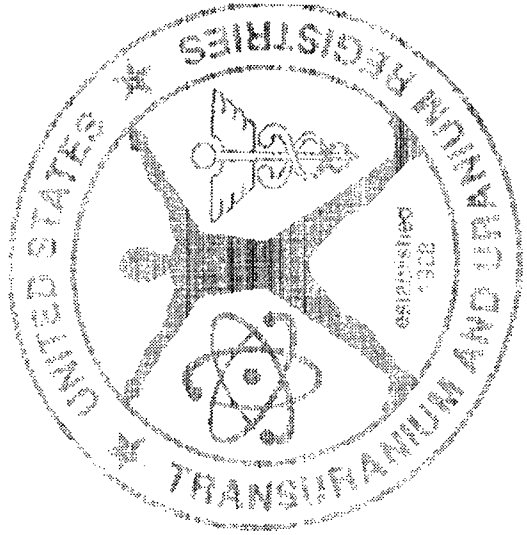
TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ACHRE	Advisory Committee on Human Radiation Experiments
AF	activity fraction
AMAD	Activity median aerodynamic diameter
CEDR	Comprehensive Epidemiological Data Resource
CR	concentration ratios
DNA	deoxyribonucleic acid
DRMIA	Dosimetry Registry of the Mayak Industrial Association
EPA	Environmental Protection Agency
EPR	electron paramagnetic resonance
FISH	fluorescence in situ hybridization
GPA	glycophorin-A
HEHF	Hanford Environmental Health Foundation
ICD-9	International Classification of Diseases-9th Revision clinical Modification
ICRP	International Commission on Radiological Protection
LANL	Los Alamos National Laboratory
NHRTR	National Human Radiobiology Tissue Repository

NIST	National Institute of Standard and Technology
OSTI	Office of Scientific and Technical Information
PHA	phytohemagglutinin
PNNL	Pacific Northwest National Laboratory
RBC	red blood cells
RES	reticuloendothelial system
RNA	ribonucleic acid
USTUR	United States Transuranium and Uranium Registries
UW	University of Washington
WSU	Washington State University
WWW	World Wide Web

Administrative



Executive Summary

This report documents the activities of the United States Transuranium and Uranium Registries for the year October 1, 1994 through September 30, 1995. Administrative accomplishments during the year included the publication of a new brochure, the Annual Newsletter and renewal of all active Registrants. Records and files were microfilmed and the microfilmed duplicates were stored in a protected location in the campus library. In response to a request from the President's Advisory Committee on Human Radiation Experiments, the Registries provided information and specific documentation pertaining to human subjects considerations. The Registries program was found to be ethically sound and in full compliance with all applicable regulations.

A Registries home page was created on the World Wide Web. In addition to general information about the Registries program, it includes summaries of the two most recent Annual Reports; a list of publications; and access to the Registries database. The Registries home page address is www.tricity.WSU.edu/htmls/ustur/page1.html. Considerable progress was made with respect to computerization of the database; the data base now includes, in addition to the administrative information on all registrants, radiochemical results for all tissues collected at autopsy and health physics information including radiourinalysis results and other dosimetry data for all deceased registrants. In progress are a table of the health history for all registrants and a clinical history table.

During the reporting period, Registries staff authored or coauthored more than 45 scientific papers or abstracts published or submitted for publication in the open peer reviewed scientific literature and presented more than two dozen scientific papers, seminars, and public presentations. The Director was named Hartman Medalist and Orator by the Radiology Centennial and was also the recipient of the Herbert M. Parker Award.

The radiochemistry laboratory became fully operational with primary effort devoted to reduction of the sample backlog received from Los Alamos National Laboratory and to quality assurance. Quality assurance intercomparisons with the University of Washington and Los Alamos National Laboratory were carried out and revealed no indications of random or systematic error.

Evaluation of USTUR Case 0259, a whole body donor who had incurred an acute inhalation intake of high fired $^{238}PuO_2$ 18 years prior to death, revealed a systemic distribution pattern of the 238 isotope of plutonium not significantly different from that observed for ^{239}Pu. About half the total body burden of ^{238}Pu was found in the liver, but only 37 per cent in the skeleton. There was, however, considerably less activity in the respiratory tract than would be expected on the basis of current models, and this observation, coupled with the urinary excretion pattern observed during life, are indicative of more rapid clearance of

the 238 isotope from the respiratory tract as compared with ^{239}Pu, likely attributable to particle breakup because of the higher specific activity and consistent in this regard with what has been observed in animal studies.

Examination of tissue concentration ratios for both plutonium and americium in Registries cases as a function of time after intake suggests that there are no significant differences in the retention half-time among the various soft tissues as compared with the liver. Teeth were evaluated as a means of estimating total skeletal content of plutonium or americium. No consistent relationship was found between plutonium and americium concentration or content in the teeth and in the skeleton as a whole. The activity concentration in certain bones, notably the ribs, was found to be a constant fraction of the average skeletal concentration, and these bones can thus be used to estimate total skeletal content of actinide making appropriate assumptions relative to the mass of the skeleton.

Cytogenetic studies were initiated utilizing glycophorin-A and fluorescence *in situ* hybridization techniques to examine circulating red blood cells in persons with a known history of exposure to the actinide elements with the ultimate goal of utilizing stable chromosome changes to quantify exposure to the actinide elements.

The feasibility study was completed for joint USTUR-Russian research collaboration. This work documented the similarities and differences between the Registries of the two countries and a plan was developed for future effort.

ADMINISTRATIVE ACTIVITIES

Lynn A. Harwick and M. June Markel

Microfilming

This year the Registries secured the funding necessary to microfilm all Registrant and related records. Each individual record was microfiched and is kept with the physical files in a secured room in the USTUR building. Another microfilmed copy is stored in the Max E. Benitz library at WSU in Richland. Although the microfilm is stored in the library, it is unavailable for public use since it contains personal identifiers and other information that requires protection in accordance with state and federal law. The records will be microfilmed periodically to ensure they are kept current and accurate.

Many benefits have been gained through the completion of the microfilming. Registries faculty and staff now have an extra copy of Registrant data for scientific and administrative use. Previously, only one staff member could use a particular file. It has also provided the security of having an additional copy in the event of a fire or natural disaster which may destroy documents significant to the Registries research. Additionally, the microfilming process actually added clarity to many of the older documents which were difficult to read due to fading.

Advisory Committee Meeting

The annual USTUR Advisory Committee Meeting was held October 17-18, 1995 at the University Inn in Moscow, Idaho. The meeting was attended by the USTUR Advisory Committee, USTUR staff, and others associated with the program. All Advisory Committee members were in attendance: Keith Schiager, Advisory Committee Chairman; Borje K. Gustafsson, Kenneth G. W. Inn, George L. Voelz, Bruce Lawson, MaryBelle Thompson and the newly appointed Robert Thomas, recently retired from Argonne National Laboratory. The report of the Committee is included as an Appendix D.

The meeting was held in Moscow, Idaho which borders Pullman, Washington to allow meeting attendees to tour the recently remodeled radiochemical laboratory in the Nuclear Radiation Center on WSU's main campus where radiochemical analyses in Registries research formerly performed by the Los Alamos National Laboratory (LANL) are now carried out.

Color Brochure

A full-color information brochure on the Registries was printed and distributed. The brochure combined the information contained in the first USTUR brochure and that in the document formerly known as "Questions and Answers" about the USTUR. Charles Powell, Information Coordinator for the WSU College of Veterinary Medicine, and the USTUR Advisory Committee assisted with editing the material into an easily read and non-technical format.

The brochure provides an overview of the USTUR and the National Human Radiobiology Tissue Repository

(NHRTR). It also briefly discusses the research interests of the program and how post-mortem tissue donations are obtained. Inside the brochure is a postage paid business reply card which can be returned to the USTUR to request further information about the program.

Human Subjects Review

As noted in the 1994 Annual Report, all research programs at WSU which use human subjects must be granted approval by the WSU Institutional Review Board (IRB). The USTUR which was initially granted approval by the IRB in February, 1992, and again this year received approval for continued research involving human subjects in 1995. No changes were recommended by the IRB.

Manuscript Tracking System

Due to rapid programmatic growth and the addition of the radiochemistry operations last year, a significant increase in publications has arisen necessitating the establishment of a manuscript tracking system. Each manuscript receives a tracking number in the following format: USTUR-####-YY.

The five letters identify the program and are followed by a unique four-digit number, with the last two digits corresponding to the year of publication. Once a number is assigned, a file is established and the publication is either submitted to a peer-reviewed journal or to the Office of Scientific and Technical Information (OSTI).

Persons interested in receiving a publication registered with OSTI can request a copy from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831, as well as directly from the Registries, although supplies from the latter source are limited.

Registrant Newsletter

The second registrant newsletter was published and mailed in December to all currently active Registrants. Once again, the newsletter highlighted USTUR activities for the past year and gave Registrants the opportunity to see how their participation is essential to the continued research of the Registries. The newsletter also gives the Registries an opportunity to extend season's greetings to several hundred program Registrants located in various parts of the country.

New Phone System for the campus

WSU installed a new phone system this past Fall. The system allows anyone on any WSU campus to reach any of the other WSU campus by dialing a five-digit number. This is not only more convenient, but toll-free as well. In the past, the phone number had to be dialed in its entirety and there was a long-distance charge for each call. The system has also brought voice mail to the campuses and several new features which bring WSU into the "communications 90's."

Prior to the switch to the new phone system, the Richland campus received all new phone numbers. Previously the prefix was 375-9XXX, but was changed to 372-7XXX in anticipation of the new system.

376-6010 Disconnect

As mentioned in the previous Annual Report, the Registries now has an 800 telephone number which is replacing the

hotline which was formerly used to place collect calls to the USTUR. If you dial the hotline at (509)376-6010, you will hear a recorded message that refers you to the new 800 number, (800)375-9317. This number is toll-free and was established for the use of Registrants, their families, and caretakers as well as others who may have questions or need more information about the Registries.

The recording will eventually be disconnected, so please make note of the new 800 number.

Advisory Committee on Human Radiation Experiments (ACHRE)

ACHRE was created by President Clinton to evaluate the history and policies of human radiation experiments carried out or sponsored by the U.S. Government. As part of their evaluation, ACHRE began a Research Proposal Review Project in which several programs funded by various federal agencies were selected and asked to provide specific documentation pertaining to their human subjects research approval. The USTUR provided this information as well as offered copies of the Registries' pertinent policies and procedures. The Registries program was found to be ethically sound and in complete compliance with all applicable regulations.

Registrant Renewal 1994-95

After the 1993 audit review of all Registrant files, it was concluded that a mass renewal of Registrant agreements was required. Historically and prior to the transfer of the Registries, the participants in the tissue donor program were renewed every five (5) years with the date of determination for renewal being the date the completed forms were signed by the Registrant and accepted by the Registries. This method, while previously adequate, was inefficient and incompatible with the modern automated system at Washington State University. The Registrant renewal began with a mass mailing to all active Registrants regardless of the donor expiration date.

A comprehensive review of the Registrant files indicated that a majority were not complete, lacking medical and health physics information on virtually every active case. Prior to the 1992 Registries transfer to WSU, standard practice was to request medical and dosimetry records after death and at the time of tissue analysis. However, to gain information necessary to determine whether Registrants met the criteria for enrollment in the Registries, it was decided that information should and would be requested prior to acceptance of the enrollment forms. This task compounded the renewal by slowing down the process, adding a financial and time burden to former Registrant employers faced with a dwindling medical and dosimetry workforce and in some cases, outright refusal by the employer to release medical and dosimetry records.

As a result of the renewal, a number of improvements have been implemented including color coding of the file labels which gives instant recognition of Registrant status and minimizes the possibility of completing incorrect documentation at the time of a death.

The Long Range Plan

The future development, growth and

USTUR have been identified in the Long Range Plan 1996-2005. These include contributions of interests and vision by Registries staff members as well as suggestions put forth by the Advisory Committee in previous years. A copy of this document is available and can be requested directly from the USTUR or by writing to OSTI, as instructed in the Manuscript Tracking System. The tracking number for the Long Range Plan is #USTUR-0040-95.

Record Archives

Review of the archival records and files transferred from HEHF indicated a need to implement an alpha-numeric coding system to access information, not required in the every day functions of the office but valuable as historical information on the Registries and other entities involved with the inception and continued effort. This task was tabled until the Renewal was completed and has now been reactivated.

USTUR Database

USTUR DATABASE

Minh V. Pham

Introduction

During fiscal year 1995, notable progress was made with the USTUR database system, which has been modernized to eliminate software and format incompatabilities and now utilizes a unified standard format. The improved high reliability and consistency of the data not only facilitates statistical analyses, but enables certain mathematical and other procedures to be carried out expeditiously and with a previously unattainable degree of accuracy. Several major database files have been completed, and at the same time supplementary database files continue to be developed to accommodate the growing needs of the Registries. Much of the data has also been made readily accessible to the scientific community both nationally and internationally through the Registries' homepage on the World Wide Web and the Comprehensive Epidemiologic Data Resource (CEDR).

Database Files

The three main files in the USTUR database are labeled Radiochemical, Health Physics, and Medical. The first two files are complete and contain large volumes of data which are regularly updated, while the Medical file is still under development.

The Radiochemical file contains basic file information about radiochemical analysis of tissue donations from USTUR registrants. These data were originally collected from a number of sources, primarily national laboratories. Because of differences in the data collection protocols for the various sites, it was necessary to convert the data into a consistent format which was accomplished using the commercially available PARADOX For Windows software. The data generated from the radiochemical laboratory in Pullman have also been incorporated into the USTUR database. Additional data are routinely integrated into the system as it is received from the laboratory.

The Health Physics file contains bioassay and other health physics data and was the second major database file to be completed. This file contains about 14,000 registrant records including external dose assessments and information, and results of excreta analysis and *in vivo* counting. Although there was a large volume of records, all those existing have been inputted and will continually be updated. To ensure quality control, the data are also cross-checked for accuracy.

The Medical file contains both personal and clinical data and is currently being developed. To remain consistent and be able to share data with other research institutes. the file has been created utilizing ICD-9 CM Coding, a world recognized standard medical format which is commonly used for medical data coding. The personal data have been entered and input of the analyzed data has continued through this reporting period.

Figure 1 illustrates the workings and accountabilities of cognizant Registries'

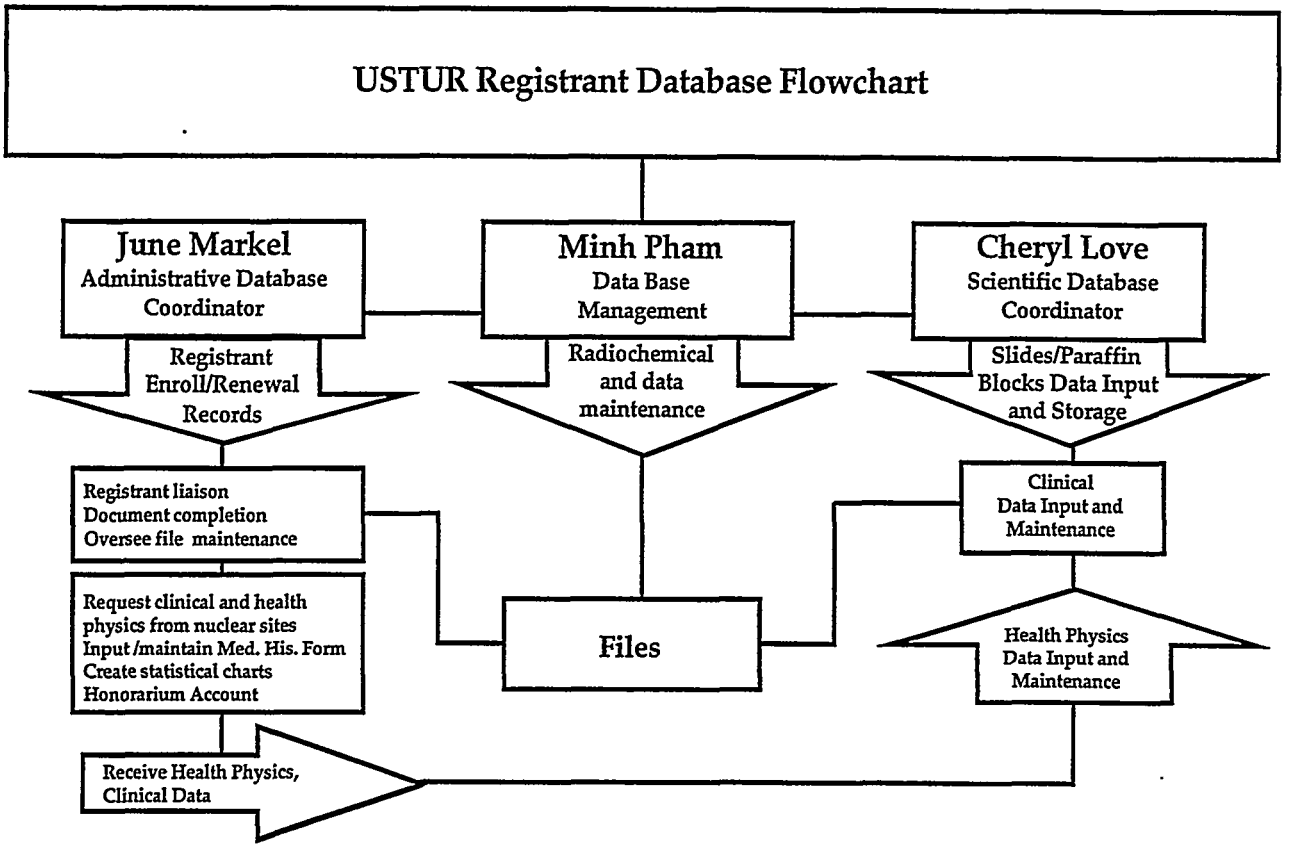
staff with regard to the USTUR database.

World Wide Web

The Registries now have a homepage on the World Wide Web. This new technology has allowed the Registries to make the entire electronically formatted database available through CEDR. In addition to data, the homepage also allows users to access Registries' information such as annual reports, publications, and the program's history which all can be downloaded. Comments and questions can be sent to the Registries through the homepage, and inquiries will be responded to via computer or mail. The Registries home page is linked to the Washington State University home hage, and the CEDR home page.

USTUR World Wide Web address is:
http://www.tricity.wsu.edu/htmls/ustur/page1.html

Figure 1. USTUR Registrant Database Flowchart



Scientific Progress

CYTOGENETIC STUDIES AND RADIATION CARCINOGENESIS

Principal Faculty Investigator: John J. Russell

It has become increasingly apparent that the development of a tumor involves a number of specific mutations including deletions of partial or entire chromosomes. From studies using chemical carcinogens, certain oncogenes have been associated with phenotypic changes of transformation. It is not known which oncogenes are responsible for radiation-induced transformation, but numerous studies have demonstrated that agents other than ionizing radiation can cause neoplasia via a series of steps. These steps are identified as initiation, promotion, and progression and suggest that similar steps may be involved in radiation tumorigenesis as well. Thus, in addition to identifying which and how many oncogenes may be involved and in what manner they become activated, it is also essential to know what role they play in the overall carcinogenic process.

Whether in human or animal tissue, it is clearly impossible to distinguish a tumor or neoplasm induced by ionizing radiation from one that occurs spontaneously. Radiation induced neoplasms are identified in a population study by calculating the difference between the background frequency of spontaneous tumors and the excess rate (BEIR IV). It is also equally true that neoplasms can be induced in virtually any tissue or organ of the body if the exposures are appropriate; however, there are significant differences in the oncogenic potential of irradiation in different tissues.

Radiation is generally accepted as a complete carcinogen in that a single exposure can induce neoplasia. Many combinations of physical and chemical agents can have varying degrees of effects on carcinogenesis. Their interactions can be additive, synergistic, or multiplicative. Several studies have shown radiation serving as the second event in the multi-step process of oncogenesis after initiation by other means.

The value of tissue specimen banking projects such as those at National Institute of Standards and Technology (NIST) and the Environmental Protection Agency (EPA) have provided baseline environmental data for monitoring chemical toxicant trends over time and among different sites, and provided samples for reanalyses as well as samples for retrospective analysis with new and or improved techniques. They have also helped to evaluate the stability of biological samples and environmental pollutants in archived or long-term storage. These advantages and numerous others can be obtained from the use of human tissue samples archived in the NHRTR.

In addition to the traditional studies of organ retention, dosimetry, microdosimetry, and biokinetic modeling, the Registries' research efforts have expanded into other areas, including studies of radiation carcinogenesis and exposures to mixed hazardous wastes. Thus, we be-

lieve that additional analyses of these archival samples for such things as hazardous chemicals i.e. halogenated hydrocarbons, heavy metals, asbestos, or other toxic compounds frequently encountered in the work place, will provide valuable information. This information regarding the level and type of interactions produced in combination with radiation, and whether or not the combination of exposures are more deleterious than either alone, could be very significant.

The importance of gross chromosomal changes has been recognized and valued in the very recent past as a marker for cellular damage. New techniques for characterizing chromosomes have been developed that allow whole or pieces of chromosomes to be identified and the subsequent loss, partial deletion, or rearrangement of chromosomes in tumors to be examined. The emergence of new and improved biodosimetric techniques have made it possible to evaluate a radiation worker in new ways never before possible. In addition, these biodosimeter techniques can be used to augment or challenge official dosimetry record information maintained during employment.

Two such biodosimeter techniques, glycophorin-A (GPA) and fluorescence *in situ* hybridization (FISH), detect somatic mutations and chromosome translocations that are stable with time post-exposure and integrate radiation damage from chronic radiation conditions. Two other techniques, micronuclei and dicentrics, are unstable and only detect relatively recent radiation exposures.

The first one, GPA, detects mutations in the GPA gene of bone marrow euthyroid precursor cells that produce variant peripheral blood erythrocytes that fail to express a normal form of GPA. The FISH assay was developed to detect chromosome translocations in peripheral blood lymphocytes using *in situ* hybridization of chromosome-specific DNA probes. The *in situ* hybridization technique has become a very powerful and versatile tool for detecting and localizing nucleic acid (RNA or DNA) sequences within cell nuclei of tissue sections or cell preparations. The sub cellular target i.e., chromosome translocation, is detected by the hybridization of a complimentary probe that has been labeled with a fluorescent dye with the tissue section or cell preparation. For these studies, a heparinized blood sample is cultured with phytohemagglutinin (PHA) to stimulate the growth of T lymphocytes which are then arrested in metaphase by colcemide treatment.

GPA is a cell surface sialoglycoprotein of red blood cells (RBC). For the GPA assay, a heparinized blood sample is fixed and the RBC's are labeled with monoclonal antibodies and analyzed on a flow cytometer. The assay is used to determine the frequency of RBC's lacking the expression of one of the allelic forms of the cell surface protein GPA that may have resulted from a mutation induced in the GPA locus in bone marrow erythroid precursor cells.

In an effort to expand understanding of the effects of radiation exposures in humans, the Registries are set to pursue, identify, and quantify the cytogenetic aberrations, both induced and spontaneous, in existing living registrants who are cur-

rently identified as long range follow-up study participants. To perform the outlined studies above, we will use a 10-15 ml blood sample from each participant, collected twice a year to accommodate seasonal variations. The blood samples will be collected by independent qualified medical personnel using routine procedures and safety precautions.

Selected Future Studies

To understand radiation-induced carcinogenesis, it is necessary to identify the specific genes responsible for the initiation, promotion, and progression events of the multi-step carcinogenic process. Currently, there are approximately 100 oncogenes that can, if they malfunction, cause uncontrolled cell growth. Conversely, there are at least six known genes that suppress the growth of potential cancer cells. How ionizing radiation affects genes and gene expression is a hotly debated issue and a highly promising area for Registries related research. Accordingly, the Registries, through the NHRTR, has initiated collaborations with other investigators. Specific study areas include:

1. Iteration or deletion of genes such as c - myc, that function in cell proliferation, differentiation, and tumor promotion.

2. The relationship of p53 and the retinoblastoma gene in the development of bone tumors.

3. The development of biological dosimeters or biomarkers for retrospective dosimetry such as electron spin resonance (ESR) of tooth enamel, FISH for the detection of gene translocations, and glycophorin-A analysis for somatic mutation detection.

4. Whether one or all of the above are dose and or dose-rate related.

5. Mixed hazardous wastes exposure-induced health effects incurred from accidental exposures received during site cleanup activities.

6. The induction of micronuclei in deep lung epithelial cells as a model for radiation sensitivity of the respiratory tract.

A number of the study areas listed above are currently under active investigation with collaborative institutions and will be reported in the near future. However, the successful development of much needed *in vitro* cell culture methodology to grow and maintain deep lung and nasal epithelial cells has been accomplished in collaboration with scientists at Battelle Pacific Northwest National Laboratory (PNNL). These techniques are being used to investigate the relationship between cancer induction and cytogenetic instability induced by radiation exposure. Results from these initial studies were discussed in two papers presented at the 12th Annual Meeting of the Pacific Northwest Association of Toxicologists, September 15-16, 1995 in Moscow, Idaho. The presentations were made by Registries faculty member Shiping Bao and were entitled, *Induction of Micronuclei In The Respiratory Tract Following Exposure To ^{60}Co Gamma Rays* and *Use of Cellular Damage To Determine The Relationship Between Exposure And Dose From Inhaled Radon.*

Availability of NHRTR Tissue Samples

The unique materials of the NHRTR are available to investigators for research purposes. Any scientific investigator may request NHRTR tissues or tissue samples by writing to the Registries. Investigators agree to maintain the privacy of the cases and follow all legal requirements as well as the published policies of the Registries. If available, the Registries will provide the most suitable tissue requested, e.g. frozen, formalin-fixed, or dried. In addition, if the radiochemical data are known at the time of the request, it will be provided as well. The only stipulation is that the Registries be acknowledged as the source of the samples or radiochemical data used in scientific proposals or manuscripts submitted for publication. Scientific collaboration with the Registries scientific staff is encouraged.

References

National Research Council. Committee on the Biological Effects of Ionizing Radiations (BEIR IV). Health risks of radon and other internally deposited alpha-emitters. Washington, DC: National Academy Press; (1988).

