FACT SHEETS

U.S. DEPARTMENT of ENERGY

ARGONNE NATIONAL LABORATORY

9700 SOUTH CASS AVENUE, ARGONNE, Illinois 60439

TELEPHONE 312/972-4146

702519

November 19, 1979

TO: Review Committee Members

FROM: A. F. Stehney

SUBJECT: Fact Sheets on Research in the Center for Human Radiobiology

Attached are additional Fact Sheets that were prepared for the AUA review of November 19-21, 1979. These are as follows:

Center for Human Radiobiology	Prepared by:
1. Theory of the Induction of Bone Cancer by Radiation	John H. Marshall
2. Progress of Medical Studies	Evelyn E. Adams, M.D.
3. Immune Response of Radium and Thorium Workers	Charles S. Serio & Elizabeth L. Lloyd
4. Microdosimetry at Endosteal Bone Surfaces	Robert A. Schlenker
5. Plutonium Microdistribution in Human Bone	Robert A. Schlenker
6. Excretion of ^{210}Pb Following Occupational or Medical Exposure to ^{226}Ra	Richard B. Holtzman
7. Distribution of Plutonium in Hair and Its Relation to Concentration in Blood	Richard E. Toohey
8. Environmental Contamination from Uranium Mill Tailings	Richard B. Holtzman

REPOSITORY ARGONNE /CHR
COLLECTION RECORDS RELATING TO INDUSTRIAL/MEDICAL EXP. TO RADIUM
BOX No. BOX 121 ASH BINDER
FOLDER #33 - CHR FACT SHEETS REVIEW COMMITTEES HISTORY OF CHR from ANL REPORTS

AFS:llf

Attachments

0019748

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Theory of the Induction of Bone Cancer by Radiation

The purpose of this work is to provide a logical synthesis of all the data concerning the induction of osteosarcoma by radiation in man, animals and cell culture in terms of cellular, molecular and systemic mechanisms. We focus upon osteosarcoma and radiation for two reasons: (1) They are of prime interest to the Center in its effort to learn from the human radium cases how to derive solidly-based predictions for the risk to man at any dose level following any kind of exposure from internal emitters, such as strontium, plutonium, thorium, or uranium, and (2) bone cancer as induced by alpha or beta radiation appears to be one of the best defined problems in cancer induction. The dosimetry is excellent; there is a wealth of data in mice, rats, dogs and man for both long-term and short-term, long-range and short-range ionizing radiation; the cells at risk have been identified; and bone cancer has a very low natural incidence with no known complications with other environmental carcinogens. These favorable conditions, plus powerful new computer techniques, plus basic research on mechanisms, plus the crucial human data, lead us to believe that the Center for Human Radiobiology may be in a position to produce such a synthesis.

The following steps in this plan have been accomplished:

1. Metabolic Model. The relations between internal retention of radium in compact and cancellous bone and the measured body burden of radium as a function of time for man have been derived from a metabolic model based upon mechanisms and fitted to available world data (Alkaline Earth Metabolism in Adult Man, J. H. Marshall, E. L. Lloyd, J. Rundo, J. Liniecki, G. Marotti, C. W. Mays, H. A. Sissons, and W. S. Snyder, Health Physics 24, 125-221 (1973) and ICRP Publication 20).

2. Dosimetry Model. The relations between the above internal retention functions and the dose to the endosteal cells at risk were derived as a function of distance from bone surface (Dose to Endosteal Cells and Relative Distribution Factors for Radium-224 and Plutonium-239 Compared to Radium-226, J. H. Marshall, P. G. Groer, and R. A. Schlenker, Health Physics 35, 91-101 (1978)).

3. Bone Cancer Model. What is probably the simplest possible comprehensive model of the induction of bone cancer by radiation was developed to relate specific mechanisms of initiation, promotion, cell killing, cell replacement, and tumor growth to the data for the induction of osteosarcoma by alpha particles in man and dog. This paper also presented a three-dimensional format for analyzing the data of the radiation-cancer field which is the first to represent accurately both the time-dependence and the dose-dependence of original data on cancer induction while correcting for competing

Prepared by John H. Marshall Argonne National Laboratory

0019749

risks. With this analysis, it is shown that a few simple postulates about the basic mechanisms provide an explanation for many of the complex features of bone cancer induction as a function of time, dose, and dose rate (A Theory of the Induction of Bone Cancer by Alpha Radiation, J. H. Marshall, and P. G. Groer, Radiation Research 71, 149-192 (1977)).

4. Two-Target Model for the Two Initiation Events. The above theory predicted that if its two initiation events corresponded to two targets within the cell nucleus which must each be hit once, then there would be a linear component in dose response at low doses. There is no evidence for such a linear component in the human data for long-term radium (R. E. Rowland, A. F. Stehney, and H. F. Lucas, Jr., Dose-Response Relationships for Female Radium Dial Workers, Radiation Research 76, 368-383 (1978)), so it became important to find at exactly what alpha particle dose one would expect the linear and square terms of dose response to be equal. This calculation for the two-target model was published (A Possible Low-Lying Linear Component in the Induction of Bone Cancer by Alpha Radiation, J. H. Marshall, and P. G. Groer, in Energy and Health, edited by A. S. Whittemore, and N. E. Breslow, SIAM Institute for Mathematics and Society, Philadelphia, pp. 39-60, 1978). It showed that we could understand the existence of the dose-squared component in the human radium data by a two-target model only if those two targets were free to roam the whole cell nucleus. A pair of chromosomes will fit this two-target requirement. The tiny cross section for initiation found in the model of step 3 above is strongly suggestive that each of the two initiation events is a deletion of information from a single DNA molecule.

This whole-nucleus site for two targets would be a marked departure from the Kellerer-Rossi Theory and from the universal linear model of the radiation protection committees. Biologically, it seems much sounder: it leads to a square dose-response for low LET radiation, a linear-square dose response for bone-volume sources of alpha particles incident on flattened cells, a linear response for bone-surface sources incident on flattened cells, and a linear response for alphas on rounded cells.

5. Two-Ionization Model for each Initiation Event. The present work concentrates on the track structure of alpha particles, beta particles, and x-rays in watery medium in order to find whether the above-postulated model involving hits on two DNA molecules within a cell nucleus is consistent with the fundamental physics of ionization processes as represented by the work of Inokuti and Kim. We are using new data on secondary-electron production by both beta particles and alpha particles in water vapor, together with Bethe's formula for electron-atom and alpha-atom collisions, Rutherford's formula for alpha-electron and Moller's formula for electron-electron collisions to write expressions for the number of ionizations per unit pathlength along the main tracks and all delta ray tracks of the different kinds and energies of incident particle. From these track structure representations, checked against data for energy per ion pair as a function of energy (given us by Inokuti), we find the probability of tiny clusters of ionization on the scale of a DNA molecule.

It has been thought (from work of Barendsen and Howard-Flanders) that 10-20 ionizations within 100-200 Å might be the crucial radiation event. Though our work on this is not complete, it seems possible that a simpler model can explain the LET-dependence of the primary event in initiation, mutation, or cell killing. For example, we have calculated the probability of placing one ionization within 3 Å of each of the two sugar-phosphate backbones of the double helix of DNA. The results provide about the right ratio between the cross sections for alpha particles, beta particles, and low energy x-rays (Goodhead et al.) regarding cell killing and mutation. We will test also the ratio of the induction of osteosarcoma by alpha-particles and beta-particles in the Salt Lake dogs. This ratio depends on, on initiation cross section since all other model parameters are fixed. Distances of only a few Angstroms appear to be consistent with calculations of the direct polarization effect of ionizations within the DNA molecule which, conceivably, cause it to explode.

0019750

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Progress of Medical Studies

Radium cases (5 person-years)

Medical examinations are continuing as before; six are ordinarily scheduled each week, and the times of examination are coordinated with times of measuring radium burden. In addition to routine re-examinations this year, we have seen 30 new previously unmeasured radium workers. Frequency of re-examination of radium patients is determined by the radium burden and the age of the patient; however, all persons under follow-up are contacted at least annually by telephone or letter with questionnaire. Since a major thrust of the program in correlation of pathologic changes with radium burdens, ascertainment of radium content is of prime importance and efforts are made to obtain the best feasible medical profile of each person in the study.

1. A few individuals remain too anxious to be willing to visit the Center, and a small number have declared their active hostility. The mobile unit has enabled us to obtain measurements of some of these persons in several parts of the country. Several person have willed their bodies to the Center and the exhumation program has been opened up in the midwest.