COMPARING ACTINIDE CONCENTRATIONS IN THE SKELETONS AND LIVER OF USTUR ROUTINE AUTOPSY CASES

Principal Faculty Investigator: Ronald E. Filipy

In the USTUR annual report for 1994, the report of progress in actinide biokinetic investigations was focused on several soft tissues of the body (Kathren and Harwick 1995); the results of that investigation were recently published (Filipy and Kathren 1996). The skeleton and the liver are the major deposition sites of actinide elements in the body and they are of primary concern for radiation protection purposes because, next to the lungs, they are the organs of highest risk for radiation-induced biological changes including cancer. Therefore, deposition and retention of the actinides in those two organs are the focus of this report. As indicated in another section of this report (Filipy 1996), the Dosimetry Registry of the Mayak Industrial Association (DRMIA) has collected similar human tissue data from Russian plutonium workers and some of these data were included in the analysis.

Initial systemic depositions of actinides in most USTUR cases can only be roughly approximated from urinalyses, fecal analyses, and/or whole body counting; therefore, estimates of the contents of individual organs, initially or at any given time after exposure, are highly uncertain. Such information is necessary for characterization of clearance rates from individual organs, as well as for accurate dose estimation, which in turn is crucial to epideimiologic and risk and effects studies. A useful means of circumventing that problem is to compare concentration ratios of the organs with residence times (times between exposure and death).

Skeleton-to-liver $^{239+240}$Pu and ^{241}Am concentration ratios were calculated and plotted as a function of residence times in Figures 2 and 3, respectively. Also shown in the figures are regression lines through the observed data and lines representing concentration ratios calculated by ICRP-67 methodology (ICRP 1994). There is a notable difference between the magnitude of the concentration ratios of plutonium and americium. Most ratios of plutonium are in the range between 0.05 and 1.0 while those of americium are generally between 0.1 and 10.0. This indicates greater deposition and retention of americium than plutonium in the skeleton; or less americium than plutonium in the liver; or both, not surprising in light of previous reports that arrived at the same conclusions (ICRP 1986; Kathren et al. 1988; McInroy et al. 1989; Kathren 1994).

For plutonium (Fig. 2), the regression line and the model-predicted lines are very nearly parallel for the entire range of residence times. The slight positive slope of the lines suggests that the retention half-time of the liver is slightly shorter than that of the skeleton although the slope of the regression line was not significantly different from zero which would indicate no difference in retention half-times in the two organs. The ratios calculated by the ICRP technique are about 1.5 times greater than

those of the regression line which suggests that the ICRP model predicts a slightly greater than observed skeletal concentration or a slightly less than observed liver concentration, or both. Because of the variability in the observed data, there is not a statistically significant difference between the ICRP model and the regression line through the observed data. It is noted, however, that approximately three-fourths of the observed skeleton:liver concentration ratios are smaller than the ratios calculated by the ICRP technique.

For americium (Fig. 3), the model-predicted line is higher than the regression line through the observed data by approximately a factor of two with residence times greater than 10 y. Again, the variation in data probably precludes any statistical difference between the lines although it is apparent that the majority of observed data points are below the ICRP-predicted concentration ratios. The slope of the regression line through the observed skeleton:liver americium concentration ratios was nearly the same as that for the plutonium ratios although, again, the slope was not significantly different from zero.

One possible explanation for the differences between the model-predicted lines and the regression lines, if the differences are in fact real, might be in the mode of exposure. Approximately one-third of the USTUR cases had no recorded exposure incidents or positive bioassays during the time they worked with actinides, yet they had actinide body burdens at death which indicates very low-level, chronic exposure and the ICRP models are based on acute exposures. Also, most USTUR and DRMIA exposures were by inhalation of relatively insoluble forms of plutonium so the systemic uptake from the lungs would be expected to occur over a long period of time. The effect of acute versus chronic intakes on actinide biokinetics is not known.

The ICRP models are primarily based on animal experimental data with a very limited amount of human data, largely from short-term experiences. The data shown in Figs. 2 and 3 suggest that some adjustment to the models might be appropriate to more closely align with observed, long-term human data.

References

Kathren, R.L., L. A. Harwick, R. E. Toohey, J. J. Russell, R. E. Filipy, S. E. Dietert, M. M. Hunacek, and C. A. Hall. Annual Report of The United States Transuranium and Uranium Registries, October 1, 1994-September 30,1995. USTUR-0049-95 (1996).

Filipy, R. E. and R.L. Kathren. Changes in soft tissue concentrations of plutonium and americium with time after human occupational exposure. *Health Phys.* 70:153-159 (1996).

International Commission on Radiological Protection. The metabolism of plutonium and related elements. *ICRP Publication* 48; *Ann. ICRP 16*(2/3):1-98 (1986).

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides. *ICRP Publication* 67. *Ann. ICRP* 23(3/4):1-167 (1994).

Kathren, R. L., J.F. McInroy, M.M. Reichert, and M.J. Swint. Partitioning of ^{238}Pu, ^{239}Pu, and ^{241}Am in skeleton and liver of U. S. Transuranium Registry autopsy cases. *Health Phys.* 54:181-188 (1988).

Kathren, R. L. The United States Transuranium and Uranium Registries, a twenty-five year report: Toward improved biokinetic models for actinides. *Radiat. Prot. Dos.* 53:219-227 (1994).

Kathren, R. L. and L.A. Harwick. eds. Annual Report of the United States Transuranium and Uranium Registries. October 1, 1993 - September 30, 1994. Washington State University. USTUR-0036-95:69 (1995).

McInroy, J. F., R.L. Kathren, and M.J. Swint. Distribution of plutonium and americium in whole bodies donated to the United States Transuranium Registry. *Radiat. Prot. Dos.* 26:151-158 (1989).

Figure 2. Skeleton: liver plutonium concentration ratios as a function of estimated time between exposure and death (residence time) in USTUR and DRMIA cases, including the predicted ratios calculated by ICRP (1994) methodology and the regression line through the observed data.

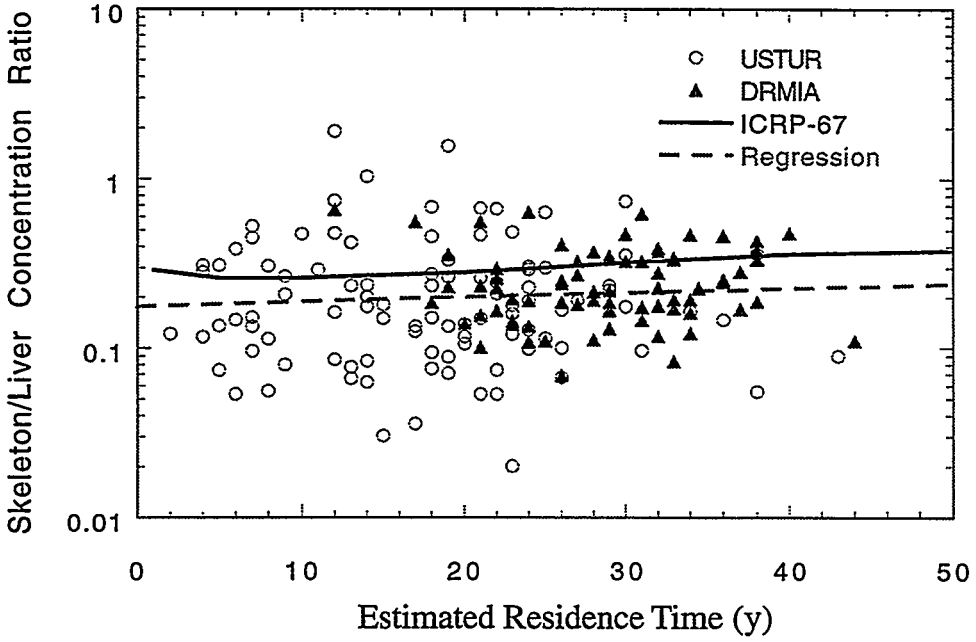
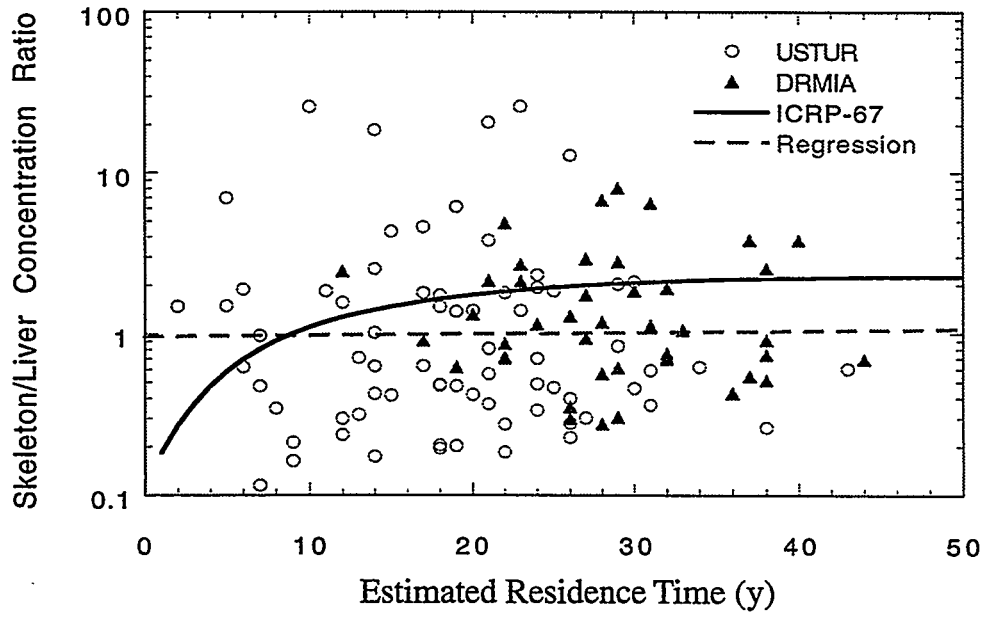


Figure 3. Skeleton: liver americium concentration ratios as a function of estimated time between exposure and death (residence time) in USTUR and DRMIA cases, including the predicted ratios calculated by ICRP (1994) methodology and the regression line through the observed data.



THE RUSSIAN-U.S. REGISTRIES COLLABORATION

Principal Faculty Investigator: Ronald E. Filipy

Scientists of the First Branch of the Russian Institute of Biophysics have been collecting autopsy and human tissue analytical data nearly as long as the USTUR has been operating. The Russians have concentrated mainly on occupationally-exposed plutonium workers from Mayak, the Russian plutonium production facility.

In January, 1995, USTUR Professor Ronald E. Filipy attended a scientific symposium at Chelyabinsk, Russian Federation (140 km from Mayak) and presented a paper entitled "*Estimation of Actinide Element Biokinetics and Organ Doses in Humans on the Basis of a Limited Number of Samples Collected at Autopsy.*" At the symposium, meetings with Russian scientists involved with the DRMIA resulted in a collaborative research agreement, sanctioned by the U. S. and Russian governments. The project, officially started in March, 1995 as a one-year feasibility study, is expected to greatly enhance understanding of plutonium biokinetics and dosimetry in man.

The primary focus of the first year of the joint Russian - U.S. collaboration focussed on comparison of the methods used by the DRMIA and the USTUR for collection and limited comparison of data. Communication with DRMIA scientists has been accomplished primarily by electronic mail and facsimile transmission. However, in August of 1995, three Russian scientists visited the USTUR facilities. During that visit, a project progress report comparing the methods and data of the two Registries was drafted and submitted to a peer-reviewed journal for publication. A number of differences in the Registries methods of operation were noted. Among them were:

1) The USTUR cases are derived from a number of work sites with differing operational, dosimetry, bioassay, and medical practices whereas, the DRMIA cases are from a single site and more likely homogeneous in terms of exposure histories and dosimetry;

2) Autopsies on DRMIA cases have been performed by a single group of pathologists, as compared with the USTUR which relies on pathologists available at the location and time of registrant death;

3) The USTUR has received and analyzed several whole-body donations which have provided more complete data regarding distribution of the actinide elements among body organs than that of the DRMIA;

4) Actinide levels in tissue samples collected by the DRMIA were generally higher than those of the USTUR;

5) Tissues collected by the DRMIA have all been analyzed on site by a single laboratory, while USTUR tissues have been analyzed by four separate laboratories, with intercomparisons available;

6) Radiochemical analytical techniques differ between the two Registries; the DRMIA utilized co-precipitation techniques and direct scintillation counting while the USTUR routinely uses radiotracers with alpha-spectrometry using state-of-the-art counting equipment.

Overall, there are more similarities than differences between the two Registries providing a number of advantages to be gained from the joint use of data. Some advantages are:

1) The USTUR and the DRMIA have post mortem data from more than 350 and 750 deceased registrants, respectively. Collaboration would increase the number of cases available for analysis by a factor of four relative to the number of USTUR deceased registrants thereby greatly enhancing the statistical power for variable data analysis.

2) Combining data sets will result in greater heterogeneity of the population studied. For example, the USTUR has very few female registrants while there were a large number of females in the Russian plutonium production work force.

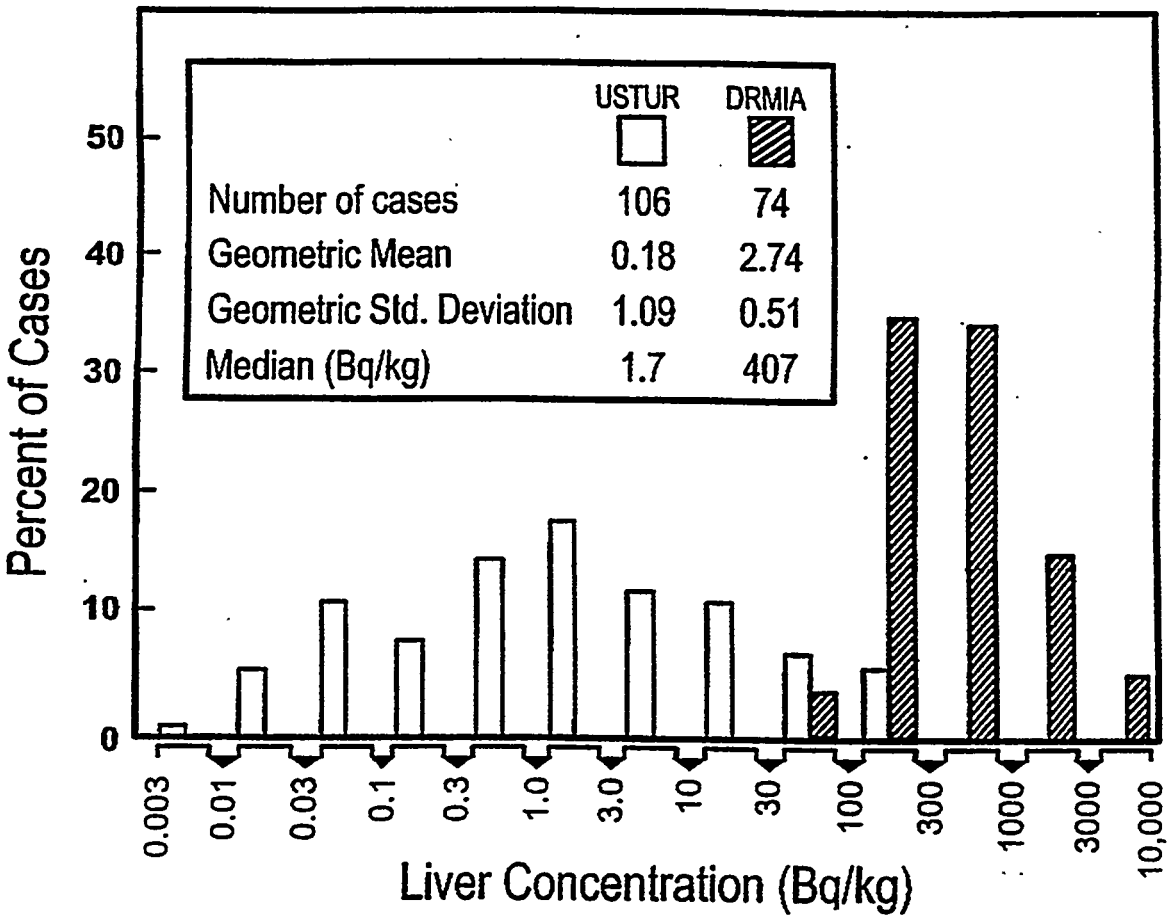
3) A broader range of exposures and exposure situations will result from combination of data. The Russian workers had much higher occupational exposures to actinides as evidenced by a comparison of liver burdens in USTUR and DRMIA cases (Fig. 4). Median liver contents of plutonium in DRMIA cases were 240 times those in USTUR cases and over 90% of DRMIA cases had higher liver concentrations than those of USTUR registrants.

4) The differences in body burdens of the Registries cases will allow an investigation of the dose-dependence or independence of biokinetic parameters. Body burdens in some of the Russian workers have been sufficiently such high such that some plutonium-related effects may be noted. In general, body burdens of U. S. workers were low enough that few effects could be conclusively ascribed to actinide exposures.

Frequency distributions of plutonium liver concentrations in USTUR and DRMIA cases are shown in Figure 4; both were log-normally distributed. The median liver concentration in the DRMIA cases was more than 200 times that of the USTUR cases. Since the liver is one of the major deposition sites of actinide elements, liver concentrations relate differences in the total body burdens or incorporation of actinide.

A proposal has been submitted to extend the collaborative project beyond the first-year feasibility study. This proposal contains many long-term objectives including a full investigation of actinide biokinetics in the human body as well as the relationship of body burdens at death to results of bioassays (urinalyses, fecal analyses, and in-vivo counts) made during life.

Figure 4. Frequency distribution of plutonium liver concentrations in USTUR and DRMIA cases.



ESTIMATION OF TOTAL ACTINIDE SKELETAL CONTENT FROM CONCENTRATIONS IN INDIVIDUAL BONE SAMPLES COLLECTED AT AUTOPSY

Principal Faculty Investigator: Ronald E. Filipy

During routine autopsies (non whole-body donations), the USTUR collects bone samples which may include the sternum, one or more ribs, one or both clavicles, one or both patellae, and a vertebral wedge cut from within the abdominal cavity (Kathren 1989; 1995). These limited bone samples are the basis for estimation of the total skeletal content of plutonium and/or americium in these cases.

The USTUR has had a number of whole-body donations and, typically, one-half the bones of each skeleton is radiochemically analyzed (McInroy et al. 1985). The remainder is used for other studies and for further radiochemical analysis if more data are required. Actinide activities of the analyzed portions of six of the whole-body skeletons (Kathren et al. 1994) were used to derive total skeletal activities for each case and are shown in Table 1. Relationships of the measured actinide concentration in individual bones or bone groups to the average concentration in the entire skeletons of whole-body donors is a basis for estimation of skeletal content of routine autopsy cases if these ratios or relationships are found to be more or less constant from individual to individual.

The mean skeletal actinide concentration was calculated for each of the whole-body skeletons by dividing the sum of measured actinide contents in all the individual bone samples by the total weight of the samples. To determine the concentration ratios, actinide concentrations in individual bones or groups of bones of the same skeleton were divided by skeletal concentrations.

Both wet and ashed concentration ratios were calculated from each skeleton and the means of the six concentration ratios for each bone or bone group are shown in Table 2. The concentration ratios for ribs were based on average concentrations in ribs 5-10 of the whole-body skeletons; these ribs had similar concentrations of the actinide elements. Concentration ratios for the vertebral wedges were based on average concentrations in vertebral bodies from the fifth thoracic vertebra through the third lumbar vertebra. Again, concentrations in these bones were similar. These groups of bones were used rather than individual ribs or vertebral bodies because of the potential nonuniformity in sampling methods by pathologists performing routine autopsies. They were considered the most likely to be included in the samples collected.

For wet weight concentrations of ^{241}Am, the patellar, clavicular, and rib concentration ratios provide the most precise estimate of skeletal concentration as indicated by the relatively small coefficients of variation (CV) for those ratios among the six whole body skeletons. The sternum and the vertebral wedge ratios have the greatest variation. For ashed weight concentrations of ^{241}Am, the clavicle has

the smallest CV with the sternum, again, the largest. The bone-to-skeleton concentration ratio for the ribs provided the most precise estimate of skeletal concentrations for both ^{238}Pu and $^{239+240}$Pu whether based on wet weight or on ashed weight. The sternal and vertebral wedge plutonium concentration ratios were generally the most variable of the five bones evaluated. There are, however, no statistically significant (< 0.05) differences among the concentration ratios listed in Table 2 indicating that any of them would be equally useful for estimation of skeletal concentrations. The skeletal content can be estimated on the basis of each sample collected at an individual autopsy and the mean of those estimates reflects the total skeletal content.

There are advantages and some problems associated with the use of the concentration ratios for estimating total skeletal content of actinides from bone samples collected during routine autopsies. One primary advantage is that concentration ratios are independent of sample mass and thus essentially any sample size can be used, assuming the entire bone is sampled and analyzed to eliminate nonuniformity within an individual bone. Some of the problems include:

1. in a number of the early USTUR cases, it is not known whether the entire bone was sampled and analyzed;

2. there was occasional wide variation in analytical results for individual bone samples collected in the early years of the USTUR which can cause the skeletal estimates for those cases to have a high degree of uncertainty;

3. ashed bone weights were not measured for many of the early USTUR cases so wet concentration ratios rather than ashed ratios must be used for those cases and;

4. ashed fractions of bone samples (ashed weight divided by wet weights) were not consistent among the four laboratories that have analyzed USTUR samples in the past; therefore, the ashed concentration ratios are most useful if the autopsy samples were analyzed by the same laboratory that analyzed the whole-body skeletons.

The problems mentioned above notwithstanding, either the wet or ashed concentration ratios can be used to provide a reasonable estimate of the total skeletal activity in the majority of cases analyzed by the USTUR. These estimates can be used in conjunction with analytical data from other tissues and organs to provide a more reliable approximation of the total body burdens of actinides at death.

Acknowledgement: Data tables were compiled by USTUR graduate research assistant Charlene Hall.

References

Kathren, R. L. The United States Transuranium and Uranium Registries: Overview and recent progress. *Rad. Protect. Dos.* 26:323-330; (1989).

Kathren, R. L. The U. S. Transuranium and Uranium Registries. In: Young, J. P.; Yalow, R. S., eds. *Radiation and public perception; advances in chem-*

istry 243. The American Chemical Society, Washington, DC. (1995).

Kathren, R. L.; Harwick, L. A., eds. Annual Report of the United States Transuranium and Uranium Registries. April 1992-September 1993. Washington State University. USTUR-0015-94 (1994).

Lynch, T.P.; Kathren, R.L.; McInroy, J.F. Macrodistribution of plutonium and americium in four human skeletons. *J. Rad. Prot.* 8:67-76 (1988).

McInroy, J. F.; Boyd, H. A.; Eutsler, B. C.; Romero, D. Preparation and analysis of the tissues and bones. *Health Phys., Part IV*: 49:587-621 (1985).

Table 1. Summary of whole body skeletal actinide content. Unanalyzed portions of the skeleton were estimated based on ratios to the analyzed portion. Teeth, cartilage, and finger and toenails were not included in the skeleton.

Case	0102[a]	0193	0208	0212	0213	0242
Wet Weight (grams)	8990.0	8450.0	8000.0	10400.0	8740.0	9670.0
Ash Weight (grams)	2540.0	2720.0	2630.0	3230.0	2880.0	3090.0
Skeletal Ash Fraction	0.28	0.32	0.33	0.31	0.33	0.32
Am-241						
Total Skeletal Activity Bq (SD)	4440.0	5.38	3.37	39.0	12.4	31.8
Mean Skeletal Conc.						
Bq/kg Wet Wt. (SD)	494.0	0.64	0.42	3.76	1.42	3.29
Bq/kg Ash Wt. (SD)	1750.0	1.98	1.28	12.1	4.30	10.3
Pu-238	NA					
Total Skeletal Activity Bq (SD)		0.85	0.55	2.10	16.40	3.34
Mean Skeletal Conc.						
Bq/kg Wet Wt. (SD)		0.10	0.07	0.20	1.88	0.35
Bq/kg Ash Wt. (SD)		0.31	0.21	0.65	5.69	1.08
Pu-239+240	NA					
Total Skeletal Activity Bq (SD)		49.2	87.2	113.0	177.0	408.0
Mean Skeletal Conc.						
Bq/kg Wet Wt. (SD)		5.83	10.9	10.9	20.2	42.2
Bq/kg Ash Wt. (SD)		18.1	33.2	35.0	61.4	132.0

Mean Skeletal Ash Fraction for all six cases 0.32

[a] Per Lynch, et al. (1988)

Table 2. Concentration ratios.

Bone	Wet Weight		Ash Weight	
	Ratio	SD[a](CV)[b]	Ratio	SD(CV)
Am-241 n=6				
Clavicle	1.04	0.124(1.19)	0.926	0.090 (9.7)
Patella	0.844	0.08 (10.1)	1.13	0.212(18.7)
Rib 5-10	1.37	0.177(12.9)	1.45	0.277(19.1)
Sternum	0.662	0.346(52.3)	1.85	1.06 (57.3)
Vertebral Bodies				
Thoracic 5 - Lumbar 3	0.916	0.163 (0.178)	1.95	0.396(20.4)
Pu-238 n=5				
Clavicle	0.875	0.292 (33.4)	0.803	0.290 (36.1)
Patella	0.720	0.193 (26.8)	0.964	0.322 (33.4)
Rib 5-10	1.38	0.128 (9.3)	1.53	0.156 (10.2)
Sternum	0.909	0.162 (17.8)	2.46	0.897 (36.5)
Vertebral Bodies				
Thoracic 5 - Lumbar 3	1.32	0.149 (0.113)	2.82	0.292 (10.4)
Pu-239+240 n=5				
Clavicle	.986	0.110 (11.2)	0.896	0.142 (15.8)
Patella	0.720	0.141 (19.6)	0.962	0.269 (28.0)
Rib 5-10	1.33	0.116 (8.7)	1.48	0.053 (3.6)
Sternum	0.891	0.118 (13.2)	2.34	0.534 (22.8)
Vertebral Bodies				
Thoracic 5 - Lumbar 3	1.22	0.294 (24.1)	2.64	0.768 (29.1)

[a]Standard deviation of the mean concentration ratios calculated from all analyzed skeltons.