2. In addition to an exhaustive medical history and physical examination, a full profile of biochemical analyses (SMA-24 and thyroid profile, plus others as indicated) and a full set of skeletal x rays including special views of mastoids and paranasal sinuses on at least one examination are secured. Careful audiograms are taken, including bone conduction, on account of the vulnerability of mastoids to radium damage.

The coding of pathologic states for computer retrieval, according to the standard nomenclature (SNOP) has been done on the 5400 cases on whom files exist in the Center, yielding over 128,000 entries. Most of the present work now consists in coding conditions found in hospital records that are being obtained, and in first examinations of new entries. About half of these files contain minimal information (this might arbitrarily be defined as less than 10 entries) and the remainder contain an average of 47, with apparently quite uniform recording of common conditions likely to be identified in a complete examination.

A file of tumor diagnoses has been complied from the SNOP listings. This file includes 774 verified entries in 729 cases. By keeping this tumor diagnosis file up to date it will be possible to retrieve current data on any subgroup of patients in the radium study. The development of the SNOP tumor file makes it easier to investigate incidence as well as mortality. For example, a preliminary investigation of breast cancer incidence in measured radium workers before 1930 (numbering 779) has been undertaken. This is of particular interest since no

Prepared by E. E. Adams, M.D. Argonne National Laboratory

0019751

human data on breast cancer association with internally administered radionuclides is currently available.

Our collection of slides and tissue blocks is being expanded to include as large a segment of our study population as possible. One result of this pathology review has been the publication by Littman, Kirsh, and Keane of a definitive paper on radiogenic tumors of the mastoid and paranasal sinuses. A similar effort is now being made in regard to bone sarcoma.

Former thorium workers (3 person-years)

Medical and radioactivity examinations are underway for over 400 living persons (all males) who worked at a thorium refining plant for one year or longer. Measurements of body radioactivity and thoron exhalation show a considerable difference between individuals and reasonably good reproducibility between measurements on individuals made at different times.

The vivo measurements that are made are not yet translatable into body and organ thorium content, therefore each person at the time of examination is advised of the willed body program with a frank explanation of the scientific reasons for it. Several individuals have indicated willingness to participate.

The same medical and laboratory examinations are given as in the radium study, with the exception of detailed audiometry and the x-ray survey, which in thorium studies is limited to chest, abdomen, and any other films that are required for particular indications that become evident at examination. In addition, all of the participants in this study are given respiratory function testing including CO diffusion rates and total lung volume as well as the routine spirometric and voluntary ventilation measurements. It is assumed that the major mode of intake of thorium has been by inhalation.

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Immune Response of Radium and Thorium Workers

Nature of Problem

The purpose of this investigation is to examine the functional status of the immune system in workers previously exposed to internal alpha emitting isotopes.

Immune defects have been demonstrated in a number of different cancer patients by various immunological techniques. The most widely used in vitro assay for the measurement of immune competence among these patients has been the induction of DNA synthesis of peripheral blood lymphocytes (PBL) by phytohemagglutinin. We have, for the last two years, utilized this assay to measure the immunocompetence of radium and, most recently, thorium workers. Since other mitogens, such as Concanavilin A and poke weed, are capable of eliciting a more selective response, they, too, have recently been utilized. The information obtained from these studies will, hopefully, allow us to monitor the competence of these workers by signaling the onset of any developing malignancy known to occur in these populations at a higher incidence than normally found in the general population.

Although none of the radium or thorium workers studied so far have demonstrated any clinical signs of malignancies, we have observed moderate decreases in lymphocyte responsiveness relative to the control subjects.

Results to Date

We have examined 44 former radium dial painters and 30 American thorium workers. Data collected on an additional 30 frozen lymphocyte samples obtained from radium workers have not been included due to variability in the mitogen stimulation assay from such frozen samples.

Maximum lymphocyte stimulation in response to optimum doses of various mitogens (PHA, Con A and PWM) in the control population and both radium and thorium workers was shown to decrease with age. However, by comparing age-related effects obtained from both the control and the radium and thorium workers, we were able to demonstrate a reduced lymphocyte response in both sets of workers that was not age-related.

The mean reduction in lymphocyte stimulation with the radium cases was 28% with PHA, 47% with Con A and 46% with PWM. Similar reductions (26% with PHA, 40% with Con A and 30% with PWM) were observed in the thorium workers.