[b]Coefficient of variation.

TEETH AS AN INDICATOR OF TOTAL SKELETAL ACTINIDE

Principal Faculty Investigator: Ronald L. Kathren

Accurate estimation of the total skeletal content of actinide from one or a limited number of samples has long been a goal of the Registries. If an appropriate technique could be developed to provide such estimates with a reasonable degree of reliability, the program of the Registries would be greatly facilitated both from the standpoint of time required to obtain a measurement of skeletal activity and cost.

A number of years ago, Lovaas and Hursh (1968) suggested that the content of ^{226}Ra and ^{210}Pb in teeth could be used to estimate the total quantity of these elements in the skeleton as a whole. For ^{226}Ra they found that the mean concentration in teeth, when compared with that in various bones (mandible, calvarium, tibia shaft, femur head, and rib) would lie within $\pm 50\%$ of the average bone concentration at the 95% confidence level. For ^{210}Pb, variability was greater and dependent upon the level in the specific bone to which the tooth concentration was compared. If this same relationship held true for the actinides, teeth could be used as a surrogate for the total skeletal deposition of actinides. This brief study was carried out to determine if either the concentration or total quantity of an actinide element in the teeth could be correlated with the total skeletal content of that same actinide.

Post mortem measurements of the actinide content in teeth and bones from whole body donors to the Registries were used for this assessment. For whole body donors, the general practice is to radiochemically determine the actinide activity in the bones from the right half of the skeleton, and to extrapolate this measurement of a half skeleton to the full skeletal content as has been previously described by McInroy and his coworkers in 1985. The basic multistep radiochemical procedure calls for dry and wet ashing, followed by dissolution in acid and ion exchange separation, electrodeposition onto a suitable planchet, and final assay by quantitative alpha spectrometry (McInroy et al. 1985; McInroy, Gonzales, and Miglio 1992).

Results of the radiochemical analyses of the various bones or bone pieces and teeth are given in Table 3 along with a calculated Activity Fraction (AF) for each tooth. The AF is defined as the activity in a tooth relative to that in the total skeleton, or, in other words, the fraction of the activity in skeleton as a whole that is found in the tooth. Concentration Ratios (CR) were established by comparing the concentration of the nuclide in each tooth with the mean skeletal concentration. The variance of the measured CR values was determined using simplified rules for compounding errors as reported by Brodsky in 1982. In general, the CR was reasonably consistent among the several teeth obtained for any individual case, although the variation from case to case was marked.

No correlation was found between total actinide in the skeleton and the activity in the teeth, or between the average skeletal concentration and the concentration in the teeth. This finding indicates that teeth do not provide a reliable means

of determining the total skeletal content or average concentration of plutonium or americium and thus cannot be used as a surrogate for the skeletal burden of actinide.

The above finding is not surprising in view of the physiology of the teeth and bone. Unlike radium and lead, which as calcium analogues deposit throughout the bone matrix (i.e. are volume seekers), the actinide elements, specifically plutonium and americium, are bone surface seekers and are deposited onto both the periosteal and the endosteal surfaces of the bone. Bone resorption or turnover occurs continuously, and at a rate that is determined by a number of factors including age, hormonal balance, diet and exercise, so that in time, some of the actinide deposition is covered by a layer of new bone with some actinide released and later redeposited on the new bone surface (Toohey, 1994). However, teeth do not remodel as bone does, and although attrition occurs with aging of the tooth, the enamel is not replaced. The enamel, covering the top of the tooth, is completely established by eight years of age in all teeth except the third molar, in which the enamel is completed by age sixteen.

Cementum is similar to bone, chemically and physiologically. The blood supply to the tooth is only within the pulp and the periodontium, which includes the cementum. With age, the cementum is covered over with new cementum, comparable to the activity of resorption and recycling of bone, but the old cementum is only covered over and is not reabsorbed, a mechanism similar to, yet different from the surface deposition of actinides which are apparently recycled or released to the transfer compartment (blood) at least in part, albeit with a long residence half-time. There are blood vessels within regions between the roots of those teeth with multi-roots, the molars and premolars.

There is no blood supply to the enamel in any teeth and thus only the inner surface of the tooth and the outer portion of the root come into contact with blood that would be carrying actinides following an intake (Oser 1965; Sicher and DuBrul 1975). Hence, actinide deposition could only occur through the root canal and the pulp to the cementum and dentin layers of the tooth.

Acknowledgement: Data tables were compiled by USTUR graduate research assistant Mickey M. Hunacek.

References

Brodsky, A., Ed. Statistical methods of data analysis. In: CRC Handbook of Radiation Measurements and Protection. Section A. Vol. II, Biological and mathematical information. Boca Raton, FL: CRC Press (1982) pp. 261-330.

Lovaas, A. I. and J.B. Hursh. Radium-226 and Pb-210 in human teeth and bones. *Health Phys.* 14:549-55 (1968).

Kathren, R.L., L. A. Harwick, R. E. Toohey, J.J. Russell, R.E. Filipy, S.E. Dietert, M.M. Hunacek, and C.A. Hall. The United States Transuranium and Uranium Registries. Report of the period October 1, 1992-September 30,1993. Washington State University. USTUR-0015-95 (1994).

McInroy, J. F., H.A. Boyd, B.C. Eutsler and D. Romero. Preparation and analysis of the tissues and bones. Part IV; *Health Phys.* 49:587-621 (1985).

McInroy, J. F., Gonzales, E. R. and J.J. Miglio. Measurement of thorium isotopes and ^{228}Ra in soft tissues and bones of a deceased Thorotrast patient. *Health Phys.* 63:54-71 (1992).

McInroy, J. F., R.L. Kathren, R. L., and M.J. Swint. Distribution of plutonium and americium in whole bodies donated to the United States Transuranium Registry. *Rad. Prot. Dos.* 26: 151-158 (1989).

Oser, B.L. Hawk's Physiological Chemistry. Fourteenth Ed. NY: McGraw-Hill Book Co. (1965).

Sicher, H. and E.L. DuBrul. Oral Anatomy. St. Louis: C.V. Mosby Co. (1975).

Toohey, R. E. "Biokinetics of bone-seeking radionuclides" In: Internal Radiation Dosimetry. Raabe, O.G., ed. Health Physics Summer School, Madison, WI: Medical Physics Publishing (1994) pp.197-216.

Table 3. Fraction of Skeletal Activity in Teeth

USTUR case # / Nuclide		Wet wt Tooth[a] (g)	Activity[a] (mBq)	Activity[c] Fraction (x1000)	Conc Wet[a] Bq kg^{-1}	SD Wet[a]	Conc Ash[a] Bq kg^{-1}	SD Ash[a]	Conc[b] Ratio Wet	Conc[b] Ratio Ash
0102 Am	Total Skeleton		4.440,000	1,000						
	Mean Skeleton				494	4	1749	13		
	Canine L	1.5	760	.17	505	27	702	38	1.02	0.40
	Canine U	1.8	900	.20	497	21	673	29	1.01	0.38
	Incisor L1	0.5	330	.074	662	52	788	62	1.34	0.45
	Incisor L2	0.7	450	.10	641	40	916	57	1.30	0.52
	Incisor U1	1.2	620	.14	513	24	699	32	1.04	0.40
	Incisor U2	0.8	430	.10	542	25	734	34	1.10	0.42
	Molar L7	2.3	1020	.23	442	24	620	34	0.89	0.35
	Molar L8	1.9	1010	.23	533	33	751	47	1.08	0.43
	Molar U7	2.4	1410	.32	588	30	810	41	1.19	0.46
	Molar U8	1.9	1290	.27	642	37	880	51	1.30	0.50
	Premolar L4	1.1	690	.16	626	45	861	62	1.27	0.49
	Premolar L5	1.1	740	.17	704	46	968	63	1.43	0.55
	Premolar U4	1.1	650	.15	595	28	838	40	1.20	0.48
	Premolar U5	1.1	610	.14	554	25	743	33	1.12	0.42
Total		19.4	10,910							
Means		1.4		.18	575		785		1.16	0.45
SD		0.6		.066	74		99		0.15	0.06

Table 3. Fraction of Skeletal Activity in Teeth (continued)

USTUR Case # / Nuclide		Wet wt Tooth[a] (g)	Activity[a] (mBq)	Activity[c] Fraction (x1000)	Conc Wet[a] Bq kg^{-1}	SD Wet[a]	Conc Ash[a] Bq kg^{-1}	SD Ash[a]	Conc[b] Ratio Wet	Conc[b] Ratio Ash
0193 Pu	Total Skeleton		49,200	1000						
	Mean Skeleton				5.83	0.05	18.10	0.15		
	Canine LL	1.30	7.9	.16	6.05	0.77	9.59	1.22	1.04	9.59
	Canine RL	1.17	7.5	.15	6.41	0.91	8.52	1.21	1.10	8.52
	Incisor LL1	0.62	4.5	.092	7.26	1.24	9.38	1.60	1.25	9.38
	Incisor LL 2	0.77	5.4	.11	6.97	1.04	14.12	2.11	1.20	14.12
	Incisor LR1	0.64	5.2	.11	8.18	1.41	10.68	1.84	1.40	10.68
	Incisor LR2	0.79	4.9	.01	6.16	1.01	15.21	2.50	1.06	15.21
Total		5.29	35.3							
Means		0.88	5.9	.12	6.84		11.25		1.17	0.62
SD		0.28	1.4	.029	0.81		2.76		0.14	0.15

Table 3. Fraction of Skeletal Activity in Teeth (continued)

USTUR Case # Nuclide		Wet wt Tooth[a] (g)	Activity[a] (mBq)	Activity Fraction[c] (x1000)	Conc WET[a] Bq kg^{-1}	SD Wet[a]	Conc ASH[a] Bq kg^{-1}	SD Ash[a]	Conc[b] Ratio Wet	Conc[b] Ratio Ash
0208 Pu	Total Skeleton[b]		87,200	1000						
	Mean Skeleton[b]				10.9	0.05	33.16	0.16		
	Canine RL	1.28	11.6	.13	9.05	0.67	9.00	0.68	0.83	0.27
	Canine RU	1.26	8.5	.097	6.78	0.59	8.21	0.71	0.62	0.25
	Incisor LR2	0.63	5.4	.062	8.6	0.87	10.83	1.10	0.79	0.33
	Incisor UR1	2.41	3.7	.042	1.54	1.58	7.43	7.63	0.14	0.22
	Incisor UR2	0.78	4.6	.053	5.85	0.68	8.30	0.96	0.54	0.25
	Molar RL 6	2.83	13.1	.15	4.61	0.42	14.50	1.31	0.42	0.44
	Molar RL7	1.54	14.4	.17	9.35	0.61	14.54	0.95	0.86	0.44
	Molar RU6	2.45	16.3	.19	6.67	0.42	11.75	0.74	0.61	0.35
	Molar RU7	5.07	17.4	.20	3.42	0.20	9.49	0.55	0.31	0.29
	Premolar L4	0.93	9.0	.10	9.69	0.81	11.55	0.96	0.89	0.35
	Premolar L5	0.65	7.3	.084	11.27	1.12	15.26	1.52	1.03	0.46
	Premolar U4	1.28	7.1	.081	5.51	0.49	8.02	0.72	0.51	0.24
	Premolar U5	0.89	7.7	.088	8.62	0.75	11.62	1.02	0.79	0.35
Total		22.00	12.6							
Means		1.69	9.7	.11	7.00		10.82		0.64	0.33
SD		1.25	4.5	.052	2.78		2.68		0.25	0.08

Table 3. Fraction of Skeletal Activity in Teeth (continued)

USTUR Case # Nuclide		Wet wt[a] Tooth (g)	Activity[a] (mBq)	Activity Fraction[c] (x1000)	Conc WET[a] Bq kg^{-1}	SDWet[a]	Conc ASH[a] Bq kg^{-1}	SD Ash[a]	Conc[b] Ratio Wet	Conc[b] Ratio Ash
0213 Pu-239	Total Skeleton		177,000	1,000						
	Mean Skeleton				20.21	0.1	61.35	0.30		
	Canine RL	1.15	6.6	.037	5.71	0.55	8.00	0.77	0.28	0.13
	Incisor LR1	0.62	8.6	.048	13.83	1.08	19.94	1.55	0.68	0.33
	Incisor LR2	0.72	11.9	.067	16.49	1.16	22.84	1.60	0.82	0.37
	Incisor RU2	0.75	14.1	.080	18.87	1.24	28.30	1.87	0.93	0.46
	Premolar L	0.92	21.6	.12	23.46	1.30	86.32	4.80	1.16	1.41
Total		4.16	62.8							
Mean		0.83	12.6	.071	15.67		33.08		0.78	0.54
SD		0.21	5.8	.033	6.60		30.67		0.33	0.50
0212 Pu-239	Total skeleton[c] Mean Skeleton		113,100	1,000	10.92	0.06	35.04	0.18		
Overall Pu & Am Mean				3.12					0.94	0.45
SD				5.10					0.27	0.21

Table 3. Fraction of Skeletal Activity in Teeth (continued)

USTUR Case # / Nuclide		Wet wt[a] Tooth (g)	Activity[a] (mBq)	Activity Fraction[c] (x1000)	Conc WET[a] Bq kg^{-1}	SDWet[a]	Conc ASH[a] Bq kg^{-1}	SD Ash[a]	Conc[b] Ratio Wet	Conc[b] Ratio Ash
	Canine RL	0.82	10.0	0.88	7.84	0.78	10.36	1.03	0.72	0.30
1001	Total Skeleton[c]		0.67	1000						
Th-232	Mean Skeleton		1595	584	4353[c]	1579				
	Canine RL	0.61	8.1	0.072	13.21	1.88	26.86	3.82	.0083	.0062
	Canine RU	1.54	21.7	0.19	14.09	1.32	21.70	2.03	.0088	.0050
	Incisor LR 1	0.81	13.2	0.12	16.35	2.98	22.07	4.02	.0101	.0051
	Incisor LR 2	1.21	23.6	0.21	19.50	2.91	29.49	4.40	.0122	.0068
	Molar L6 R	1.04	14.3	0.13	13.77	2.77	20.46	4.11	.0086	.0047
	Molar L7 R	1.55	36.2	0.32	23.37	1.88	32.93	2.65	.0147	.0076
	Molar U6 R	4.48	52.5	0.46	11.71	0.85	17.49	1.27	.0073	.0040
	Molar U7 R	2.14	43.2	0.38	20.19	1.93	30.86	2.95	.0127	.0071
	Premolar L5	1.71	38.4	0.34	22.43	2.24	34.87	3.48	.0141	.0080
	Premolar U5	2.67	19.2	0.17	7.20	1.23	8.36	1.43	.0045	.0019
Mean		1.78							.0101	.0056
SD		1.13							.0032	.0019

[a] Kathren et al. 1993
[b] Ratio of concentration in tooth to mean skeletal concentration
[c] Fraction of total skeletal activity in tooth

Table 4. Ash Concentration Ratio for specific tooth types

Tooth	Number	Mean Ash Concentration Ratio	SD
Canine	7	0.35	0.14
Incisor	14	0.46	0.18
Molar	8	0.41	0.07
Premolar	9	0.53	0.34

POSTMORTEM DISTRIBUTION OF ^{238}Pu IN A WHOLE BODY DONOR 18 YEARS AFTER ACUTE INHALATION EXPOSURE

Principal Faculty Investigator: Ronald L. Kathren

USTUR Case 0259 was a caucasian male whole body donor who died at age 54 from arteriosclerotic heart disease. Other findings at autopsy included gall stones and simple cyst of the liver and kidney. There was no evidence of malignancy, and his medical history during life had been unremarkable. From June 1957 until his death in June 1989, USTUR 0259 was employed as a metallurgist with potential for chronic low level exposure to ^{238}Pu. There was no indication of measurable intake of this nuclide until July 1971, some eighteen years prior to his death, when suffered an acute inhalation exposure to high fired $^{238}PuO_2$ in a ceramic matrix. Subsequent to the accident, particle size AMAD was estimated as 4.4 μm (Guilmette, et al. 1994).

Nasal wipes taken immediately after the accident were positive for ^{238}Pu verifying the acute inhalation exposure. A single fecal sample was collected two days postexposure and found to contain no detectable ^{238}Pu activity (L_c=20 Bq). In vivo chest counts taken 12 days postexposure likewise failed to detect ^{238}Pu (L_c stated as 110 Bq). Initially, ^{238}Pu was not detectable in urine ($L_c \approx 1$ mBq), but within days, activity was observed in the urine and found to steadily increase with a doubling time of approximately 250 days (Figure 5).

^{238}Pu excretion in the urine peaked at about 15 mBq about 5 years postexposure, then dropped slightly to what appeared to be a more or less constant daily output of about 10 mBq until the time of his death 18 years postexposure. As shown in Figure 5, the urinary excretion of ^{238}Pu could be fit to a curve consistent with the models put forth in ICRP Publications 66 and 67. (ICRP 24, 1994, and ICRP 20(2), 1989)

After death, this whole body donation to the Registries was handled in accordance with the standard protocols in effect at the time (Breitenstein 1981; Kathren 1989). An autopsy was performed by an independent pathologist and the body sent for radiochemical analysis to LANL. The basic radioanalytical procedures used have been described in detail (Boyd, et al. 1981; McInroy, et al. 1985).

Results of radiochemical analysis of tissues of the whole body are summarized in Table 5. About half of the ^{238}Pu in the body was found in liver, with 37 per cent in the skeleton. Only 10 per cent of total body burden of ^{238}Pu was found in the respiratory tract. Assuming the route of entry to be inhalation, the systemic distribution indicated 53 per cent in the liver, 41 per cent in the skeleton, and about 3 per cent in the muscle, as compared with average values of 35, 54, and 6.5 per cent respectively in these tissues for $^{239+240}$Pu in five previous whole body donors to the Registries (McInroy, Kathren, and Swint 1989; Kathren, et al. 1994)

Considering individual variability

and the differences in exposure and time after exposure among the five $^{239+240}$Pu cases and USTUR 0259, it is impossible to state with any degree of confidence that the differences in the relative distribution between skeleton and liver of the Pu isotopes are significant, although they might be interpreted as suggestive of this possibility.

However, the USTUR 0259 results may also be compared to a previous study of the relative activity of Pu in skeleton and liver of persons with largely chronic low level exposure to Pu at several years to decades postexposure. In this study, Kathren and his coworkers (1987) found that in 36 cases for which data were available, 63.4 per cent of the total ^{238}Pu resident in both the skeleton and liver at the time of death was in the skeleton, as compared with 53.2 per cent $^{239+240}$Pu (43 cases). This difference was significant at the 95 per cent confidence level. However, in 11 of the 36 cases examined for ^{238}Pu, less than half of the total of this isotope in the skeleton and liver was in the skeleton, and in one case the fraction in the skeleton was as low as 20 per cent. For USTUR 0259, the comparable percentage is 43, well within the range and not quite one standard deviation below the mean percentage of the 36 observed in Case 0259. This not appreciably different from, and indeed was entirely consistent with the models put forth by ICRP (1979; 1986) and those developed by the USTUR (Kathren 1989, 1994) for plutonium.

A more detailed distribution of the activity in the various components of the respiratory tract is shown in Table 6. The distribution between lung and lymph nodes compares favorably with what has been previously observed in USTUR cases (Kathren, et al. 1993). In USTUR 0259, approximately 70 per cent of the total ^{238}Pu in the respiratory tract was found in the lungs. The concentration of ^{238}Pu in the lung tissue was 16 mBq/g as compared with a weighted mean concentration of 1.3 Bq/g for the associated lymph nodes, giving a ratio of concentration in the lymph nodes to that in the lungs of 81, somewhat greater than the geometric mean value of value 13$\pm$5.8 reported for 29 cases, but well within the range of values (0.046-261) reported for all cases.

The urinary excretion data shown in Figure 5 provides striking evidence of a biokinetic difference between inhaled particulates of ^{238}Pu and $^{239+240}$Pu. As has been shown recently by Guilmette, et al. (1994) on the basis of in vivo measurements, urinary excretion of ^{238}Pu in humans acutely exposed to ceramic $^{238}PuO_2$ particles is consistent with studies with experimental animals which show a progressive increase in the urinary excretion rate over the first few years post exposure. This has been explained as a result of the continuous fragmentation of the initially insoluble $^{238}PuO_2$ particles after deposition in the lung caused by their high specific activity relative to that of $^{239+240}$Pu. This process does not occur with insoluble particulates the lower specific activity $^{239+240}$Pu, and likely does not occur in most cases of occupational inhalation exposure to $^{239+240}$Pu even though some ^{238}Pu is present in the isotopic mix.

Discussion

It is well known that plutonium is rapidly bound to plasma proteins which

help inhibit the formation of large and rapidly phagocytized plutonium aggregates and is most likely responsible for the slow initial appearance of Pu in the urine. Plutonium has also been shown to complex with the iron-transport protein transferrin which is subsequently converted to ferritin and stored in such RES tissues as: liver, spleen, lymph nodes, and bone marrow.

The failure to detect ^{238}Pu activity in the fecal sample taken only 2 days postexposure is a reflection of the high insolubility of the high fired $^{238}PuO_2$ particles which were retained initially in the respiratory tract. As the particles began to disintegrate due to particle recoil and possibly enzyme action, the smaller plutonium-protein complexes formed are translocated via the blood to other tissues i.e., lung lymph nodes, liver, spleen, an skeleton. The small quantity of ^{238}Pu detected in the fecal sample of one of the other individuals involved in the same accident was most likely from particles passing from the mouth or nose down to the stomach via ciliary action.

References

Boyd, H. A., Eutsler, B.C. and McInroy, J.F. Determination of americium and plutonium in autopsy tissue: Methods and Problems. In: Actinides In Man and Animals, M.E. Wrenn, Ed. Salt Lake City: RD Press pp. 43-52 (1981).

Breitenstein, B.D., Jr. The United States Transuranium Registry. In: Actinides in man and animals. M.E. Wrenn, Ed. Salt Lake City: RD Press pp. 269-272 (1981).

Guilmette, R.A., Griffith, W.C., Hickman, A. W. Intake assessment for workers that inhaled ^{238}Pu Aerosols. *Rad. Prot. Dos.* 53:127-132 (1994).

International Commission on Radiological Protection (ICRP), Human respiratory tract model for radiological protection. ICRP Publication 66, *Ann. ICRP* 24 (1-3):1 (1994).

International Commission on Radiological Protection, Age-dependent doses to members of the public from intake of radionuclides: Part 1, ICRP Publication 56, *Ann. ICRP* 20(2):1 (1989).

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides. Oxford: Pergamon Press; ICRP Publication 67, Part 2; *Ann. ICRP* 23(3/4):1 (1993).

International Commission on Radiological Protection. Limits for intakes of radionuclides by workers. Oxford: Pergamon Press; *ICRP Publication 30*, *Ann. ICRP* 2(2/4):1-116 (1979).

International Commission on Radiologi cal Protection (ICRP). The metabolism of plutonium and related elements. *Ann. ICRP* 16(2/3):1-98 (1986).

Kathren, R.L. Towards improved biokinetic models for actinides. *Rad. Prot. Dos.* 53:219-2277 (1994).

Kathren, R.L., McInroy, J.F., Pixley, M.M., and Swint, M.J. Partitioning ratio of

^{238}Pu, ^{239}Pu and ^{241}Am in liver and skelton of US Transuranium Registry autopsy cases. *Health Phys.* 54(2):181-188 (1987).

Kathren, R.L., et al. The United States Transuranium and Uranium Registries. Report of the period October 1, 1992 - September 30,1993. Washington State University. USTUR-0015-95 (1994).

McInroy, J.F., Kathren, R.L. and Swint, M.J. Distribution of plutonium and americium in whole bodies donated to the United States Transuranium Registry. *Rad. Prot. Dos.*26,(1-4): 151-158 (1989).

McInroy, J.F., Boyd, H.A., Eutsler, B.C. and Romero, D. The U.S. Transuranium Registry report on the ^{241}Am content of a whole body: Preparation and analysis of tissues and bones. Part IV; *Health Phys.* 49: 598-621 (1985).

Figure 5. ^{238}Pu urinary excretion for USTUR case 0259.

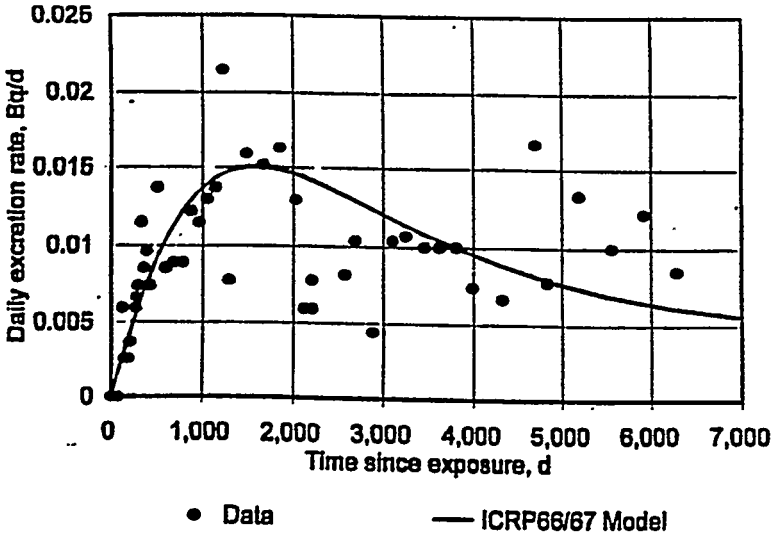


Table 5. Postmortem ^{238}Pu content of whole body.

Tissue/Organ	*Wet Weight (g)*	*Ash Weight (g)*	*Activity (Bq)*	*Distribution (%)*	*Systemic Distribution*[a]
Respiratory Tract	1,455		30	10	(%)
Liver	1,483		137	48	53
Kidneys	303		0.31	0.11	0.12
Spleen	213		1.1	0.37	0.41
Smooth Muscle Organs	2,079		0.85	0.30	0.33
Striated Muscle	28,054		6.1	2.1	2.4
Other Muscle	711		1.2	0.42	0.47
Skin	15,994		2.4	0.83	0.92
Other Soft Tissue	2,219		1.8	0.63	0.71
Testes	23		0.04	0.01	0.01
Skeleton and Teeth	9,806	3,270	106	37	41
Total Whole Body	62,340	3,270	287	100	100

[a] Route of entry taken as respiratory tract

Table 6. Postmortem ^{238}Pu content of whole body.

Tissue/Organ		*Wet Weight (g)*	*Activity (Bq)*
Lung	(left)	599	8.5
	(right)	696	12.4
Trachea		15.2	0.04
Tracheal scraps		27.3	0.19
Larynx		105.7	0.31
Lymph nodes	(TBLN - 1)	0.6	0.20
	(TBLN - 2)	0.6	1.9
	(TBLN - 3)	1.3	0.48
	(TBLN - 4)	1.3	0.12
	(hilar - 1)	3.5	2.0
	(hilar - r)	3.6	3.7
Total		1,454	29.9

A STUDY OF ACTINIDE MICRODOSE DISTRIBUTION IN SELECTED BONES USING ELECTRON PARAMAGNETIC RESONANCE (EPR)

Principal Faculty Investigator : John J. Russell

In conjunction with Marc Desrosiers at the National Institute of Standards and Technology (NIST), the Registries have been studying electron paramagnetic resonance (EPR) in bone from USTUR donors. Previous studies have demonstrated the production of radiation-induced paramagnetic centers in the hydroxyapatite crystal matrix of bone tissue. In addition, these paramagnetic centers have been shown to be long-lived (from months to years) and their induced numbers, radiation dose dependent. These induced paramagnetic centers have been used as markers of radiation exposure in radiation accidents (Desrosiers 1991) and to measure absorbed dose from administered radiopharmaceuticals (Desrosiers et al 1991).

Using EPR, the ability to detect doses as low as 1 Gray in bone samples as small as 100 mg has been demonstrated. Compared to conventional autoradiography, the EPR method is the first direct technique for measuring and mapping the absorbed radiation dose in bone mineral matrix. To determine if EPR can provide a more exacting skeletal dose mapping technique than autoradiography, selected cortical and trabecular bone samples have been analyzed from two radium dial painter cases, each with a radiochemically determined total skeletal dose of >50 Gy from the many tissue samples maintained and available for further study at the NHRTR. Depending on the success of the initial investigations, additional samples from the NHRTR collection will be examined.

Accordingly, four different bone samples, one trabecular and one cortical from the humerus of radium dial painter case # 03-551 and samples of cortical bone from the fibula and ilium of radium dial painter case # 05-958 were prepared for measurement by first cutting into approximately 4x10 mm cylindrical pieces. The bone samples were rinsed in distilled water twice, air-dried, and then measured in a sensitive EPR spectrometer equipped with a sensitive microwave resonator. Preliminary examination of the spectra produced in all four samples indicated the presence of a signal from the organic component. However, in the ilium sample there was also an indication of a signal from a hydroxyapatite center (Fig. 6). Current work is underway to attempt to enhance this weak apatite center signal by removal of the larger organic component signal by Soxhlet extraction treatment with diethylenetriamine.

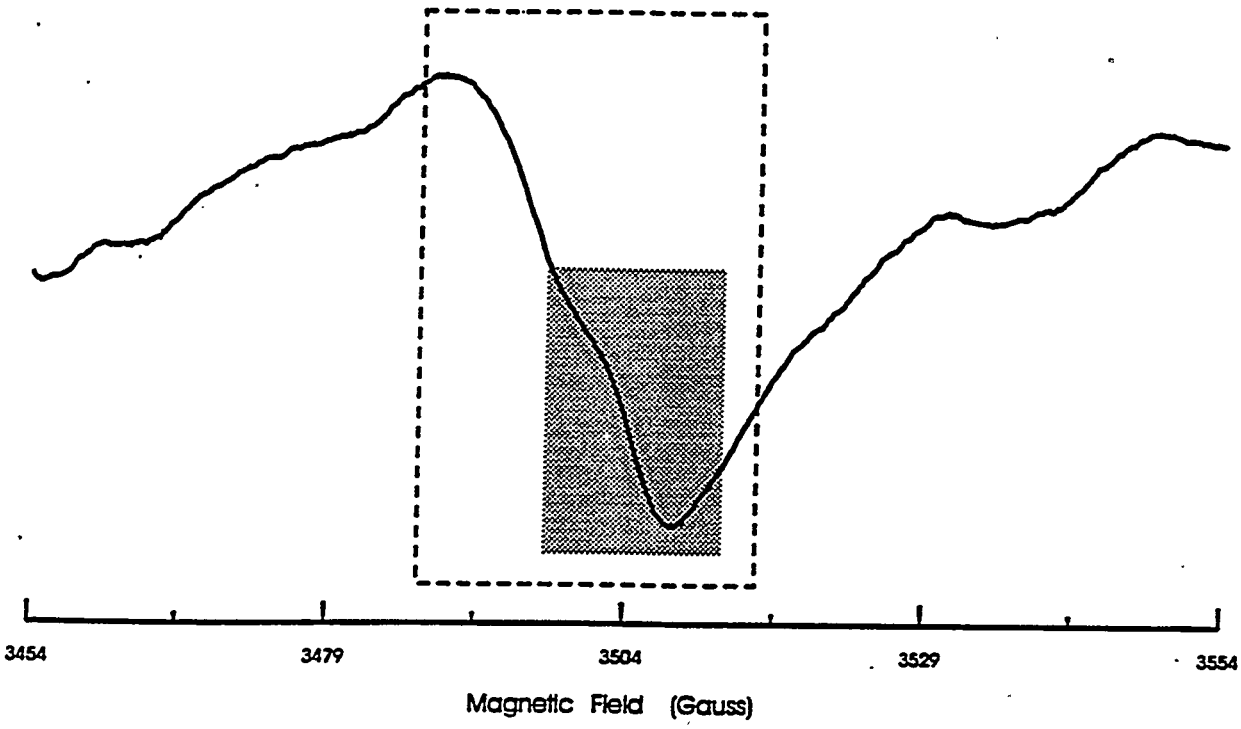
Acknowledgement: EPR measurements have been performed at NIST under the direction of Dr. Marc Desrosiers.

References

Desrosiers, MF. In vivo assessment of radiation exposure. *Health Phys.* 61(6): 859-861; (1991).

Desrosiers, M.F., B.M. Coursey, M. J. Avila and N.J. Parks. Radiation dose. *Nature* 349:349-287 (1991).

Figure 6. EPR spectrum of ilium bone (USTUR #03-551).



RADIOCHEMISTRY PROJECT

Principal Faculty Investigator: Roy H. Filby

Radiochemistry Laboratory Facilities

The start-up phase of the radiochemistry laboratories began during the last reporting period. The laboratory designed for handling, drying and ashing of human tissues (room 215) required remodelling before use. It was necessary to install approximately 30 kW of 208 volt new power for the large drying oven and the high-temperature, high-capacity, muffle furnace which operates up to 1100°C. Also for both biohazard and radiological protection reasons, the gases and fumes from the oven and muffle furnace during drying at 120°C and ashing at 450°C, respectively, needed to be vented directly to the atmosphere through the roof of the building. This required significant remodelling in room 215 and the mounting of fans on the roof of the building. The remodelling was completed in March 1995 although the exhaust system had to be modified several times to prevent large temperature variations in the muffle furnace which were the result of too much air being pulled through the furnace.

The laboratory was set up as a posted biohazard area and an exposure control plan for bloodborne pathogens was written in July 1995. This plan was approved by the WSU Department of Environmental Health and Safety in August 1995 following certification of the biosafety cabinet for handling of human tissues.

LANL Sample Inventory

Considerable effort was expended in the reporting period in determining which samples from LANL required analysis or required re-analysis (i.e. previously analyzed at LANL but with unacceptable results). A total of 2004 solutions of tissues from USTUR cases was received from LANL in June 1994. A manifest from LANL was not received until October 1994 at which point samples were unpacked from crates and segregated into USTUR cases (samples had been packed indiscriminately). In December 1994, many discrepancies between the sample inventory and LANL manifest were identified and 75 samples were identified as either not received or received but not the LANL inventory listing. All samples were entered into a USTUR sample database which was completed in June 1995.

Laboratory notebooks which were essential for performing re-runs, or analyses of solutions which had not been analyzed by LANL, were received in part in April 1995 and complete set of notebooks was received in July 1995. Even at the time of writing this report (January 1996), problems still remain with some cases for which re-runs have been requested but for which we do not have samples (e.g. 67 solutions from case 0262). Whether these samples were inadvertently shipped to the NHRTR or were not shipped from LANL remains undetermined. Samples may not have been taken for analysis or may not have been dissolved In August 1995, 400 additional solutions from cases 0769 and 1002 were received from LANL, complet-

ing the sample transfer from LANL to WSU.

To improve tracking of samples in the USTUR program and to avoid the multiple identification numbers used in the LANL system, a unique seven-digit identification numbering system for each sample such that all containers, solutions, analysis data, and computer files contain certain specific information about the sample. This number has the form:

aaaabbb

Where
aaaa = four digit case number bbb = three digit serial number assigned at sample preparation (NHRTR).

Additional identifiers beyond the seven-digit sample number are used to indicate analyte (i.e. Pu, Am, U, or Th), reanalysis, re-count etc. The laboratory analysis number is directly tied to the case number, minimizing misidentification.

Validation of radiochemical procedures

To validate the transfer of the radiochemical analysis program of the USTUR from LANL to WSU, four intercomparison programs were set up. The overall intercomparison program was set up to use LANL data on previously analyzed samples,thus eliminating the need for costly additional analyses by LANL and expediting the validation process. Professor Ahmed Nevissi at the University of Washington (UW) was selected to participate in the intercomparisons as an independent third laboratory. The intercomparisons were:

Alpha Spectroscopy Intercomparison: Both WSU and the UW analyzed electrodeposited disks containing ^{241}Am and $^{238/239}$Pu previously analyzed by LANL. This was completed during the previous reporting period (Kathren et al 1994).

Spiked Solution Intercomparison: Solutions spiked with known activities of contamination-free NIST-traceable ^{239}Pu and ^{241}Am were prepared at both the UW and at WSU. These solutions were coded, exchanged between the two laboratories, and analyzed using the USTUR Radiochemistry Project procedures at WSU and using UW procedures at the UW. This intercomparison was completed in July 1995. In general the results show very good agreement between the UW and WSU over a wide range of activities. Detailed results from this intercomparison are discussed in Appendix G.

Analysis of LANL Solutions: Both the UW and WSU analyzed 8M HCl solutions from cases 0246 (^{241}Am case) and 0637 ($^{238/239}$Pu case) which had been previously analyzed and reported by LANL. Soft tissues and bone samples were included in this intercomparison. This intercomparison was designed to validate the radiochemical separation procedures in both laboratories. Results from the study were completed in September and, in general, show excellent agreement among the three laboratories. Details of the statistical procedures used and the results from the three laboratories are included in Appendix G.

NIST Standard Reference Materials NIST SRM 4351, Human Lung, and SRM

4352, Human Liver, were analyzed for ^{241}Am, $^{238+239}Pu$, $^{235+238}U$ and ^{232}Th using the USTUR Radiochemistry Project procedures developed for the routine analysis of USTUR tissue samples. No significant differences were found between the WSU values and the NIST values at the 95% confidence interval. Detailed results are given in Appendix G.

Analysis of samples from cases 0469 and 0637

The first analyses of LANL solutions using USTUR procedures were performed as part of the method validation project. Some of the samples used in the LANL/ WSU/UW intercomparison study were taken from cases 0469 and 0637 since these cases had been partially analyzed at LANL prior to transfer of the program to WSU. Routine analyses of samples from cases 0469 and 0637 which had not been analyzed or required re-runs were completed in September 1995.

Analysis of other LANL solutions

The first priority of the USTUR Radiochemistry Project after validation of the radiochemical methods used at WSU was to begin analyzing the backlog of solutions which had not been analyzed by LANL. Solutions from several other cases which had not been analyzed by LANL were begun in June. As of September 30 the status of cases for which analyses were requested was as follows:

Case 0210: No samples received from LANL.

Case 0221: No samples received from LANL.

Case 0231: Samples to be analyzed.

Case 0260: Analyses completed and reported.

Case 0262: 198 samples require re-analysis. A total of 131 samples are in the Nuclear Radiation Center inventory; 67 samples have not been located and may not have been shipped by LANL.

Case 0469: Analyses completed and reported.

Case 0579: Chemistry in progress.

Case 0637: Analyses completed.

Case 0644: Analyses to begin in October.

Case 0648: Separations on 10 samples completed.

Case 0677: To be analyzed.

Case 0775: To be analyzed.

Case 0778: To be analyzed.

Case 0779: To be analyzed.

Analysis of Case 0841

Eleven tissue samples from case 0841 were received in August and this case was used to test out the tissue preparation, ashing and decomposition procedure. No major problems were experienced in the decomposition of these tissues and $^{234+235+238}U$ data were reported in August and September and entered into the USTUR database.

USTUR Radiochemistry Project Policies and Procedures Manual

The radiochemical procedures adopted by the USTUR Radiochemistry Project were based on the procedures developed at LANL and described in LA-10300-M (Gautier, M.A. 1995). However, a number of changes were made in the radiochemical separation methods and major changes were made in the alpha spectroscopy methods. These procedures were incorporated into a raiochemistry Policies and Procedures manual that was completed in September. The procedures cover all aspects of the analytical program from receipt of the sample at WSU to reporting of data, including Quality Assurance/Quality Control procedures. This manual will be reviewed and revised at appropriate intervals.

Training

All member of the staff either received radiation safety training during the previous reporting period or during the current period. All staff were also provided with a training program on the safe handling of human tissues containing bloodborne pathogens. This training was provided by the WSU Office of Environmental Health and Safety and is an integral part of the Biohazard Plan for the USTUR Radiochemistry Project which was approved by Environmental Health and Safety. All staff members have also received Hepatitis B vaccinations. Informal training was also provided for staff on the use of the alpha spectrometry system.

Research and development programs

Several research and development projects were started during the reporting period. The objective of these projects is twofold: a) to improve existing USTUR procedures for the determination of actinide elements in human tissues by replacing ion-exchange separation methods with faster and less waste-producing extraction chromatography methods; and b) to develop new analytical capabilities for the USTUR program. These research and development projects are summarized in Appendix F.

References

Kathren, R.L., L. A. Harwick, R. E. Toohey, J. J. Russell, R. E. Filipy, S. E. Dietert, M. M. Hunacek, C. A. Hall. The United States Transuranium and Uranium Registries. Report Period October 1, 1992-September 30,1993. Washington State University. USTUR-0015-95 (1994).

Gautier, M. A., et al. Health and Environmental Chemistry: Analytical Techniques, Data Management and Quality Assurance, QCR100:1-280.7. LANL-10300-M. Los Alamos National Laboratory, Albuquerque, NM. (1995).

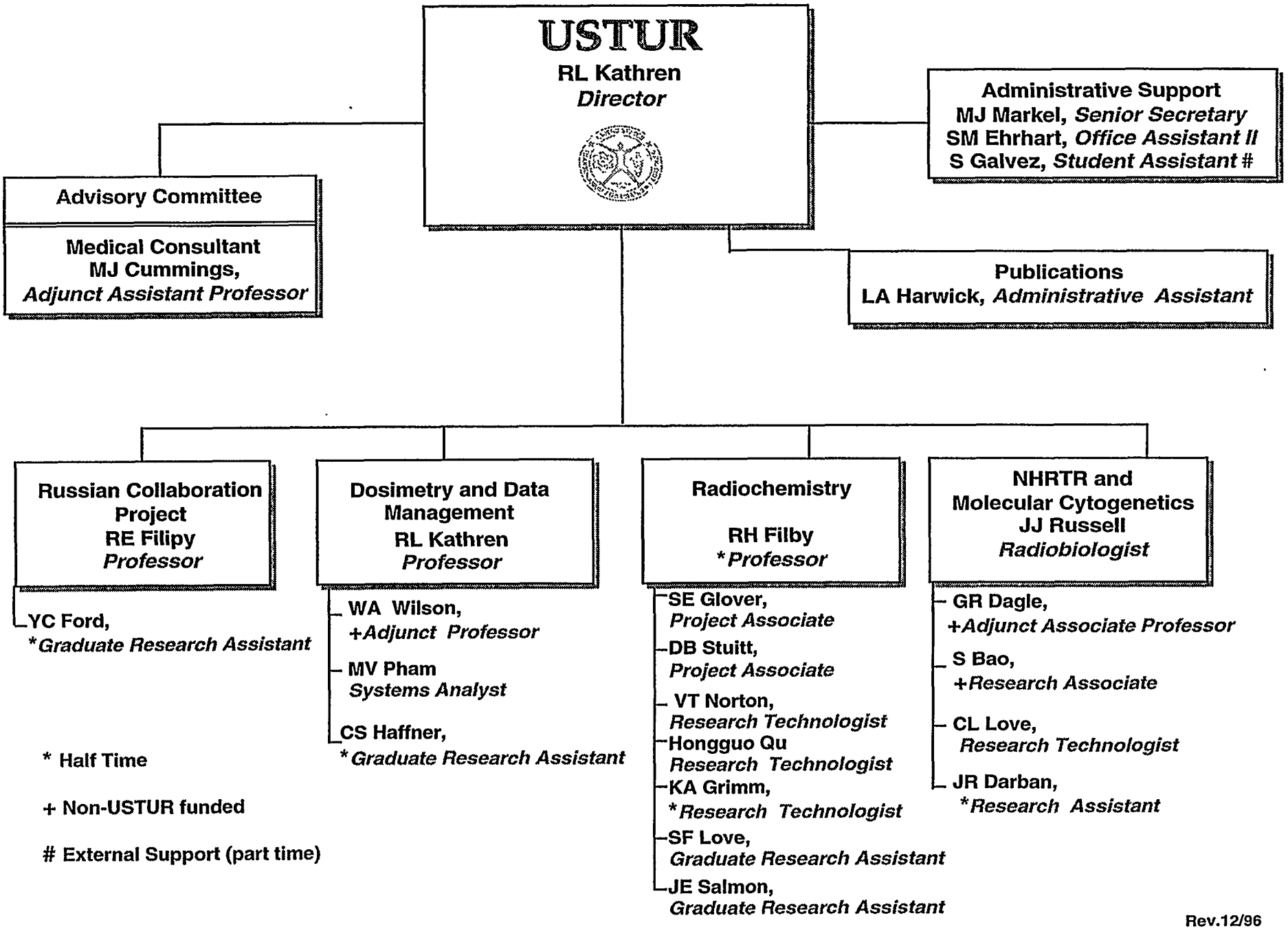
Appendix A

USTUR Policies & Procedures Manual Table of Contents

USTUR Policies and Procedures Manual
Table of Contents

Appendix B

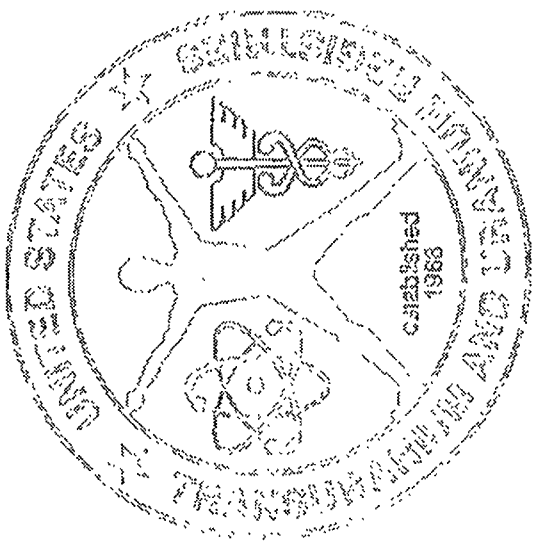
USTUR Functional Organization Chart


USTUR
RL Kathren
Director
Administrative Support
MJ Markel, Senior Secretary
SM Ehrhart, Office Assistant II
S Galvez, Student Assistant #
Advisory Committee
Medical Consultant
MJ Cummings,
Adjunct Assistant Professor
Publications
LA Harwick, Administrative Assistant
Russian Collaboration Project
RE Filipy
Professor
YC Ford,
*Graduate Research Assistant
Dosimetry and Data Management
RL Kathren
Professor
WA Wilson,
+Adjunct Professor
MV Pham
Systems Analyst
CS Haffner,
*Graduate Research Assistant
Radiochemistry
RH Filby
*Professor
SE Glover,
Project Associate
DB Stuitt,
Project Associate
VT Norton,
Research Technologist
Hongguo Qu
Research Technologist
KA Grimm,
*Research Technologist
SF Love,
Graduate Research Assistant
JE Salmon,
Graduate Research Assistant
NHRTR and Molecular Cytogenetics
JJ Russell
Radiobiologist
GR Dagle,
+Adjunct Associate Professor
S Bao,
+Research Associate
CL Love,
Research Technologist
JR Darban,
*Research Assistant
* Half Time
+ Non-USTUR funded
# External Support (part time)

Rev.12/96

Appendix C

USTUR Staff Photographs



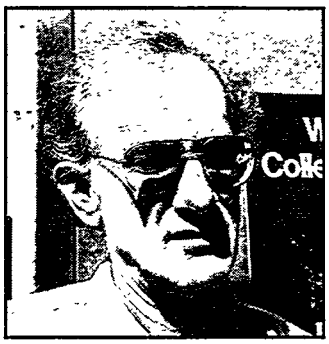
USTUR Faculty and Staff Photographs

Ronald L. Kathren,
Professor and Director

John J. Russell,
NHRTR Curator and Radiobiologist

Ronald E. Filipy,
Professor

Royston H. Filby,
Professor



Walter A. Wilson,
Adjunct Professor

Anthony C. James,
Associate Professor

Michael J. Cummings,
Adjunct Assistant Professor

Gerald R. Dagle,
Adjunct Associate Professor

Shiping Bao
Research Assiociate

USTUR Faculty and Staff Photographs

Samuel E. Glover,
Radiochemist

Dorothy B. Stuitt,
Radiochemist

Minh V. Pham,
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Lynn A. Harwick,
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M. June Markel,
Senior Secretary

Cheryl L. Love,
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Susan M. Ehrhart,
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Patricia Waldo,
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USTUR Faculty and Staff Photographs

Catherine A. Grimm,
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Ronald M. Suguitan,
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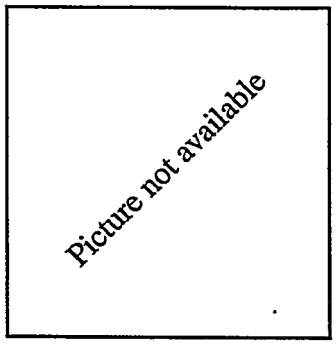
Cynthia S. Haffner,
Graduate Research Assistant

Mickey M. Hunacek,
Graduate Research Assistant

Suzanne F. Love,
Graduate Research Assistant

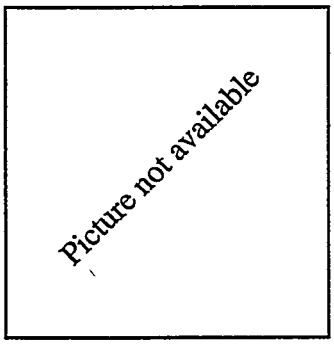
Johanna E. Norton,
Graduate Research Assistant

James Eliston,
Graduate Research Assistant



Jill Darban,
Research Assistant

USTUR Faculty and Staff Photographs

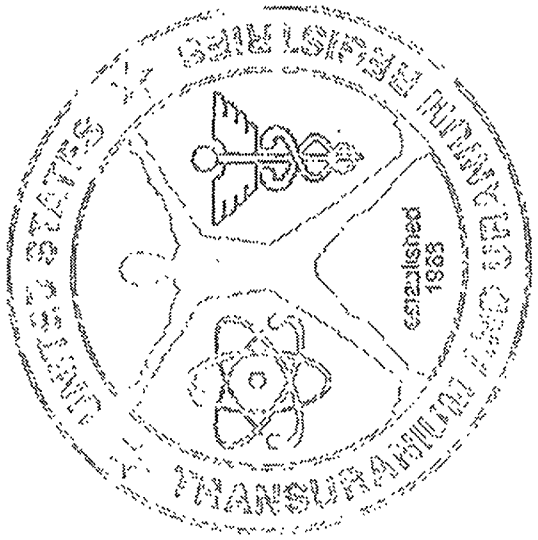


Sandra Galvez,
Student Assistant

Honggo Qu,
Student Employee

Appendix D

USTUR Advisory Committee Report



1995
REPORT OF THE ADVISORY COMMMITTEE TO THE UNITED STATES TRANSURANIUM AND URANIUM REGISTRIES

Keith Schiager, Chairman

Venue:

The Advisory Committee met at the University Inn, Moscow, Idaho on 17 and 18 October 1995. The meeting included a tour of the USTUR radiochemistry laboratories in the Radiation Center on the Washington State University campus in Pullman, Washington.

Attendance:

The meeting was called to order by Chairman Schiager at 8:30 am on 17 October 1995 with introductions of everyone present. All members of the Advisory Committee were present, i.e. Borje K. Gustafsson, Kenneth G. W. Inn, Bruce D. Lawson, Keith J. Schiager, Robert G. Thomas, MaryBelle Thompson and George L. Voelz.

Registries staff members present for part of all of the meeting included Ronald L. Kathren, Director and Professor of Health Physics; Ronald E. Filipy, Professor of Radiobiology; John J. Russell, Curator, National Human Radiobiology Tissue Repository (NHRTR); Michael Cummings, Medical Consultant; Royston H. Filby, Professor of Chemistry; Samuel E. Glover, Radiochemist; Dorothy B. Stuit, Radiochemist; and Lynn A. Harwick, Administrative Assistant. Additional Washington State University personnel in attendance for part or all of the meeting: Mahmoud M. Abdel-Monem, Dean, College of Pharmacy; Diana Scoles, Manager, Finance and Administration, College of Pharmacy.

Guests present for all or part of the meeting included Ahmed Nevissi, Radiochemist, University of Washington and Chuck Watson, National Radiobiology Archives.

The Department of Energy was represented by Barbara G. Brooks, USTUR Program Manager, Office of Epidemiological and Health Surveillance. There was no representation from cooperating DOE laboratories.

In Memoriam of Roy Thompson

The Committee recognized the contributions of Roy Thompson to the field of radiobiology, and to the work of the Advisory Committee, by brief commentaries and a moment of silence.

Review of the 1994 Committee Report

The Committee reviewed the recommendations made in its 1994 report and received comments from the USTUR staff on progress made in several areas. The remarkable progress in the analytical laboratory capabilities and quality control procedures, the significant improvements in the long-range plan, and the extensive additions to the computer data base, includtion by the Committee.

National Radiobiology Archives (NRA)

Chuck Watson, NRA Director, gave a short presentation on the purpose and status of the NRA. The NRA collects and stores data on tens of thousands of animals used in radiobiology studies, and makes these data available to researchers for reanalysis or new investigations. The collection includes "tons of documents," some slides, tissue blocks in The NRA collaborates with Dr. Gerber, who represents the Commission of the European Communities, in compiling a similar database for experimentation done in Europe over the past several decades.

DOE Perspective

Barbara Brooks reviewed the current status and future projections of DOE funding. She also commented on the results of the human experimentation review conducted by the DOE and the report recently released by the GAO. With respect to the Advisory Committee, she recommended that the Committee define its own role more clearly and that it encourage the Registries to focus its research on current concerns with the health protection of workers.

Staff Presentations

Director Kathren reviewed the activities and accomplishments of the Registries during the preceding year. He noted that 93% of deceased registrants have no medical records and 37% have no dosimetry records. He raised the question as to whether there should by a policy of recontacting selected inactive registrants to recapture scientifically important cases. The Committee concurred with this concept and suggested that review of all registrants, active as well as inactive, to identify scientifically important cases would be worthwhile.

Professor Filipy reviewed the status of cooperative studies with the Mayak Industrial Association, Russian Federation. The study involves a large population with high internal and external doses from a large accidental release from a processing plant. The Committee expressed the opinion that the doses (up to two orders of magnitude larger than any of the USTUR registrants) would make the finding of significant biological effects much more likely than in the USTUR population. It is not yet clear whether there will be a possibility to share tissue specimens or only some data.

John Russell presented data on the status of whole body donors alive as of 10/1/95, and on the expected number of registrant deaths during the coming year. It seems clear that stringent prioritization will be necessary to ensure that the scientifically important cases are identified and accepted, and that they can be analyzed in a timely manner.

John Russell also presented an overview of collaborative studies that are currently being performed, or are proposed for future funding, utilizing materials available from the USTUR registrants or from NHRTR tissues.

Tour of Radiochemistry Laboratories

The Committee was treated to a very informative tour of the Nuclear Science Center and the Radiochemistry Laboratories. Essentially all of the radiochemistry staff was present, with ample time allowed for the Committee members to raise questions and become acquainted with the staff.

MAJOR TOPICS OF DISCUSSION AND COMMITTEE RECOMMENDATIONS

Radiochemistry Laboratories

The Registries is to be congratulated for the progress made in reestablishing its radiochemistry capabilities: 1) new, dedicated laboratory space and equipment have been obtained, installed and made operational; 2) qualified laboratory personnel were being trained; 3) a variety of analytical procedures and radiochemical separations methods have been documented; 4) research and developments of new analytical techniques were being pursued; and 5) a quality assurance program, including second party cross-check with the University of Washington has been initiated on sion requirements should be established for each project prior to initiation of work.

The overall up-front planning of all projects should include input from all research participants on establishing the objectives and the execution of subsequent steps - including sampling strategies, sample preservation, subsampling techniques, analytical accuracy and precision requirements, statistical analysis, and interpretation. Financial resources are too scarce to simply employ the undefined "best effort." The ANSI N13.30 draft standard offers a minimum set of accuracy and precision criteria for radiobioassay laboratories. Certain registries projects, however, will require higher levels of accuracy and precision than those specified in ANSI N13.30 to meet the interpretive needs of the work, and these requirements should be defined to avoid generation of inadequate or erroneous data. It is also important to establish accuracy and precision requirements with the external cross-check, reference and QA laboratories. This is necessary so that the laboratory can plan and price the degree of effort required to meet the needs of the Registries' program.

Advisory Committee Recommendation

Documented Procedures

Each procedure should be reviewed by experts to assure that a competent analyst could execute the instructions and satisfactorily meet the stated objective of the process.

As an example, Procedure USTUR 070, Preparation of Tracers, should be rewritten as a set of instructions to generate high quality tracers. The current procedure does very little in terms of detailed instructions to this end. Furthermore, there are several steps that could be easily taken to greatly improve the quality of tracers, e.g. 1) prepare dilutions gravimetrically, 2) use flame-sealed glass vessels for long-term solution storage, and 3) verify dilutions with measurements of adequate precision.

Advisory Committee Recommendation

Recommendation on
Quality Assessment

The Registries should establish a means of conducting measurement quality assessments. Assessment of process quality should be serviced by internal or external experts. In either case, quality

assessment personnel must be independent of routine measurement process to provide independent evaluations.

Quality assessments are conducted through "blind" testing of the analytical process through "blank", replicate and well-prepared reference samples. Interpretation of assessment results must be made against established accuracy and precision criteria that are periodically reexamined. Although quality assessment personnel can work closely with the process personnel, they should ultimately report directly to the Director of the Registries. Quality assessment is an important component in the logic of quality assurance and necessarily requires strong commitment from upper management and adequate financial support.

A second benefit of using an experienced external laboratory for quality assessments is that they can also serve as a reference laboratory for special samples, or backup laboratory capacity under extraordinary circumstances.

Advisory Committee Recommendation

External Measurement Assurance Programs

In addition to verifying analytical methods with reference materials, the Registries' radiochemistry group should participate in appropriate tracer standards, alpha spectra evaluations and LANL solution analyses. These efforts must be continued to meet the Registries' current and future technical needs.

Advisory Committee Recommendation

Analytical Requirements

As a minimum, accuracy and preciexternal measurement assurance programs (MAPS).

Unfortunately, not all of the existing MAPs fit the Registries' needs well: a) the EPA Cross-check Program is primarily designed to support water analyses; b) the USEML QAP is designed for soils, sediments, vegetation and perhaps air filters; c) the NIST-NEI Traceability Program is designed for nuclear power plant radiochemistry; d) the IAEA Intercomparisions (Seibersdorf/Monaco) materials include soils, sediments, vegetation, water and animal tissue; e) the DOELAP is a pilot test phase and will have both in-vivo and in-vitro (urine and feces) test samples; and f) the NIST natural-matrix radionuclide SRM intercomparisons are limited to lung, liver and bone matrices. The Registries' radiochemistry program would derive benefits through judicious selection of matrix intercomparison for participation.

Recommendation on Reference Materials: Five or more replicate analyses should be used to adequately evaluate the accuracy and precision of a method.

While the results of measurements on NIST SRMs are encouraging, two analyses are statistically inadequate to draw the conclusion that the methods used have been validated. ANSI N13.30 suggest the use of five or more replicate analyses. A secondary benefit from these mea-

surements is an estimate of "best case" accuracy and precision. This information can be used to establish realistic accuracy and precision requirements for individual projects or redesign the measurement protocols to meet the need of the Registries' projects.

Advisory Committee Recommendation

Reference Method

A guaranteed reference sample dissolution, radiochemical purification and measurement method should be established to help validate new methods and to be used for special or high visibility samples.

Although the LANL procedures were adopted and new radiochemical methods are being developed it is important to establish a "bombproof" method for reference. An "unquestioned" sample dissolution is extremely important because the fundamental assumption that radiochemists rely on for quantitative analyses is that the tracer and analyte are completely homogenized. If this condition is not met, the resulting data will not be valid. The method of choice is high temperature fusion. Although messy, difficult and labor intensive, this technique is highly regarded and should be added to the Registries' radiochemistry skills.

EXPOSURE RECORDS, RECRUITMENT AND REGISTRATION

Advisory Committee Recommendation

The Director and senior staff should place the highest priority on developing personal contacts and rapport with appropriate health physics personnel at registrants' employer sites to facilitate identification of prospective new registrants and recovery of appropriate exposure data on new and existing registrants. The Committee recommends soliciting a liaison person at each participating DOE site, preferably an individual designated as such by the manager of the Health and Safety Division, or equivalent.

Both, the USTUR staff and the Advisory Committee recognize that adequate exposure records are essential to the scientific value of any specific registrant. Registrants are currently accepted on the basis of a "documented" actinide intake; however, according to the Director, there are no dosimetry records for 37% of deceased registrants, and exposure records are missing or incomplete for many active and inactive living registrants. This constitutes a serious deficiency in the scientific value of the current value of the current registrants.

The Committee believes that the dosimetry status of all registrants, active or inactive, should be reviewed to determine if the exposure information is sufficient to support scientific use of tissue analyses. Where data are lacking, greater effort should be devoted to obtaining the missing information. In the case of inactive registrants with adequately documented scientifically interesting exposures, an effort should be made to reenlist these individuals. More intensive efforts should also be made to identify and recruit individuals with well documented, interesting intakes. The priorities for these efforts should be based on the potential scientific

value of the information to be obtained from the registrant's donation. The primary sources of most exposure records are the health physics (including "bioassay" and/or "dosimetry"), industrial hygiene and safety organizations of the registrant's employer. In the case of accidents or injuries, however, valuable information may be contained in the registrant's medical or personnel files, although most of the information in these files may be irrelevant to the registrant's exposure. Because of the effort needed to retrieve the relevant data, some means must be found to obtain the assistance of the site personnel. If backing of the effort could be obtained from someone in DOE with sufficient authority, top-down directives to provide the assistance might be effective. Providing direct labor support, in the form of a temporary loan of a person, might be another possible approach to retrieving information.

The Advisory Committee believes that the level of trust and confidence of employees enjoyed by staff physicians at participating laboratories places them in a unique position to encourage potential registrants. To take advantage of this situation, however, the staff physicians must first be convinced of the value of the Registries, and the specific nuclides, modes of exposure, and minimum levels of deposition of interest to the Registries need to be clearly enunciated. The Advisory Committee believes that personal contact be a peer physician may be the most effective way to gain the attention and cooperation of these staff physicians. Although a personal services contract has been established with Dr. Michael Cummings, it is only for approximately one per month, which the Committee believes that participation in the regular meetings of the medical directors of DOE laboratories by a physician on the Registries' staff, and personal visits to medical departments of participating laboratories, could significantly improve recruitment and registration effectiveness.

The Committee believes that developing personal rapport with one or more appropriate individuals at each of the major DOE registrants' employer sites should be considered one of the highest priorities of the Director and senior staff of the Registries. Form letters and other official requests by correspondence have been shown to be ineffective. Without the personal contacts and sharing of the labor, suitable exposure records will continue to be elusive.

Advisory Committee Recommendation

RUSSIAN COLLABORATION

Collaborative research with the Russian Federation and the Joint Coordinating Committee for Radiation Effects Research (JCCRER) should be continued, and at an increased pace is feasible. The Registries should seek to integrate the research efforts of Ronald Filipy and John Russell to work with the Dosimetry Registry of the Mayak Industrial Association (DRMIA) to maximize our understanding of dose-effect relationships following radiation exposure of humans.

There is an agreement between the United States and the Russian Federation governments that is under the surveillance

of a Joint Coordinating Committee for Radiation Effects Research (JCCRER) that is comprised of upper-level officials from each country. The US representation is from the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), Health and Human Services (HHS), and the Department of Defense (DOD); there are four representatives from the Russian Federation. The US component is comprised of political appointees and not front line scientists. In keeping with governmental organizations, there are several subcommittees: Executive Committee, Scientific Review Group, a group of Principal Investigators, and Project Research Teams. Dr. Ron Filipy has prime responsibility for the USTUR work that is associated with this program, with collaboration of Professor Kathren and his staff. The prime scientific involvement of the USTUR is under the topic of Occupational Dosimetry, a fitting obligation for this team.

In addition to the organizational complex described above, there is an organization called the Dosimetry Registry of the Mayak Industrial Association (DRMIA), operated by the institute of Biophysics of the Russian Federation. In general terms, the objective from the USTUR viewpoint is to establish respectable and analytically sound methods for tissue sampling from exposed individuals, the radiochemical plutonium and americium), and to build a database which will include the results obtained from the exposed Russian workers and those exposed in the United States. The DRMIA currently has dosimetric data on 1500 workers, 1000 of which have estimated body burdens of >1500 Bq (>40nCi) compared with about 350 deceased individuals in the USTUR, with body burdens of <500 Bq (12 nCi). Total tissue samples from the two institutions is approximately 40,000. The strength that the additional data from the DRMIA will add to those data from the USTUR is without question.

Dr. Filipy presented data to the Committee showing the results of some plutonium tissue analyses from the USTUR and the DRMIA. It was clear from his presentation that the two sets of data are complimentary, as the tissue concentrations (shown for liver) are all essentially higher than those from the USTUR, in terms of Bq per weight of tissue. Most cases in the USTUR are in the range of 0.03-30 Bq/kg while most of those in the DRMIA fall between 100 and 10,000 Bq/kg. There is some overlap of results be tween 30 and 300 Bq/kg. Although Filipy did not present skeletal data, his charts indicated a concentration ratio of plutonium in bone to that in liver to be about 0.25 for both USTUR and DRMIA data over estimated residence times to 40 years post-exposure.

The greatest advantages for collaboration between the USTUR and the DRMIA are the increase in number of cases and the broader range of exposures it provides. The disadvantages are the ever-present problem of having direct access to the Russian data; this problem has shown little progress in this or other areas of inter-governmental collaboration. There is a generic mistrust involved and post-cold war movements have not been encouraging. This sharing of basic data

with the Russian scientists is one of the major problems the USTUR has and will continue to have with being able to merge all data on tissue analysis. For instance, even if data are presented on the tissue concentrations of plutonium in liver and bone, information concerning the individual exposure conditions (how, where, why) may not be readily forthcoming. However, it appeared to the Committee that Dr. Filipy and the staff have done a highly commendable job in getting the data they already have and it would appear with time that this cooperative venture will pay high dividends for both countries.

EXPANDED RESEARCH EFFORTS

One area of some concern to the Committee was the significant expansion into sub-cellular research. The questions may be stated as follows: does this area of research fit into the program goals of the USTUR and where does it belong in the list of priorities that need emphasizing to reach those program goals? One direction the Committee thought might be appropriate to emphasize was an incorporation of John Russell's laboratory techniques into an analysis of tissue samples from the Russian exposure cases. There must be a wealth of biological data buried in these tissues, which if liberated could be correlated with dosimetric findings for a given tissue. Major questions arise, however, as to whether such samples could be obtained from the Russian scientists and whether the tissues had been maintained at a sufficiently low temperature (say, -70° C) to enable meaningful molecular-biological analyses. If the samples could be available and could be used for such analyses, then it seems to the Committee that a golden opportunity exists to obtain information that will never again be possible to retrieve and that this should be pursued with vigor. The best orientation of this vigor is not clear to the Committee and can only be decided by those more closely involved, both at the USTUR and the DRMIA, and probably more importantly, the JCCRER. One direction Russell emphasized that could be extremely important to pursue is that of biodosimetry, perhaps using some of the available in situ hybridization techniques that could be pursued and/or developed which could be very useful in correlating latent damage to the causative radiation dose. In summary on this aspect, the Committee agrees that John Russell's research is first class and at the forefront, but is concerned with the priorities and that it may be difficult to find funding in these times of tight budgets.

Advisory Committee Recommendation

USTUR Policies and Procedures Manual

USTUR Policy 104, USTUR Advisory Committee, should state in section 5 that the agenda for the annual meeting of the Committee shall be developed jointly by the Director and the Chair of the Committee.

A draft revision of USTUR Policy 104 was distributed to the Committee at the meeting. The changes from the previous version were minimal. The Committee believes that the policy should state that the Chair will work jointly with the Director to develop the agenda, as is currently be-

ing done.

Advisory Committee Recommendation

Terms of Appointment

The Registries should clarify the terms to which current members have been appointed.

Several members have not been contacted during the third year of their term regarding reappointment, and received no letter of reappointment. Some correspondence and documents from the Registries have contained conflicting information regarding terms of appointments. The Committee believes that the terms of the appointment should be treated some what more formally by the Registries' staff.

Advisory Committee Recommendation

LONG-RANGE PLAN

The Long-Range Plan should clearly identify the essential purpose of the Registries and the specific goals that must be accomplished to achieve that purpose. It should then address in detail the processes for reaching those goals, i.e. the specific tasks that must be performed and the priorities and costs associated with those tasks.

The current Long-Range Plan is improved substantially over previous versions. The Plan is intended to be a living document and should be reviewed and modified as needed to meet the needs of the Registries. The descriptive sections on "Background" and "Goals and Objectives" are well done. The several planning sections (Near Term, Intermediate and Longer Term) could be read more easily if functional heading were used within these sections

The Plan should represent the staff's thinking about future work loads, especially on the basic research goals. The number and types of volunteers needed, and the projected death rates by year bases on ages of current volunteers, should be included. Such numbers would help in estimating the future work load of the radiochemistry laboratory.

Recruitment of cases with specific radionuclide depositions, like Pu-238, Cf-252 or Cm-244, may be possible with special efforts similar to the Thorotrast cases.

Interest in special cases should be identified for special recruitment efforts. Placing priorities on the existing cases will also assist in directing the order of the work load. The Plan should try to focus efforts along these directions.

The problems of obtaining occupational histories and exposure records of registrants, which were detailed in the meeting, should be discussed in the Plan. Whatever work is being planned or done in this area should be included. Provision for future dosimetry updates, including at the time of death, should also be presented.

The Plan does no make a distinction between the basic core work (essential) which is funded and future work (desired) which could be considered unfunded

under current objectives. The Committee is perturbed when it sees more work in the latter category than in the former. One heading in each section of the Plan (as suggested above) might identify those activities for which the Registries plan to seek future funding, and their various priorities. In these days of limited research funding, efforts to diversify support could pay big dividends and should be part of the Plan.

EXECUTIVE SESSION

Keith Schiager was re-elected to continue as chair, with Kenneth Inn elected as vice-chair. The executive session was primarily devoted to discussion of the topics to be addressed as Committee recommendations. The Committee also returned to the subject of representation by the participating DOE laboratories which had been discussed earlier in the open meeting. We concluded that the invitations should come from the Committee, and that we should obtain from the Director a list of the Registries' site contacts or representatives well in advance of the meeting to facilitate planning and providing invitations.

Advisory Committee Recommendation

Laboratories Representatives

The Committee recommends that the meeting should be two full days in order to cover all relevant business.

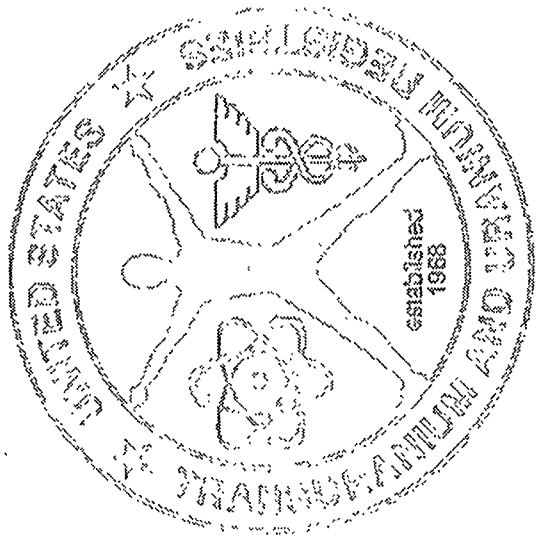
A slightly longer meeting is needed to cover thoroughly the items of concern to the Committee. Further, if DOE site representatives are invited, we should have some time to receive feedback as well as to inform them of the benefits of the Registries' programs.

Adjournment:

The meeting was adjourned at 12:15 PM on 18 October 1995. Dates for the next meeting were not set, although sometime in October 1996 is probable.

Appendix E

USTUR Publications and Presentations List



USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
Publications

Bair, W.J., M.R. Bailey, F.T. Cross, R.G. Cuddihy, P. Gehr, A.C. James, J.R. Johnson, R. Masse, M. Roy, and W. Stahlhofen. International Commission on Radiological Protection (ICRP) Human respiratory tract model for radiological protection. ICRP Publication 66. Ann. ICRP 24 (1/3); 1994.

Birchall, A., N.S. Jarvis, A.C. James, and G. Akabani. Algebraic functions to approximate the fractions of energy absorbed by target tissues in the 1994 ICRP respiratory tract model. National Radiological Protection Board. NRPB-M573; 1995.

Brodsky, A., R.L. Kathren, and C.A. Willis. History of the medical uses of radiation: Regulatory and voluntary standards of protection. *Health Phys.* 69:783-824; 1995.

Dagle, G.E., R.E. Weller, R.E. Filipy, C.R. Watson, and R.L. Buschbom. The distribution and effects of inhaled $^{239}Pu(NO_3)_4$ deposited in the liver of dogs. *Health Phys.* (in press).

Filipy, R.E. and R.L. Kathren. Changes in soft tissue concentrations of plutonium and americium with time after human occupational exposure. *Health Phys.* 70:153-159; 1996.

Filipy, R.E. and R.L. Kathren. Changes in soft tissue concentrations of plutonium and americium with time after human occupational exposures. (Abstract) *Health Phys.* 66:S73; 1994.

Filipy, R.E., R.L. Kathren, and J.F. McInroy. Relative concentrations of plutonium and americium in the liver, testes, and thyroid gland. (Abstract) *Health Phys.* 62:S17; 1994.

Filipy, R.E., R.L. Kathren, J.F. McInroy, and R.A. Short. Soft tissue concentrations of plutonium and americium in occupationally-exposed humans. *Health Phys.* 67:477-485; 1994.

Filipy, R.E., R.E. Toohey, R.L. Kathren, and S.E. Dietert. Deterministic effects of ^{241}Am exposure in the Hanford americium accident case. *Health Phys.* 69:338-345; 1995.

Hall, C.A. and R.E. Filipy. Estimation of skeletal deposition of plutonium from analysis of a selected bone subset. (Abstract) *Health Phys.* 66:S26; 1994.

Hofer, K.G. and S. Bao. Low-LET and High-LET radiation action of ^{125}I Decays in DNA: effect of cysteamine on micronucleus formation and cell killing. Radiat. Res. 141:183-192; 1995.

USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
(cont'd)

Hopke, P.K., B. Jensen, C. Li, N. Montassier, P. Wasiolek, A.J. Cavallo, K. Gatsby, R.H. Socolow, and A.C. James. Assessment of the exposure to and dose from radon decay products in normally occupied homes. Environ. Science and Tech. 29(5):1359-1364; 1995.

Hui, T.E., A.L. Brooks, and A.C. James. Microdosimetry of micronuclei induction and cell killing in mammalian cells irradiated in vitro by alpha particles. Int. J. Radiat. Biol. (in press).

Hunacek, M. and R.L. Kathren. Alpha radiation risk coefficients for liver cancer, bone sarcomas, and leukemia. *Health Phys.* 68:41-49; 1995.

James, A.C., G. Akabani, A. Birchall, N.S. Jarvis, J.K. Briant, and J.S. Durham. International Commission on Radiological Protection. Annexe H: Absorbed fractions for alpha, electron, and beta emissions. In: Human respiratory tract model for radiological protection. ICRP Publication 66. Ann. ICRP 24(1/3); 1994.

James, A.C. and A. Birchall. New ICRP lung dosimetry and its risk implications for alpha emitters. *Radiat. Prot. Dos.* 1995.

James, A.C., M. Roy, and A. Birchall. International Commission on Radiological Protection. Annex F:Reference values for regional deposition. In: Human respiratory tract model for radiological protection. ICRP Publication 66. Ann. ICRP 24(1/3); 1994.

James, A.C., W. Stahlhofen, G. Rudolf, J.K. Briant, M.J. Egan, W. Nixon, and A. Birchall. International Commission on Radiological Protection (ICRP). Annexe D: Deposition of Inhaled Particles. In: Human respiratory tract model for radiological protection. ICRP Publication 66. Ann. ICRP 24(1/3); 1994.

Kathren, R.L. Book Review: Low-Level environmentalradioactivity: Sources and evaluation by Richard Tykva and Josef Sabol. *Health Phys.* 69(6):990-990; 1995.

Kathren, R.L. Pathway to a Paradigm: The linear nonthreshold dose response model in historical context. *Health Phys.* 70:621-635; 1996.

Kathren, R.L. Primeval X-ray Protection: X-rays and x-ray protection before there were state regulators: The first fifty years of x-ray protection, proceedings of the 1995 Annual national meeting of the conference of radiation control program directors, San Antonio, Texas, May 7-10, 1995, CRCPD Publication; 95/4:6-18; 1995.

Kathren, R.L. Postmortem verification of internal dose. In Internal Radiation Dosimetry. Ed. O.G. Raabe. Madison, WI: Medical Physics Publishing; 1994, pp. 517-528.

USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
(cont'd)

Kathren, R.L. Toward improved biokinetic models for actinides: The United States Transuranium and Uranium Registries, A twenty-five year status report. *Radiat. Prot. Dos.* 53:219-227; 1994.

Kathren, R.L. The United States Transuranium and Uranium Registries. Chapter 5 in radiation and public perception, ACS advances in chemistry Eds. J.P. Young and R.S. Yalow, Washington: American Chemical Society, series No. 243: 459-482; 1995.

Kathren, R.L. and A. Brodsky. Historical development of radiation protection. Book chapter in radiology centennial physics history. Ed. P. Almond. (in press).

Kathren, R.L., J.B. Gough, and G.T. Benefiel. The Plutonium Story: The Journals of Professor Glenn T. Seaborg. Columbus, Ohio: Battelle Press; 1994.

Kathren, R.L. and L.A. Harwick. The United States Transuranium and Uranium Registries. Report of the Period October 1, 1993 - September 30, 1994. USTUR-0036-95. College of Pharmacy, Washington State University, Richland, WA (August 1995).

Kathren, R.L., L.A. Harwick, R.E. Toohey, J.J. Russell, R.E. Filipy, S.E. Dietert, M.M. Hunacek, and C.H. Hall. The United States Transuranium and Uranium Registries. Report of the period October 1, 1992 - September 30, 1993. USTUR-0015-95. College of Pharmacy, Washington State University, Richland, WA (September 1994).

Kathren, R.L., J.J. Russell, and A.C. James. Preliminary evaluation of the distribution and biokinetics of $^{238}PuO_2$ in a whole body donor to the USTUR. *Health Phys.* 68:576; 1995.

McInroy, J.F., R.L. Kathren, R.E. Toohey, M.J. Swint, and B.D. Breitenstein, Jr. Postmortem tissue contents of ^{241}Am in USTUR case 246. *Health Phys.* 69:318-323; 1995.

Medley, D.W., R.L. Kathren, R.E. Filipy, and A.G. Miller. Diurnal variation in urinary uranium levels. *Health Phys.* 67:122-130; 1994.

Park, J.F., R.L. Buschbom, G.E. Dagle, A.C. James, C.R. Watson, and R.E. Weller. Biological effects of inhaled $^{238}PuO_2$ in beagles. *Radiat. Res.* (submitted).

Priest, N.D., A. Freemont, J.A.M. Humphreys, and R.L. Kathren. Histopathology and ^{241}Am microdistribution in the skeleton of USTUR case 246. *Health Phys.* 69:330-337; 1995.

Rudolf, G., R. Köbrich, W. Stahlhofen, and A.C. James. Regional deposition in man - A statistical and algebraic model. In: Inhaled particles VII. Eds. J. Dodgson and R.I. McCallum, Oxford: Pergamon Press:1-14; 1994.

USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
(cont'd)

Russell, J.J., R.A. Guilmette, and R.L. Kathren. Autoradiographic localization of ^{241}Am in selected soft tissue samples from USTUR Case 246. *Health Phys.* 69:316-317; 1995.

Russell, J.J., R.L. Kathren, and S.E. Dietert. A histological kidney study of uranium and non-uranium workers. *Health Phys.* 70(4):466-472; 1996.

Russell, J.J., R.L. Kathren, R.A. Short, and J.F. McInroy. Long-term organ retention and pathology in a Thorotrast patient: A preliminary report. In: Health effects of internally deposited Radionuclides: Emphasis on radium and thorium. Eds. G. VanKaick, A. Karaoglou, and A.M. Kellerer. World Scientific; 1995.

Schlenker, R.A., R.E. Toohey, E.G. Thompson, and B.G. Oltman. Bone surface concentrations and dose rates 11 years after massive accidental exposure to ^{241}Am. *Health Phys.* 69:324-329; 1995.

Stannard, J.N. and R.L. Kathren. Radiation protection and medical practice with special reference to health physicists and the health physics society. *Health Phys.* 69(5):837:844; 1995.

Stark, A.A., J.J. Russell, R. Langenbach, D.A. Pagano, E. Zeiger, and E. Huberman. Localization of oxidative damage by glutathione-g-glutamyl transpeptidase system in preneoplastic lesions in sections of livers from carcinogen-Treated Rats. *Carcinogenesis* Vol. 15, No. 2:343; 1994.

Suslova, K.G., R.E. Filipy, V.F. Khokhryakov, S.A. Romanov, and R.L. Kathren. Comparison of the dosimetry registry of the mayak industrial association and the United States Transuranium and Uranium Registries: A preliminary report. *Radiat. Prot. Dosim.* (submitted)

Toohey, R.E. Biokinetics of Bone-seeking Radionuclides. In: Internal Radiation Dosimetry. Ed. O.G. Raabe. Madison, WI: Medical Physics Publishing; 1994, pp. 197-216.

Toohey, R.E. Measurement and analyses techniques for direct assessment of body radioactivity. invited paper for special issue on environment and waste management technology. *Nuclear Technology* (in press).

Toohey, R.E. and R.L. Kathren. Overview and dosimetry of USTUR Case 246. *Health Phys.* 69:310-316; 1995.

Wasiolek, P.T., S.D. Schery, J.E. Broestl, and A.C. James. Experimental and modeling studies of thoron decay products in outdoor air near the ground surface. Presented at the national radiation environment VI, Montreal, Canada, June 5-9, 1995. *Science of the Total Environment.* (in press).

USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
(cont'd)

Wasiolek, P.T. and A.C. James. Outdoor Radon Dose Conversion Coefficient in South-Western and South-Eastern United States. *Radiat. Prot. Dosim.* 59, 269-278; 1995.

Wasiolek, P.T. and A.C. James. Suitability of Radon Gas Concentration for Lung Dose Estimation Outdoors. *Radiat. Prot. Dosim.* (in press).

Presentations

October

- R.L. Kathren visited the Rocky Flats site and also moderated a Socratic discussion of radiation and chemical risks at a joint meeting of the local Denver chapters of the American Society of Safety Engineers, American Industrial Hygiene Association, Health Physics Society, Society for Risk Analysis, American Association of Occupational Physicians, and American Association of Occupational Nurses.

November

- R.L. Kathren presented "Ethical Considerations of Human Radiation Experimentation: A Health Physics Perspective" at the joint meeting of the Hoosier and Bluegrass Chapters of the Health Physics Society in Lexington, KY.

December

- R.L. Kathren presented "The United States Transuranium and Uranium Registries" to the President's Committee on Human Radiation Experiments.
- R.L. Kathren presented "The United States Transuranium and Uranium Registries" to the Agency for Toxic Substances and Disease Registry in Atlanta, GA.
- R.L. Kathren presented "The United States Transuranium and Uranium Registries" to the Advisory Board of the Agency for Toxic Substance and Disease Registry.

February

- R.L. Kathren presented "Radioactivity in Everyday Life" to Mathematics, Engineering and Science Achievement (MESA) students.

March

- R.E. Filipy participated in "The United States-Russian Federation Experience in Health Effects of Occupational Radiation Exposure" workshop in St. Petersburg, Florida.

April

- R.L. Kathren presented "Ethical Considerations of Human Radiation Experimentation: A Health Physics Perspective" as the Third Annual Newell Stannard Lecturer at the Annual Meeting of the Sierra Nevada Chapter of the Health Physics Society.

USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
(cont'd)

- R.L. Kathren presented "Environmental Radioactivity" to the California State Department of Health.
- R.L. Kathren presented "Radioactivity Labeled Antibodies" to the Nuclear Medicine Research Working Group in Richland, WA.

May

- R.E. Filipy presented "The Collaboration Between the Russian and American Transuranium Registries" at the Interagency Nuclear Safety Review Panel Technical Interchange Meeting in Richland, WA, May 2-3, 1995.
- A.C. James presented "New ICRP Respiratory Tract Dosimetry" at the Interagency Nuclear Safety Review Panel Technical Interchange Meeting in Richland, WA, May 2-3, 1995.
- A.C. James presented "Dosimetry Modeling of a USTUR Whole Body Donor Exposed to $^{238}PuO_2$ Microspheres" at the Interagency Nuclear Safety Review Panel Technical Interchange Meeting in Richland, WA, May 2-3, 1995.
- R.L. Kathren presented "Changes in Radiation Protection Issues at Hanford and Beyond Since 1960" to the Columbia Chapter of the Health Physics Society in Richland, WA, May 2, 1995.
- R.L. Kathren presented "The U. S. Transuranium and Uranium Registries and the Applicability of Human Tissue Studies to In-Vivo Counting and Calibration" to the DOE Lung Intercalibration Committee in Richland, WA, May 4, 1995.
- R.L. Kathren presented "Primeval X-ray Protection" to the Conference of Radiation Control Program Directors in San Antonio, Texas, May 8, 1995.

June

- A.C. James presented "An Update of the NRC's (1991) Dosimetry Study Based on ICRP Publication 66 Recommendations" to the BEIR VI Committee of the National Research Council's Mini-Workshop on Radon and Thoron in the Lung: Comparative" in Montreal, Canada, June 4, 1995.

July

- R.L. Kathren, J.J. Russell, and A.C. James presented "Preliminary Evaluation of the Distribution and Biokinetics of 238Pu in a Whole Body Donor to the USTUR" at the 40th Annual Health Physics Society Meeting in Boston, MA, July 23-27, 1995.
- R.L. Kathren presented "Pathway to a Paradigm: The Linear Nonthreshold Dose Response Model in Historical Context" at the 40th Annual Health Physics Society Meeting in Boston, MA, July 23-27, 1995.

- E.T. Marshall, R.E. Toohey, J.D. Coissart, and R.L. Kathren presented "Distribution of Uranium in Two Whole Body Donors" at the 40th Annual Health Physics Society Meeting in Boston, MA, July 23-27, 1995.

USTUR Publications and Presentations
October 1, 1994 to September 30, 1995
(cont'd)

August

- R.L. Kathren presented "X-rays and X-ray Protection: Looking Backward Over a Century of Progress for the Benefit of Mankind" at the Hong Kong Radiological Technologists' Association in Hong Kong, August 13, 1995.
- R.L. Kathren presented "The United States Transuranium and Uranium Registries" to the Laboratory of Industrial Hygiene, Ministry of Health, in Beijing, People's Republic of China, August 15, 1995.
- R.L. Kathren presented "X-rays and X-ray Protection: Looking Backward Over a Century of Progress for the Benefit of Mankind" at the Hong Kong University of Science and Technology in Hong Kong, August 18, 1995.

September

- S. Bao presented "Induction of Micronuclei Following Exposure to ^{60}Co Gamma Rays in the Respiratory Tract" at the 12th Annual Pacific Northwest Association of Toxicologists Meeting in Moscow, ID.
- S. Bao presented "Use of Cellular Damage to Determine the Relationship between Exposure and Dose from Inhaled Radon" at the 12th Annual Pacific Northwest Association of Toxicologists Meeting in Moscow, ID.

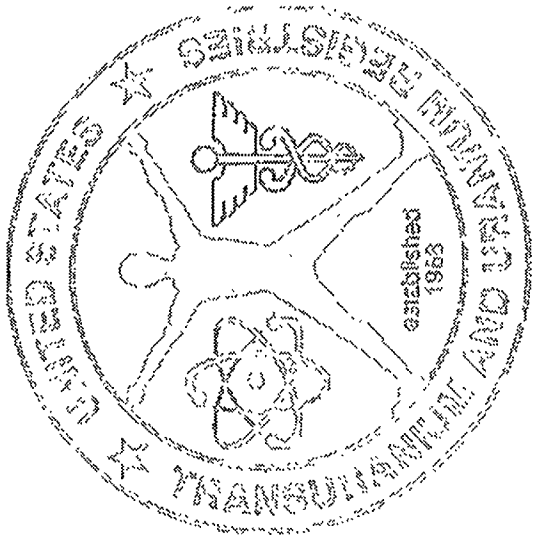
Awards

1. R.L. Kathren was the recipient of the 1994 Herbert M. Parker Award of the Columbia Chapter of the Health Physics Society.

2. R.L. Kathren was the recipient of the Hartman Medal of the Radiology Centennial.

Appendix F

USTUR Projects in Progress



USTUR STAFF	
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GRD	Gerald R. Dagle
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RHF	Royston H. Filby
RLK	Ronald L. Kathren
CLL	Cheryl L. Love
JEN	Johanna E. Norton
JJR	John J. Russell
VTN	V. Thane Norton
MVP	Minh V. Pham
HQ	Hongguo Qu
DBS	Dorothy B. Stuitt

*

USTUR
Research and Development Projects

COLLABORATING INSTITUTIONS	
BNL	Brookhaven National Laboratory
COP	College of Pharmacy
DRMIA	Dosimetry Registry of the Mayak Industrial Assoc.
IAEA	International Atomic Energy Agency
PNNL	Pacific Northwest National Lab
PRC	People's Repulic of China
U of U	University of Utah
WSU	Washington State University

Title/Description	*USTUR Lead	*USTUR Other	Other Collaborator(s)	Projected Completion
Biodosimetry Study: Chromosome aberrations and micronucleus assays are used to detect radiation damage in living registrants and these techniques are being developed. The blood lymphocytes from registrants will be used to produce cultures, and the cytogenetic damage will be linked to biological effective doses from past radiation exposures.	SPB	RLK	A. Brooks, PNNL	ongoing
Cytogenetic Instability: Epithelial cells from the rat respiratory tract were cultured after low-LET and high-LET radiation. Micronucleus assays were used to study cytogenetic instability. The experiment is partially completed and the papers are being prepared.	SPB		A. Brooks, PNNL	ongoing
Radon Study: The radon exposure and biological effective dose to respiratory tract epithelial cells from nose, trachea, and deep lung were investigated. The epithelial cell culture techniques were developed.	SPB		A. Brooks, PNNL	ongoing
Development of extraction chromatography method for actinides in bone: Current ion-exchange methods for actinides generate some organic mixed waste and also generate large amounts of chemical waste. Extraction chromatography methods are being developed for the actinides using combinations of EICHROM TRU, TEVA and U-TEVA resins.	RHF	JEN		12/1/95
Development of extraction chromatography method for actinides in soft tissues: Current ion-exchange methods for actinides generate some organic mixed waste and also generate large amounts of chemical waste. Extraction chromatography methods are being developed for the actinides using combinations of EICHROM TRU, TEVA and U-TEVA resins.	RHF		C. Moody, WSU	6/1/96
Characterization of EICHROM actinide resin for pre-concentration of actinides in tissues: The advantages and disadvantages of using the new ACTINIDE resin for preconcentration of actinides from solution is being investigated.	RHF	HQ		6/1/96

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PRC	People's Repulic of China
U of U	University of Utah
WSU	Washington State University

Title/Description	*USTUR Lead	*USTUR Other	Other Collaborator(s)	Projected Completion
ICP Method for Ca and P in bone for normalization of actinide concentration data: An ICP **method for actinides in soft tissues:** Current ion-exchange methods for actinides generate some organic mixed waste and also generate large amounts of chemical waste. Extraction chromatography methods arebeing developed for the actinides using combinations of EICHROM TRU, TEVA and U-TEVA resins.	RHF		M. Billings, WSU	3/1/96
Determination of ^{239}Pu in very low level samples by fission-track analysis (FTA): An FTA method has been developed for measurement of levels of ^{239}Pu below those currently achieved by alpha spectrometry (0.02 pCi).	RHF	CLL		6/1/96
Measurement of $^{239+240}$Pu ratios in tissues by combined spectroscopy and FTA: A method is being developed to determine total $^{239+240}$Pu by alpha spectrometry on vanadium disks followed by FTA determination of ^{239}Pu on the disk - thus giving $^{239+240}$Pu ratio.	RHF	CLL		6/1/96
Determination of actinides in NIST bone SRM: Methods are being developed for analysis of the new NIST bone SRM.	RHF	SEG, DBS		6/1/96
Trace metal distribution in human tissues: Development of methods for determination of Thorium and other trace elements in whole body tissue.	SEG	RHF, RLK		1998
Thorium electrodeposition development: Difficulties completed were experienced with the electrodeposition method used for Pu and Am. Modifications were made to improve efficiency and spectral resolution.	SEG	VTN		completed
Trace element determination in human tissues: The USTUR whole-body cases represent aunique opportunity to determine toxic metals in addition to radionuclides. An analytical method involving a combination of neutron activation analysis and ICP-AES is being developed for the determination of trace metals in solutions of tissues from whole body cases already analyzed for actinides.	SEG	RHF, RLK		6/1/96
Development of improved electrodeposition methods for Pu, Am, U: A program was begun to improve the current electrodeposition methods for Pu, Am, U, and Th, primarily to improve the efficiency, resolution and speed of analysis.	SEG	VTN		6/1/96

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Title/Description	*USTUR Lead	*USTUR Other	Other Collaborator(s)	Projected Completion
Deconvolution of overlapped alpha spectral peaks: Current alpha detectors cannot separate the peaks of ^{239}Pu and ^{240}Pu. A software program is being developed to deconvolute the combined peak using a high resolution alpha detector.	SEG		S. Lamont, WSU	6/1/96
Integration of radiochemical database: The radiochemical database is written in EXCEL and a program was written to input the analytical data into the USTUR PARADOX database.	SEG	MVP		completed
Tooth:skeletal actinide content:	RLK	MMH		12/31/95
Diurnal urinary excretion of Pu:	RLK	JJR,MMH	E. Kaplan, BNL	5/1/96
Pu in placenta and products of conception:	RLK	JJR	C. Sun,BNL E. Wrenn, U of U N. Priest, AEAHarwell	6/30/96
Evaluation of USTUR 0259:	RLK	JJR		3/1/96
Biokinetics of enriched uranium:	RLK	GRD	M. Hedaya, COP B. Birkenfeld, COP	4/1/96
Pu inhalation case (USTUR 0869):	RLK		C. Wernli, Switzerland	ongoing
International Registries:	RLK		IAEA	ongoing
Chinese collaborations development:	RLK	SPB	W. Kedao, PRC S. Chen,PRC	ongoing
Clinical database:	MVP	CLL		8/95
WWW-CEDR:	MVP			ongoing

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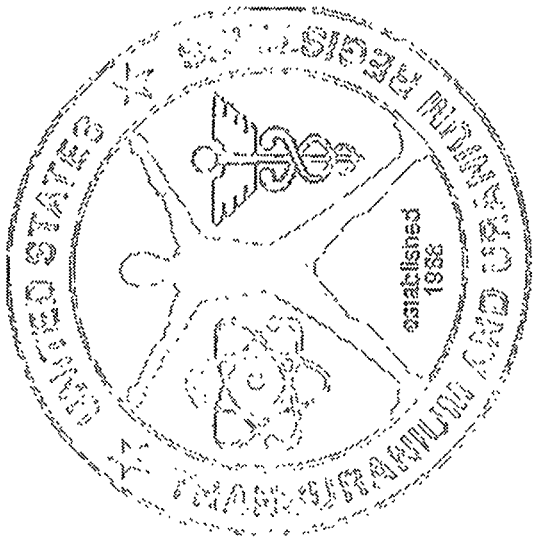
WSU	Washington State University

Title/Description	*USTUR Lead	*USTUR Other	Other Collaborator(s)	Projected Completion
Development of a Method for the Determination completed of Th isotopes: An ion exchange method was developed for $^{228+232}$Th determination in tissues. Procedures integrated with the existing U isotopes method andwas applied to the analysis of tissues from case 0841.	DBS	HQ		completed
Finalization of USTUR radiochemistry procedures: Procedures for Pu, Am, U, and Th werefinalized and the procedures written up in the Procedures Manual.	DBS	SEG RHF		completed
Actinide Concentration Ratios in Tissues/Organs	REF	RLK		12/31/96
Routine Autopsy Skeleton Actinide Content:	REF	RLK	C. Hall, WSU	12/31/95
Actinides in Lung:	REF	RHF GED RLK		Ongoing
Comparison of human and animal actinide biokinetics	REF	GED		12/31/97
JCCRER US-Russian Collaboration	REF	RLK RHF DBS	V. Khokhryakov A. Suslova DRMIA	12/28/99
Actinide microdose distribution in bone via Electron Paramagnetic Resonance (EPR)	JJR		M. Desrosiers	Ongoing
Gene translocations and somatic mutations	JJR		T. Straume	Ongoing
Suppressor gene studies	JJR		J. Hardwick	Ongoing

Appendix G

USTUR Radiochemical Intercomparisons



USTUR RADIOCHEMISTRY REPORT

Radiochemical Intercomparisons

Evaluation of the Results for Intercomparisons 2, 3, 4

Presented at the

USTUR Advisory Committee Meeting

October 17-18, 1995

Introduction

This report describes a series of three radiochemistry intercomparisons which were conducted during 1995. These were preceded by the first intercomparison which was conducted in the Fall of 1994 for the evaluation of alpha spectrometric methods and the results were reported in the 1994 USTUR Annual Report. These intercomparisons are necessary to insure and validate the transition of radiochemical measurements from Los Alamos National Laboratory (LANL) to the United States Transuranium and Uranium Registries located at Washington State University in Pullman (WSU) as well as to evaluate the capabilities of the University of Washington (UW) laboratory which will serve the USTUR radiochemistry program in a QA/QC capacity.

WSU and UW participated in Intercomparison 2 which involved the analysis of 5 blind samples prepared by the other laboratory with contaminant free ^{241}Am and ^{239}Pu traceable to NIST in 8M HCl. The activity range for these samples was requested to be within 0 to 10 dpm.

Intercomparison 3 was conducted using measurements of 8 M HCl sample solutions prepared by LANL from two USTUR cases, 0637 and 0246. The original values from LANL were used as the 'known' value for the radiochemical sample activity for comparison of the results for WSU and UW. This intercomparison was designed to evaluate the radiochemical separation methods of the various laboratories with real samples.

Intercomparison 4 presents the results from the analysis of NIST lung (SRM 4351) and liver (SRM 4352) standard reference materials (SRM's) for various actinide elements by WSU. This study was chosen in order to evaluate the entire sample analysis program at WSU for selected actinide elements.

WSU adopted procedures very similar to those reported by LANL for the radiochemical analysis of tissues as described in the United States Transuranium and Uranium Registries Radiochemical Analysis Procedures Manual, first edition. This was done in order to expedite the transition of radiochemical analysis form LANL to WSU and in keeping with the recommendations of the 1994 USTUR Advisory Committee. Details of the procedures, calculation of activity, uncertainty, and detection limits are given in the USTUR Radiochemical Analysis Procedures Manual.

The procedures used by LANL for the determination of Pu and Am in Intercomparison 3 are those reported in the Radiotissue Chemistry Section of their procedures manual, Health and Environmental Chemistry: Analytical Techniques, Data Management, and Quality Assurance (LA-10300-M). The methods were modified for case 0246 because of the very high ^{241}Am content in the registrants' tissues. These methods were discussed in a recent edition of Health Physics (September 1995) and were based on liquid scintillation counting.

The procedures used by UW for the radiochemical analysis and error propagation are attached in Appendix A. Detection limits provided by UW were calculated based on two times the value of the blank.

Results for Intercomparison 2

WSU and UW participated in Intercomparison 2. This intercomparison involved the exchange and analysis of 5 samples spiked with tracer free ^{241}Am and ^{239}Pu traceable to NIST in 8M HCl. Each laboratory prepared the samples with their own isotopic spikes and provided the solutions to the other laboratory with the content unknown. The activity range for these samples was requested to be within 0 to 10 dpm. Each laboratory then analyzed the samples according to their procedures and reported the sample activity and its associated uncertainty. The results for this intercomparison are presented on the following two pages.

The intercomparison data were analyzed in a fashion similar to that described by ANSI N13.30. The relative percent bias from the 'known' activity for each sample is defined for a given laboratory as:

$$\%\ \text{Bias for a given isotope for each sample} = B_{ri}(\%) = \left(\frac{A_{ai} - A_i}{A_i}\right) \times 100$$

A_{ai}≡The measurement for a given isotope a for sample number i for a given laboratory.
A_i≡ The 'known' isotopic value for sample number i.

The relative bias for each isotope is then defined for a given laboratory for each isotope as:

$$\text{Relative laboratory bias (\%)} = B_r(\%) = \overline{B}_{ri} = \frac{\sum_{i=1}^{N} B_{ri}}{N}$$

Where N is the number of samples values reported for a particular isotope for a given laboratory. The relative laboratory bias (%)was calculated using all reported values for each isotope, excluding those below the Minimum Testing Level (MTL). For the purposes of this intercomparison, only samples to which no activity was added were below the MTL. All other samples were well above the detection limits for that laboratory.

The relative bias precision for each isotope for a given laboratory (e.g. the WSU bias in box in the following table) is defined as:

$$\text{Precision} = S_B(\%) = \sqrt{\sum \frac{(B_{ri} - B_r)^2}{(N-1)}}$$

The results of WSU for the spiked solutions prepared by UW for both ^{239}Pu and ^{241}Am are in good agreement with the spiked values reported by UW. Sample X04 leaked slightly during transportation to WSU but was not excluded from this data set for the purposes of calculating bias or precision. WSU correctly identified samples which had no activity added as below the detection limit.

The results for UW for the spiked solutions prepared by WSU are also generally in agreement with the spiked values reported by WSU. Sample QA2 did show high bias for both ^{239}Pu and ^{241}Am. UW correctly identified that there was no ^{239}Pu activity exceeding the limit of detection in sample QA1, however mis-reported the presence of ^{241}Am in that same sample. UW defined the detection limit as :

LD for ^{239,240}Pu = 2 x blank value = 2 x.0.011 dpm = 0.022 dpm (3.7 x 10-4 Bq)
LD for ^{241}Am = 2 x blank value = 2 x 0.009 dpm = 0.018 dpm (3.0 x 10-4 Bq).

Intercomparison 2:
Results for WSU

Sample #	Sample Description	Pu Sample Result (Bq/Sample)			Am Sample Result (Bq/Sample)			WSU Bias			
		Spike Value Pu-239	WSU Pu-239	± 1 sigma	Spike Value Am-241	WSU Am-241	± 1 sigma	Pu-239	Am-241	WSU Pu-239 Notes	WSU Am-241 Notes
X01	QA/QC SAMPLE #1	0.000E+00	2.97E-04	4.06E-04	1.580E-01	1.66E-01	5.09E-03		5.06	<Ld	
X02	QA/QC SAMPLE #2	4.810E-02	4.15E-02	2.53E-03	1.380E-01	1.46E-01	4.87E-03	-13.72	5.80		
X03	QA/QC SAMPLE #3	7.210E-02	6.78E-02	3.31E-03	7.910E-02	8.13E-02	3.86E-03	-5.96	2.78		
X04	QA/QC SAMPLE #4	1.200E-01	1.27E-01	4.70E-03	3.950E-02	4.07E-02	2.58E-03	5.83	3.04		
X05	QA/QC SAMPLE #5	1.680E-01	1.76E-01	5.05E-03	0.000E+00	-1.31E-04	6.04E-04	4.76			<Ld

NOTES:

Spiked solutions prepared by UW

	Pu-239	Am-241
WSU Bias (%)	-2.27	4.17
WSU Precision (%)	9.31	1.49

Intercomparison 2:
Results for UW

Sample #	Sample Description	Pu Sample Result (Bq/Sample)				Am Sample Result (Bq/Sample)			UW % Bias			
		Spike Value Pu-239/240	UW Pu-239/240	± 1 sigma	Sample Cc (Bq/sample)	Spike Value Am-241 (a)	UW Am-241	± 1 sigma	Pu-239/240	Am-241	UW Pu-239/240 Notes	UW Am-241 Notes
QA1	QA/QC SAMPLE #1	0.000E+00	7.357E-04	4.554E-04	7.707E-04	0.000E+00	4.169E-03	1.534E-03			<Ld	>Ld
QA2	QA/QC SAMPLE #2	3.825E-02	4.483E-02	2.619E-03	7.387E-04	3.753E-02	4.892E-02	2.821E-03	17.19	30.36		
QA3	QA/QC SAMPLE #3	1.913E-01	1.761E-01	7.042E-03	7.239E-04	3.670E-02	3.798E-02	2.226E-03	-7.96	3.50		
QA4	QA/QC SAMPLE #4	1.913E-01	1.948E-01	7.786E-03	7.415E-04	1.876E-01	1.902E-01	7.684E-03	1.83	1.40		
QA5	QA/QC SAMPLE #5	3.825E-02	3.901E-02	2.299E-03	7.436E-04	1.866E-01	1.923E-01	7.707E-03	1.98	3.09		

NOTES:

Spiked solutions prepared by WSU.

Am-241 incorrecly identified as being as present in QA1

(a) Corrected for Am-241 content of Pu-239/240 spike

	Pu-239/240	Am-241
UW Bias (%)*	3.26	9.59
UW Precision (%)*	10.39	13.88

* Based on QA2-QA5 results

Results for Intercomparison 3

Intercomparison 3 was conducted among WSU, LANL, and UW. This intercomparison was conducted using samples from two USTUR cases which had been previously analyzed by LANL, 0637 and 0246. Case 0637 was analyzed by the USTUR and UW for ^{238}Pu and $^{239/240}Pu$ content, while case 0246 was analyzed for ^{241}Am. USTUR Case Number 0637 corresponds to LANL Number 56-068 while USTUR Case Number 0246 is 47-058.

The samples for both of these cases had been prepared by LANL several years previously and were recently transferred from LANL to WSU at Pullman. These samples were assigned a USTUR sample number using current procedures. Samples were picked for the USTUR, LANL, and UW intercomparison to provide a range of activity values and sample compositions. A further sample selection criterion included how much sample remained for the intercomparison. LANL often used one-half of the sample for routine analysis and thus the intercomparison was sample limited which restricted many of the samples to a two-way intercomparison (LANL-WSU). Seven samples from Case 0637 and five samples from Case 0246 were chosen for the three way intercomparison. All samples from case 0637 were processed by WSU (22 in total) including 0637016, thyroid, which had not been processed by LANL.

The LANL Case 0637 data used for this intercomparison was provided by personal with Jim McInroy (Case 0637 was in final reporting status and thus the data was not available at the USTUR-TriCities). The data for Case 0246 were derived from the USTUR database and LANL laboratory notebooks. Many of these data appeared without uncertainty information and as such these uncertainty values could not be included for evaluation. Furthermore, the standard methods used by LANL had been modified for the analysis of Case 0246 to utilize liquid scintillation counting at LANL because of the very high tissue content of ^{241}Am.

The WSU data represent the values obtained by a single alpha spectrometric radiochemical determination with its associated uncertainty. The UW repeated the analysis of the samples and reported the data as the average of the two determinations and used the average of the uncertainty values.

Samples for three way intercomparison are described in the following table.

USTUR, LANL, UW Intercomparison

Sample Number	Sample Description	Elements For Analysis		Initial Total Solution Weight (g)	Total Solution Provided to UW (g)	Estimated Aliquot Activity Range
		Pu	Am			
0637001	Liver	x		500.0	100.0	Medium
0637002	Lung-R	x		400.0	80.0	Medium
0637009	Pericardium	x		400.0	100.0	Low
0637010	Aortic Arch	x		300.0	60.0	Low
0637017	Vertebrae	x		700.0	100.0	Very Low
0637018	Rib	x		800.0	200.0	Very Low
0637021	Patella-R	x		200.1	48.3	Low
0246001	Liver #1		x	100.0	2.18	Very High
0246002	L. Lung LL		x	105.0	5.03	High
0246003	Spleen		x	100.0	5.03	Medium
0246004	Rectus Muscle		x	100.0	5.24	Medium
0246005	Clavicle Acro. Marrow		x	800.1	10.03	Low

Estimated aliquot activity range based on using one-half of the total solution provided to UW. The following definitions apply:

Very Low ≡ Aliquot Activity (dpm) <1

Low ≡ 1 < Aliquot Activity (dpm) <10

Medium ≡ 10 <Aliquot Activity (dpm) <100

High ≡ 100 < Aliquot Activity (dpm) < 1000

Very High ≡ 1000 < Aliquot Activity (dpm) <2000

The results from this intercomparison were again analyzed in a fashion similar to that described in ANSI N.13 30 using the following statistics:

- Relative bias from the 'known' activity for each sample for a given laboratory
- Relative bias for the isotope for a given laboratory
- The relative precision of the relative bias for each isotope for a given laboratory
- t value for the difference between the laboratory's value and LANL's value

The relative percent bias from the mean activity for each sample is defined for a given laboratory as:

$$B_{ri}(\%) = \left(\frac{A_{ai} - A_i}{A_i}\right) \times 100$$

A_{ai}≡The measurement for a given isotope a for sample number i for a given laboratory.
A_i≡ The average value for sample number i.

The relative bias for each isotope is defined for a given laboratory as:

$$B_r(\%) = \overline{B}_{ri} = \frac{\sum_{i=1}^{N} B_{ri}}{N}$$

Where N is the number of samples values reported for a particular isotope for a given laboratory. B_r was calculated using all reported values for each isotope, including those below the Minimum Testing Level (MTL).

The radiochemical sample activity as reported by LANL was used as the 'known' activity of the sample. Only the values for samples which had been run by all three labs and were above the MTL were included in the analysis estimation of bias and precision. The MTL for Intercomparison 3 was defined as 5 times the limit of detection as quoted by LANL procedures, 0.06 disintegrations per minute (dpm) for each of the isotopes, times 4 (only one-fourth or less of the sample was available for analysis), divided by 60 Bq/dpm. This corresponds to a MTL of 0.02 Bq/sample. This value was used as a reference for all laboratories.

The relative precision for each isotope for a given laboratory is defined as:

$$S_B(\%) = \sqrt{\sum \frac{(B_{ri} - B_r)^2}{(N-1)}}$$

The t value for the difference between the laboratory's value and LANL's was calculated as follows:

$$t = \frac{\overline{x_i} - \overline{x_{LANL}}}{\left[\frac{s_i^2}{n_i} + \frac{s_{LANL}^2}{n_{LANL}}\right]^{1/2}}$$

where n=2 for UW, and 1 for all others.

The acceptable ranges for relative bias and the relative precision are from -25% to +50% and 40, respectively, for those values which are above the laboratory's MTL (ANSI N13.30). The relative bias and the relative precision of the bias were recalculated where possible for each laboratory in each category using only those values for which the average value equaled or exceeded the MTL.

The analysis for ^{238}Pu was limited because many of the samples for case 0637 were below the MTL (0.02 Bq/sample). Furthermore, UW did not report the results for 4 of the 7 requested samples for ^{238}Pu because of very high blank values. However, based on these limited results, WSU showed no significant difference from LANL in samples above the MTL. The results for UW for the samples which were reported for ^{238}Pu and above the MTL showed negative bias. This result could be explained by the laboratory's high ^{238}Pu blank values (potentially contamination of some interfering isotope). Due to the limited number of reported analysis not much can be gained from these results.

The analysis of ^{239}Pu in the selected samples for Case 0637 were again limited by the low levels of activity present. UW reported all requested samples. Both laboratories showed excellent agreement for samples above the MTL and for which no problems were reported. Two of the samples chosen had leaked during storage or transportation and are included for review, but are not part of the statistical analysis of bias or precision. These samples also showed generally good agreement between the laboratories and LANL except for 0637021, the right patella. Both laboratories found the activity of the sample to be ~250% higher than reported by LANL It should be noted that the LANL value for this sample (right patella) may be in error since the LANL value for the left patella is 5.19E-02 Bq, consistent with the UW and WSU results for the right patella, 5.10E-02 and 5.35E-02 Bq respectively, and the WSU result for the left patella of 4.96 E-02 Bq. Only one other sample showed significant difference from the reported LANL value for WSU and that sample's results are suspect due to leakage of the bottle during storage and due to foreign material in the solution upon inspection prior to analysis. This foreign material was apparently caused by degradation of the lining in the bottle cap.

The analysis of the ^{241}Am data selected from case 0246 showed excellent agreement between the values reported by LANL and the results for WSU. All samples were above the MTL. Only one sample from UW showed significant bias (liver #1) from the reported LANL value. The bias and precision for both laboratories is good.

There are some other general comments concerning these analysis which need to be stressed. There are some difficulties associated with the analysis of samples which have been in storage for several years. The solution stability of the actinides, even in 8M HCl, is not proven. Some of the samples showed signs of leakage and in some cases foreign material was present. Given these circumstances, this intercomparison showed reasonable agreement for all laboratories.

^{238}Pu Results for Intercomparison 3

Sample #	Sample Description	Pu Sample Result (Bq/ Radiochemical Sample)						Pu-238 %Difference (Based on LANL)		Pu-238 # SD (t value)		
		LANL Pu-238	± 1 sigma	WSU Pu-238	± 1 sigma	UW Pu-238	± 1 sigma	WSU	UW	WSU	UW	Notes
O637001	Liver	2.607E-02	2.347E-03	2.764E-02	4.360E-03	1.417E-02	6.667E-03	6.0%	-45.7%	0.3	-1.7	
O637002	Lung-R	5.237E-02	2.650E-03	5.109E-02	1.070E-02	4.500E-02	1.335E-02	-2.4%	-14.1%	-0.1	-0.5	
O637003	Lung-L	4.370E-02	2.410E-03	5.533E-02	4.103E-03							
O637004	TBLN	4.200E-03	6.033E-04	2.181E-03	1.275E-03							<MTL
O637005	LN-hilar	5.667E-04	3.200E-04	2.238E-04	4.466E-04							<MTL
O637006	Kidney-R	2.000E-04	2.367E-04	1.233E-04	1.987E-04							<MTL
O637007	Kidney-L	6.667E-05	1.767E-04	2.763E-05	1.677E-04							<MTL
O637008	Heart	3.000E-04	2.467E-04	5.155E-05	3.527E-04							<MTL
O637009	Pericardium	3.033E-03	5.300E-04	2.381E-03	1.345E-03	4.000E-03	2.000E-03	-21.5%	31.9%	-0.5	0.5	<MTL
O637010	Aortic Arch	4.800E-03	7.567E-04	4.640E-03	1.927E-03	Not reported			N/A	-0.1	N/A	<MTL, C
O637011	Spleen	1.333E-04	2.367E-04	5.546E-04	4.324E-04							<MTL
O637012	Stomach & Esoph.	1.667E-04	2.667E-04	1.727E-03	2.297E-03							<MTL, A
O637013	Prostate	-2.000E-04	2.267E-04	-3.561E-05	1.754E-04							<MTL
O637014	Testis-R	0.000E+00	8.800E-03	2.675E-05	1.730E-04							<MTL
O637015	Testis-L	3.333E-05	2.000E-04	-9.836E-05	2.005E-04							<MTL
O637016	Thyroid			-2.450E-04	3.301E-04							<MTL
O637017	Vertebrae	1.533E-03	7.133E-04	2.291E-03	1.459E-03					0.5		<MTL
O637018	Rib	-2.533E-03	2.667E-03	1.585E-03	7.992E-04	Not reported			N/A	1.5	N/A	<MTL, B
O637019	Sternum	5.667E-04	4.267E-04	-7.000E-05	3.692E-04	Not reported			N/A	-1.1	N/A	<MTL
O637020	Clavicle	3.000E-04	3.867E-04	-7.699E-06	4.011E-04							<MTL
O637021	Patella-R	1.667E-04	2.433E-04	3.097E-04	4.371E-04	Not reported			N/A	0.3	N/A	<MTL
O637022	Patella-L	6.667E-04	3.600E-04	5.778E-04	6.236E-04							<MTL
O246001	Liver #1											
O246002	L. Lung LL											
O246003	Spleen											
O246004	Rectus Muscle											
O246005	Clavicle Aero. Marrow											

NOTES:

MTL equals 5 times the Ld times 4 (assumes one-fourth of sample used for analysis)=0.3 dpm*4/60dpm/Bq=0.02 Bq/sample for all isotopes

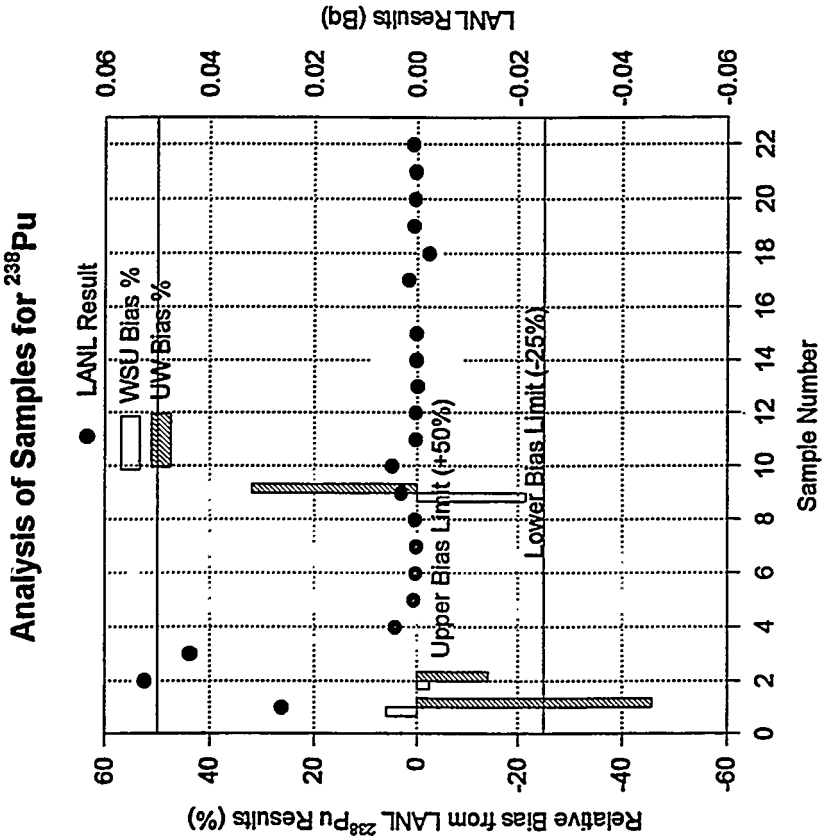
A 0637012 was analyzed twice for Pu, both low recoveries. The first analysis was used for reporting (0637012P).

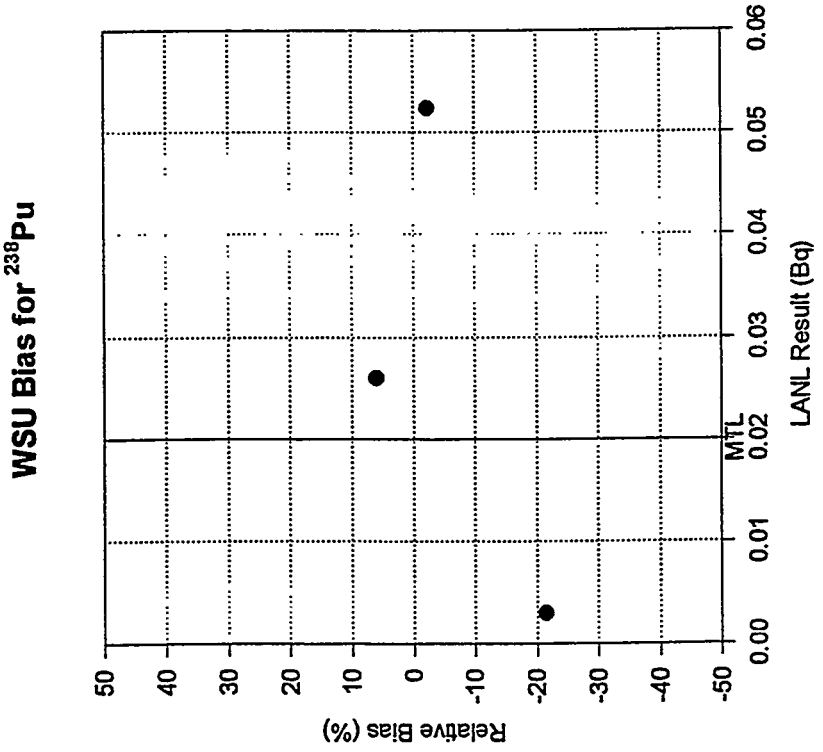
B Sample 0637018 had leaked during transportation from LANL and cap showed degredation (paper in solution). Do no use for intercomparision

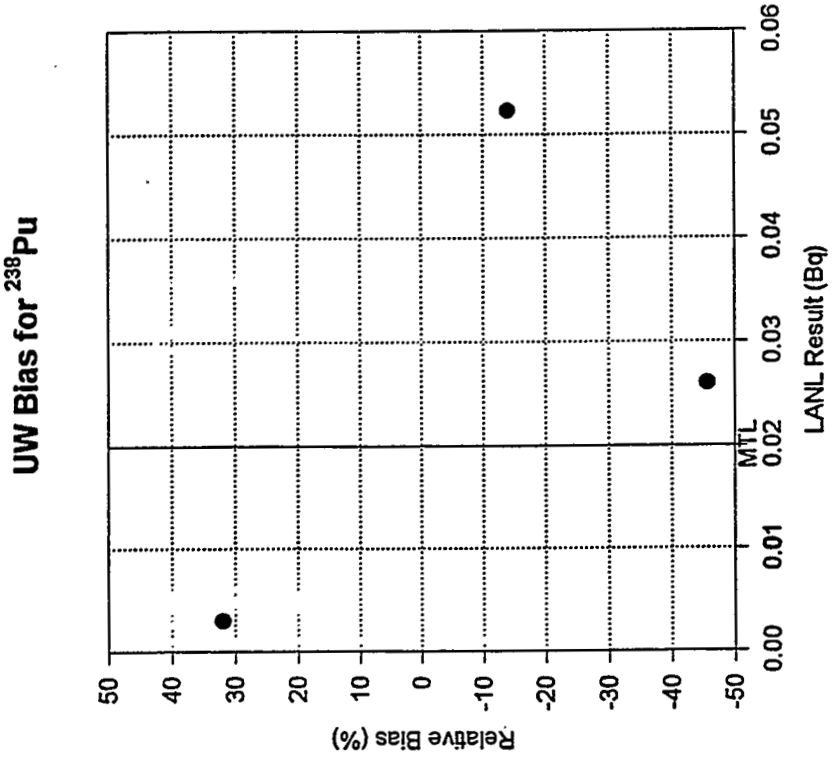
C UW Reported sample leaked during transportation. Do not use for intercomparison analysis.

	WSU	UW
Bias (%)	1.8%	-29.9%
Precision (%)	6.0%	22.3%

Only values above the MTL were used for calculation of Bias and Precision


Analysis of Samples for 238Pu
LANL Result
WSU Bias %
UW Bias %
Upper Bias Limit (+50%)
Lower Bias Limit (-25%)
Relative Bias from LANL 238Pu Results (%)
LANL Results (Bq)
Sample Number
60
40
20
0
-20
-40
-60
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
0
2
4
6
8
10
12
14
16
18
20
22


WSU Bias for ^{238}Pu
Relative Bias (%)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.00
0.01
MTL
0.02
0.03
0.04
0.05
0.06
LANL Result (Bq)


UW Bias for ^{238}Pu
Relative Bias (%)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.00
0.01
MTL
0.02
0.03
0.04
0.05
0.06
LANL Result (Bq)

$^{239/240}$Pu Results for Intercomparison 3

Sample #	Sample Description	Pu Sample Result (Bq/ Radiochemical Sample)						Pu-239 %Difference (Based on LANL)		Pu-239 # SD (t value)		
		LANL Pu-239	± 1 sigma	WSU Pu-239	± 1 sigma	UW Pu-239	± 1 sigma	WSU	UW	WSU	UW	Notes
O637001	Liver	2.541E+00	8.267E-02	2.539E+00	6.620E-02	2.393E+00	1.167E-01	-0.1%	-5.8%	-0.02	-1.26	
O637002	Lung-R	5.431E+00	1.684E-01	5.701E+00	2.368E-01	5.140E+00	2.585E-01	5.0%	-5.4%	0.93	-1.17	
O637003	Lung-L	3.986E+00	1.263E-01	4.609E+00	7.420E-02							
O637004	TBLN	4.465E-01	1.474E-02	4.896E-01	1.258E-02							
O637005	LN-hilar	5.257E-02	2.857E-03	5.835E-02	2.470E-03							
O637006	Kidney-R	6.533E-03	8.300E-04	6.131E-03	5.255E-04							<MTL
O637007	Kidney-L	6.767E-03	8.467E-04	6.359E-03	5.285E-04							<MTL
O637008	Heart	1.910E-02	1.413E-03	1.925E-02	1.223E-03							<MTL
O637009	Pericardium	3.798E-01	1.274E-02	3.757E-01	1.550E-02	3.972E-01	2.720E-03	-1.1%	4.6%	-0.21	1.35	
O637010	Aortic Arch	5.561E-01	1.984E-02	5.714E-01	2.228E-02	4.985E-01	4.600E-02	2.8%	-10.4%	0.51	-1.51	C
O637011	Spleen	4.003E-02	2.317E-03	4.068E-02	2.035E-03							
O637012	Stomach & Esoph.	5.167E-02	2.733E-03	4.318E-02	7.083E-03							A
O637013	Prostate	1.833E-03	5.233E-04	1.518E-03	3.472E-04							<MTL
O637014	Testis-R	4.467E-03	7.033E-04	2.232E-03	3.843E-04							<MTL
O637015	Testis-L	3.000E-03	1.688E-02	2.294E-03	3.840E-04							<MTL
O637016	Thyroid			5.973E-05	5.055E-04							
O637017	Vertebrae	1.677E-01	7.507E-03	1.466E-01	8.880E-03	1.540E-01	1.540E-02	-12.6%	-8.2%	-1.82	-1.04	<MTL
O637018	Rib	8.433E-02	1.006E-02	2.175E-03	1.024E-03	1.040E-01	8.800E-03	-97.4%	23.3%	-8.12	1.66	B
O637019	Stemum	5.643E-02	3.010E-03	1.199E-02	1.056E-03							
O637020	Clavicle	4.530E-02	2.657E-03	4.367E-02	1.808E-03							
O637021	Patella-R	1.447E-02	1.200E-03	5.348E-02	2.007E-03	5.096E-02	4.143E-03	269.7%	252.2%	16.69	11.53	<MTL
O637022	Patella-L	5.188E-02	2.754E-03	4.958E-02	3.793E-03							
O246001	Liver #1											
O246002	L. Lung LL											
O246003	Spleen											
O246004	Rectus Muscle											
O246005	Clavicle Aero. Marrow											

NOTES:

MTL equals 5 times the Ld times 4 (assumes one-fourth of sample used for analysis)=0.3 dpm*4/60dpm/Bq=0.02 Bq/sample for all isotopes

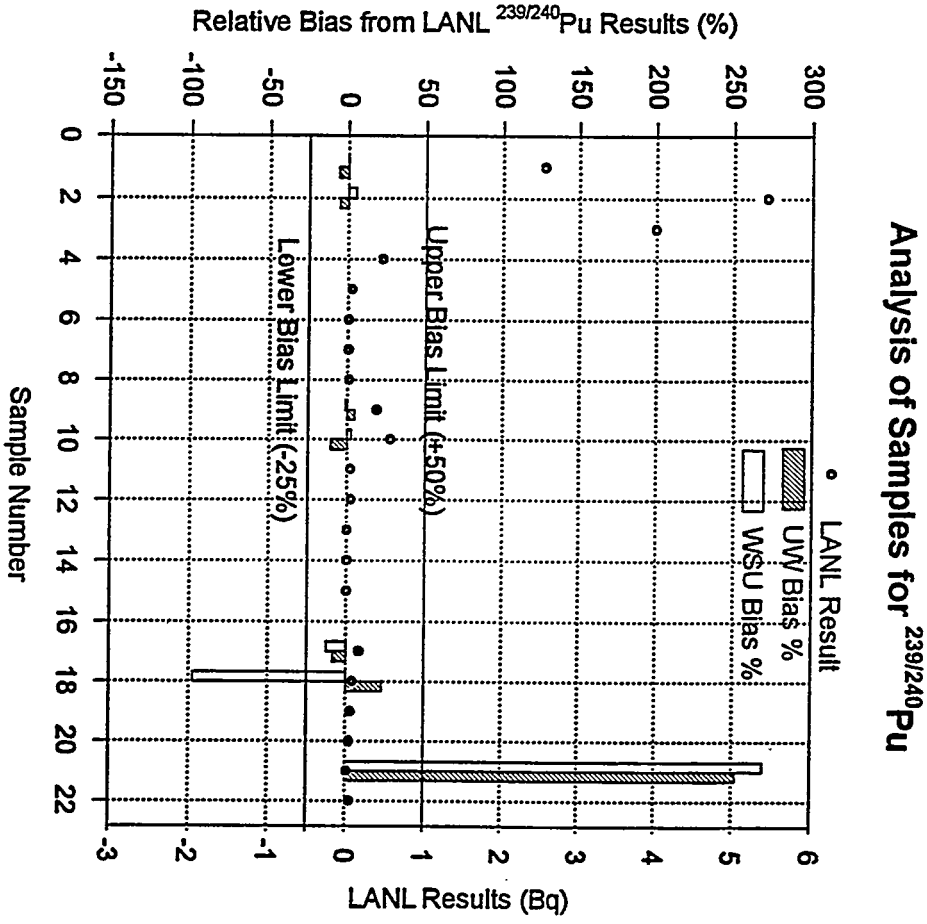
A 0637012 was analyzed twice for Pu, both low recoveries. The first analysis was used for reporting (0637012P).

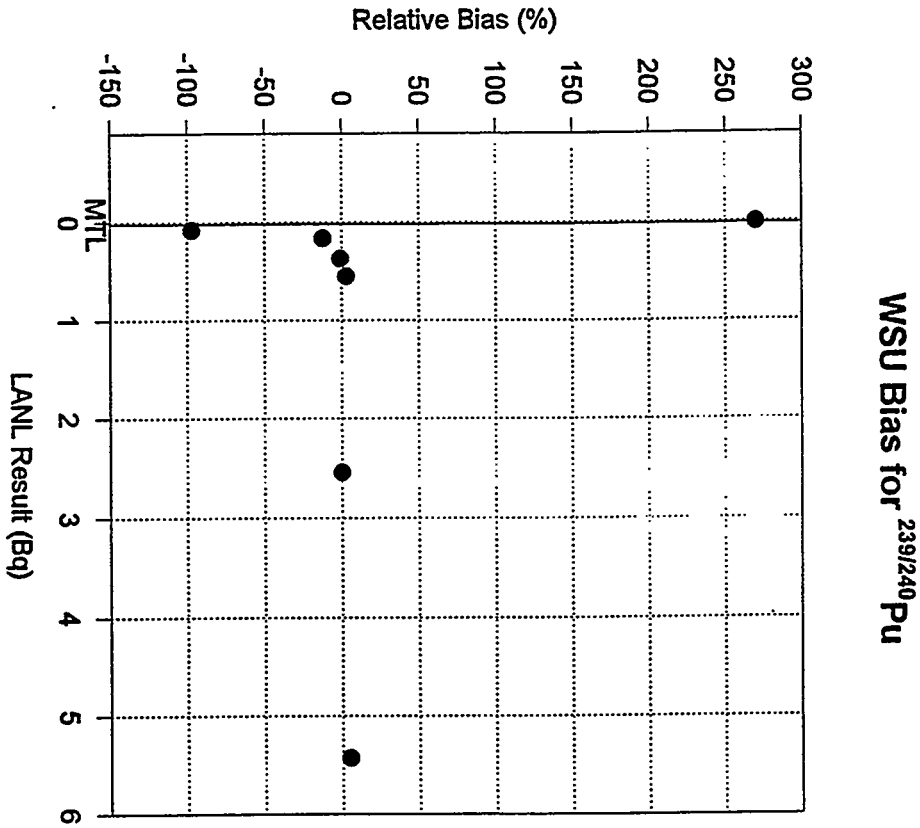
B Sample 0637018 had leaked during transportation from LANL and cap showed degredation (paper in solution). Did not use for intercomparision

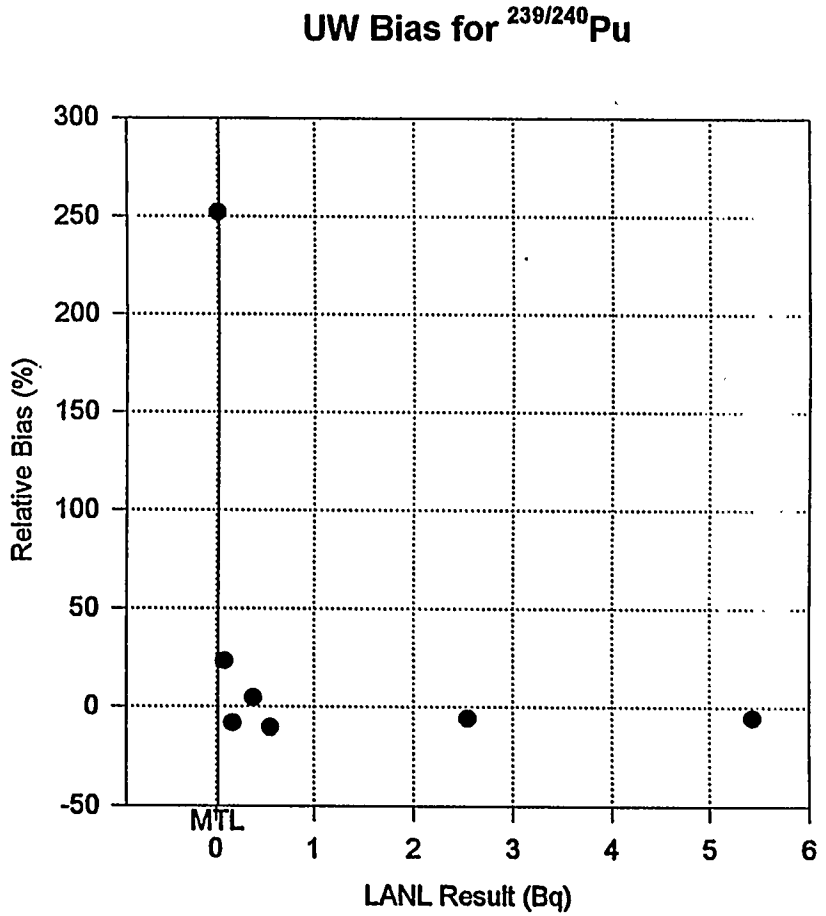
C UW Reported sample leaked during transportation. Do not use for intercomparison analysis.

	WSU	UW
Bias (%)	1.3%	-2.2%
Precision (%)	3.2%	5.9%

Only values above the MTL were used for calculation of Bias and Precision


Analysis of Samples for 239/240Pu
Relative Bias from LANL 239/240Pu Results (%)
LANL Result
UW Bias %
WSU Bias %
Upper Bias Limit (+50%)
Lower Bias Limit (-25%)
Sample Number
LANL Results (Bq)
300
250
200
150
100
50
0
-50
-100
-150
0 2 4 6 8 10 12 14 16 18 20 22
6 5 4 3 2 1 0 -1 -2 -3


WSU Bias for 239/240Pu
Relative Bias (%)
-150
-100
-50
0
50
100
150
200
250
300
LANL Result (Bq)
MTL
0
1
2
3
4
5
6


UW Bias for 239/240Pu
Relative Bias (%)
300
250
200
150
100
50
0
-50
MTL
0
1
2
3
4
5
6
LANL Result (Bq)

^{241}Am Results for Intercomparison 3

Sample #	Sample Description	Am-241 Sample Result (Bq/Radiochemical Sample)						Am-241 %Difference (Based on LANL)		Am-241 # SD (t test)		
		LANL Am-241	± 1 sigma	WSU Am-241	± 1 sigma	UW Am-241	± 1 sigma	WSU	UW	WSU	UW	Notes
O637001	Liver											
O637002	Lung-R											
O637003	Lung-L											
O637004	TBLN											
O637005	LN-hilar											
O637006	Kidney-R											
O637007	Kidney-L											
O637008	Heart											
O637009	Pericardium											
O637010	Aortic Arch											
O637011	Spleen											
O637012	Stomach & Esoph.											
O637013	Prostate											
O637014	Testis-R											
O637015	Testis-L											
O637016	Thyroid											
O637017	Vertebrae											
O637018	Rib											
O637019	Stemum											
O637020	Clavicle											
O637021	Patella-R											
O637022	Patella-L											
O246001	Liver #1	2.971E+03	-	2.914E+03	6.786E+01	2.398E+03	2.294E+02	-1.9%	-19.3%	-0.8	-3.5	
O246002	L Lung, LL	2.539E+02	-	2.420E+02	6.367E+00	2.463E+02	2.296E+01	-4.7%	-3.0%	-1.9	-0.5	
O246003	Spleen	4.407E+01	-	4.322E+01	9.700E-01	4.294E+01	2.584E+00	-1.9%	-2.6%	-0.9	-0.6	
O246004	Rectus Muscle	1.810E+01	-	1.830E+01	4.346E-01	1.832E+01	1.908E+00	1.1%	1.2%	0.5	0.2	
O246005	Clavicle Acro. Marrow	6.600E+00	2.630E-01	7.170E+00	3.139E-01	6.701E+00	5.584E-01	8.6%	1.5%	1.4	0.2	

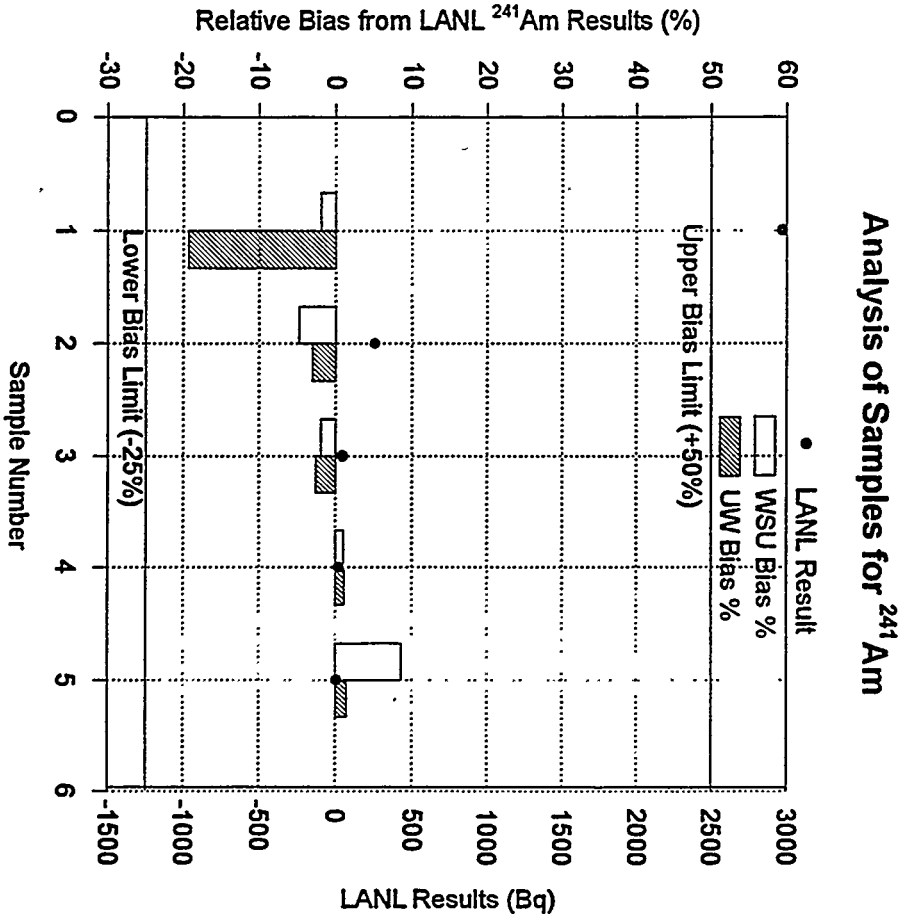
NOTES:

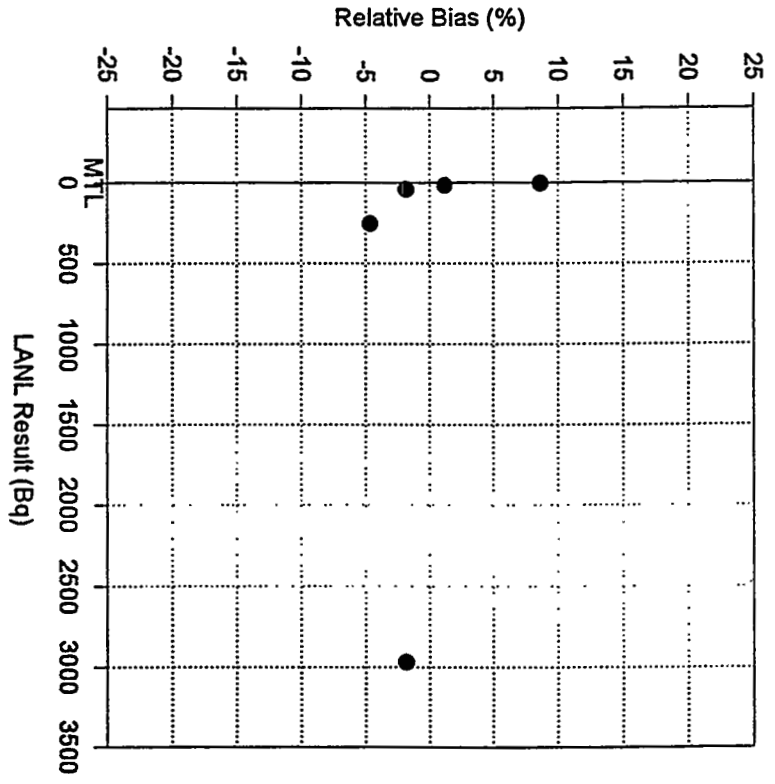
MTL equals 5 times the Ld times 4 (assumes one-fourth of sample used for analysis)=0.3 dpm*4/60dpm/Bq=0.02 Bq/sample for all isotopes

A 0637012 was analyzed twice for Pu, both low recoveries. The first analysis was used for reporting (0637012P).

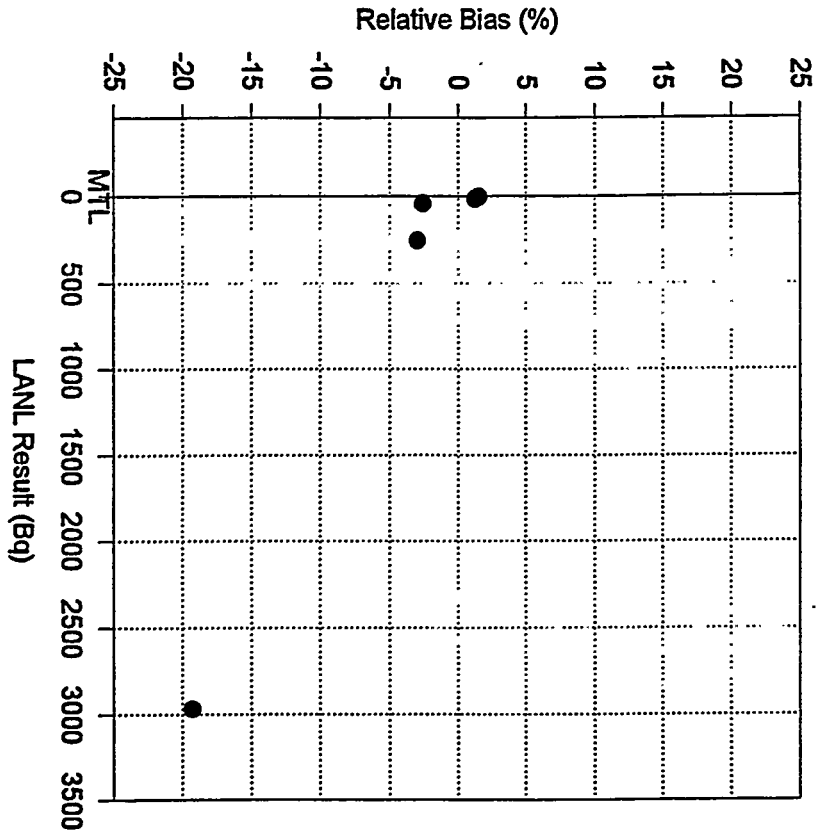
B Sample 0637018 had leaked during transportation from LANL and cap showed degredation (paper in solution). Did not use for intercomparision

	WSU	UW
Bias (%)	0.2%	-4.4%
Precision (%)	5.1%	8.6%


Analysis of Samples for 241Am
Relative Bias from LANL 241Am Results (%)
-30
-20
-10
0
10
20
30
40
50
60
LANL Result
WSU Bias %
UW Bias %
Upper Bias Limit (+50%)
Lower Bias Limit (-25%)
Sample Number
0
1
2
3
4
5
6
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
LANL Results (Bq)



WSU Bias for ^{241}Am



UW Bias for ^{241}Am

Results for Intercomparison 4

Intercomparison 4 assesses the complete radiochemical analysis method of samples by WSU. Two bottles of NIST SRM 4352, human liver, and two bottles of NIST SRM 4351, human lung, were prepared for analysis using the complete dissolution methods and radiochemical separation techniques as described in the USTUR Radiochemical Analysis Procedures Manual, (1st edition) for selected actinides. The entire content of each SRM bottle was used as a sample. Each SRM sample was then run in duplicate, using an aliquot of solution equal to one-half of the sample solution for each analysis. The average of the four values for each SRM were then compared against the NIST certified isotopic values based on the 95% confidence limits reported for the SRM and the 95% confidence limits of the WSU result.

The results of these analyses indicated no significant difference between the NIST SRM reported activity concentration and the WSU results at the 95% confidence level.

Intercomparison 4 Results

Sample	Description	Pu-238 (Bq/g)	Pu-238 SD (Bq/g)	Pu-239/240 (Bq/g)	Pu-239/240 SD (Bq/g)	Am-241 (Bq/g)	Am-241SD (Bq/g)	U-234 (Bq/g)	U-234 SD (Bq/g)	U-235 (Bq/g)	U-235 SD (Bq/g)	U-238 (Bq/g)	U-238 SD (Bq/g)
X006	NIST Liver	4.530E-05	1.240E-05	2.136E-03	7.709E-05	2.272E-04	2.908E-05						
X006	NIST Liver	6.916E-05	2.016E-05	1.955E-03	1.121E-04	2.148E-04	3.543E-05						
X007	NIST Liver	6.283E-05	1.216E-05	1.997E-03	6.435E-05	1.822E-04	3.497E-05						
X007	NIST Liver	3.106E-05	1.366E-05	2.207E-03	8.473E-05	2.488E-04	3.021E-05						
	Average Liver	5.209E-05	1.727E-05	2.074E-03	1.180E-04	2.183E-04	2.786E-05						
	NIST Liver Cert	5.500E-05		2.060E-03		1.500E-04		0.0001*		0.000009*		0.000088*	
X008	NIST Lung			1.085E-03	1.280E-04			7.209E-05	1.396E-05	-1.558E-06	4.142E-06	7.438E-05	1.416E-05
X008	NIST Lung			1.070E-03	8.012E-05			7.931E-05	1.478E-05	-2.311E-07	5.105E-06	9.719E-05	1.631E-05
X009	NIST Lung			1.879E-03	1.543E-04			7.818E-05	1.499E-05	-2.656E-07	4.191E-06	5.480E-05	1.247E-05
X009	NIST Lung			1.487E-03	1.524E-04			9.551E-05	1.694E-05	6.812E-06	5.817E-06	8.143E-05	1.544E-05
	Average Lung			1.380E-03	3.847E-04			8.685E-05	1.225E-05	3.273E-06	5.005E-06	6.812E-05	1.883E-05
	NIST Lung Cert.	1.650E-05		1.100E-03		1.1e-4*		1.000E-04				1.010E-04	

NIST Liver

	NIST Liver Certified Conc. (Bq/g)	NIST Lower 95% CL (Bq/g)	NIST Upper 95% CL (Bq/g)	USTUR Conc. (Bq/g)	USTUR Lower 95% CL (Bq/g)	USTUR Upper 95% CL (Bq/g)
Pu-238	5.500E-05	3.080E-05	7.920E-05	5.209E-05	4.139E-06	1.000E-04
Pu-239/240	2.060E-03	1.669E-03	2.451E-03	2.074E-03	1.746E-03	2.401E-03
Am-241	1.500E-04	9.450E-05	2.055E-04	2.183E-04	1.409E-04	2.956E-04
U-234*	1.000E-04					
U-235*	9.000E-06					
U-238*	8.800E-05					
Th-228*	5.100E-04					
Th-230*	2.000E-04					
Th-232*	5.800E-05					

NIST Lung

	NIST Liver Certified Conc. (Bq/g)	NIST Lower 95% CL (Bq/g)	NIST Upper 95% CL (Bq/g)	USTUR Conc. (Bq/g)	USTUR Lower 95% CL (Bq/g)	USTUR Upper 95% CL (Bq/g)
Pu-238	1.650E-05	1.353E-05	1.947E-05			
Pu-239/240	1.100E-03	5.500E-04	2.310E-03	1.380E-03	3.125E-04	2.448E-03
Am-241*	1.100E-04					
U-234	1.000E-04	7.500E-05	1.250E-04	8.685E-05	5.285E-05	1.208E-04
U-235*						
U-238	1.010E-04	8.989E-05	1.121E-04	6.812E-05	1.583E-05	1.204E-04
Th-228*	2.200E-04					
Th-230*	2.000E-04					
Th-232	2.100E-04	1.827E-04	2.373E-04			

* Non-certified value

Conclusions

Based on the outcome of these first four intercomparisons, the radiochemical analysis of USTUR tissue samples has been successfully transferred from LANL to WSU-Pullman. WSU has successfully adopted LANL's radiochemical methods and put in place a radiochemistry analysis program to meet the analytical needs of the USTUR program.

Future Activities

There are several additional studies which need to be performed over the next year. We are currently evaluating a procedure for the analysis of Th in human tissues which will be intercompared against the results for Case 1001 and NIST SRM's. The analysis of the SRM's will be repeated for plutonium, americium and uranium (where certified values exist) as part of the USTUR Radiochemistry Project routine QA program. The USTUR will also participate in the NIST bone ash intercomparison.

Additionally there will be continued evaluations of new procedures which are being developed for the analysis of actinides in tissues.

Appendix A

Radiochemical Methods for the University of Washington

1. Weigh the bottle + sample. Pipette 5 ml into a 200 ml beaker. Re-weigh the bottle to obtain the weight of the sample.

2. Add to the beaker 10 λ Am-243 tracer, 10 λ Pu-242 tracer, and 300 λ = 6 mg Fe-carrier, and evaporate to dryness.

3. Add 15 ml 8 M HNO3 and few mg NaNO2, boil the solution, cool, and pass through the Pu-column (AG 1-X8 100-200 mesh anion exchange resin prepared in 8 M HNO_3).

4. Wash the column with 8 M HNO3 until all the Fe is removed from the column. Evaporate the column effluents to dryness for Am measurements.

5. Elute the Pu with 40 ml 0.4 M HCl/0.01 M HF and evaporate the eluent to dryness.

6. Add 2-3 ml of 2 M NH_4SCN/0.1 M formic acid to the americium fraction and allow to stand overnight to assure dissolution of the sample.

7. Prepare an EIChroM TEVA-Spec column by washing with 3 ml water followed by 5 ml of 2 M NH4SCN/0.1 M formic acid.

8. Transfer the sample to the column and wash the beaker with four 0.5-1 ml of thiocynate solution and add them to the column.

9. Wash the column with 1 M NH_4SCN/0.1 M formic acid until all the iron is removed from the column.

10. Elute the Am with 20 ml 2 M HCl. Add 3 ml Conc. HNO_3 to the solution and evaporate to dryness.

ELECTRODEPOSITION

1. To the dry beakers containing Pu and Am fractions add 10 drops of Conc. H_2SO_4, 2 ml H2O2 (30%) and 10 ml water. Cover with a watch glass and evaporate to fumes of sulfuric acid.

2. Dilute with 10-15 ml water, boil for few minutes, cool, adjust the pH to 2.5-3.0 with Conc. NH_4OH, transfer to electroplating cells, and electroplate for 3 hours at 0.2 Amp.

3. Take the stainless steel disks out, rinse, flame, and alpha count. Counting time ≥23 hours.

EQUATIONS

Equation for calculation of PU-239,240 activity and error:

$$A_{Pu-239} \pm a_{Pu-239} = \frac{C_{Pu-239} \pm c_{Pu-239}}{C_{Pu-242} \pm c_{Pu-242}} \times A_{Pu-242} \pm a_{Pu-242} - (\text{Blank} \pm b)$$

Where:

$A_{pu\text{-}239} \pm a_{Pu\text{-}239}$ = Activity of Pu-239 and the associated error

$C_{pu\text{-}239} \pm c_{Pu\text{-}239} = [Cg \pm Cg)^{1/2}] - [C_b \pm (C_b)^{1/2}]$

$C_{pu\text{-}239}$ = Net counts under PU-239 peak

$c_{pu\text{-}239}$ = Error associated with Pu-239 net counts

C_g = Gross counts under Pu-239 peak

$(C_g)^{1/2}$ = Error associated with gross counts under Pu=-239 peak

C_b = Background counts in Pu-239 channels (for the same counting time as sample)

$(C_b)^{1/2}$ = Error associated with background counts in Pu-239 channels

$C_{pu\text{-}242} \pm c_{Pu\text{-}242} = [Cg \pm Cg)^{1/2}] - [C_b \pm (C_b)^{1/2}]$

$C_{pu\text{-}242}$ = Net counts under Pu-242 peak

$c_{pu\text{-}242}$ = Error associated with Pu-242 net counts

C_g = Gross counts under Pu-242 peak

$(C_g)^{1/2}$ = Error associated with gross counts under Pu-242 peak

C_b = Background counts in Pu-242 channels (for the same counting time as sample)

$(C_b)^{1/2}$ = Error associated with background counts in Pu-242 channels

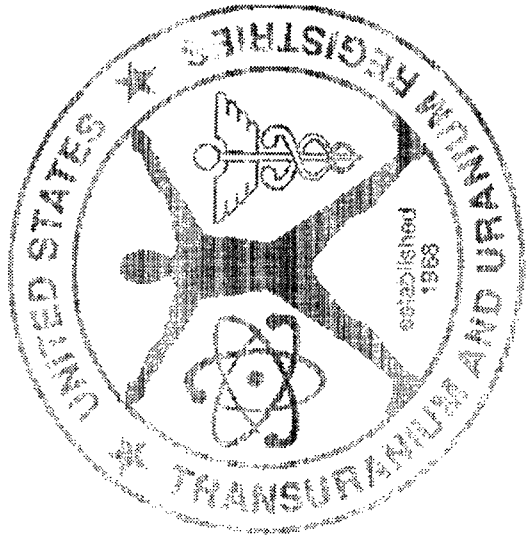
$A_{pu\text{-}242} \pm a_{Pu\text{-}242}$ = Activity of Pu-242 tracer and the corresponding uncertainty

Blank $\pm$ b = Average blank value and the corresponding uncertainty. A similar equation is used for Am-241 calculations.

ERROR PROPAGATION

Operation	Answer	Uncertainty
$(A \pm a) + (B \pm b)$	$A + B$	$(a^2 + b^2)^{1/2}$
$(A \pm a) - (B \pm b)$	$A - B$	$(a^2 + b^2)^{1/2}$
$(A \pm a) \times (B \pm b)$	$A.B$	$A.B[a/A)^2+(b/B)^2]^{1/2}$
$(A \pm a) / (B \pm b)$	A/B	$A/B[a/A)^2+(b/B)^2]^{1/2}$

Appendix H
Distribution List



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