Evidence for Suppressive Serum Factors

Since suppressive factors which may affect lymphocyte stimulation have previously been demonstrated in certain cancer patients, we initiated studies to

Prepared by Charles S. Serio & Elizabeth L. Lloyd Argonne National Laboratory

0019753

examine the sera from our radium population for possible suppressive factors. The sera from both high and low body burden radium patients, along with control homolog(sera, were incubated with normal control lymphocytes.

We were unable to demonstrate any sera-related effects on normal lymphocytes stimulated with PHA or PWM. However, Con A was shown to stimulate selected "subgroups" of normal lymphocytes while showing a diminished response in other "subgroups". A 40% reduction in normal stimulation was observed when control lymphocytes were pre-incubated with sera from high body burden radium workers. A 23% decrease was observed with normal lymphocytes pre-incubated with low body burden radium sera.

Conclusions

We cannot attribute the observed decreases in either the radium or thorium workers to age or body burden. Nutritional and medication-related effects cannot, at this time, be ruled out as possible causes of this diminished activity. Information is currently becoming available that should allow us to quantitate the external radioactive exposure received by the thorium workers. Hopefully, this information will permit us to either implicate, or rule out, the effects of radioactivity in showing the differences observed in the thorium workers.

0019754

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

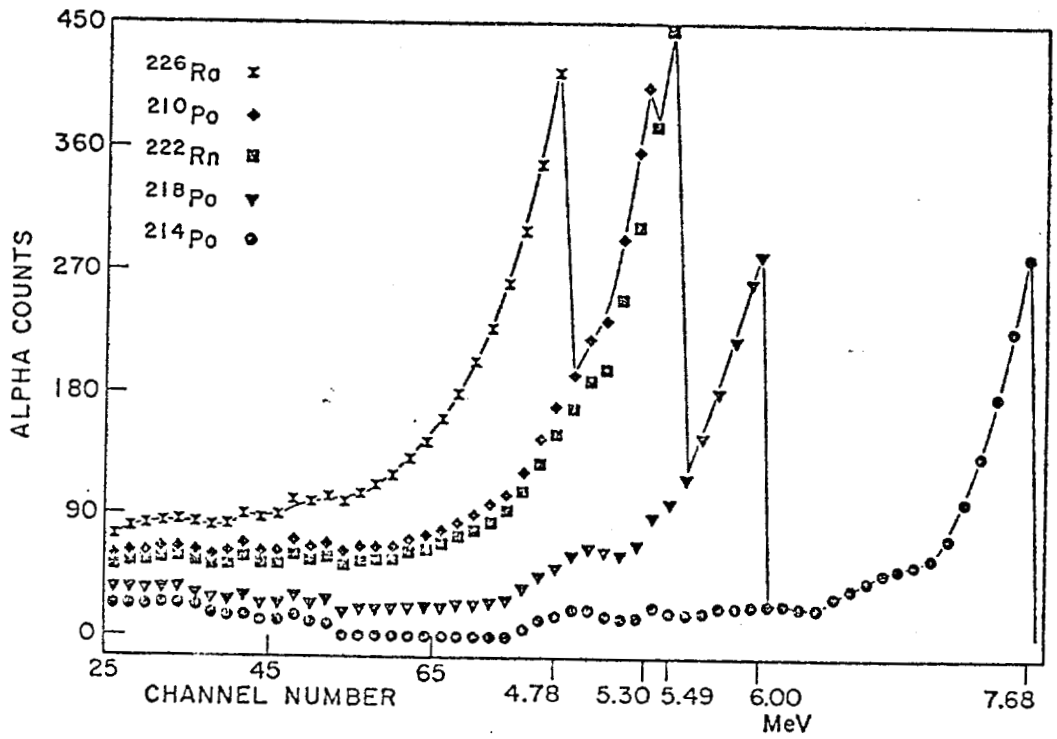
Fact Sheet on

Microdosimetry at Endosteal Bone Surfaces

Radium Distribution Near Bone Surfaces

Models of bone tumor induction proposed by Marshall and Groer predict a lower dose to bone cells at endosteal surfaces than predicted from simple models of radium distribution. Direct measurements of the energy released from bone surfaces are now being made using alpha particle spectrometry. Because of its high spatial resolution, spectrometry also allows us to determine the distribution of radium as a function of depth below the bone surface and, thus, to test a specific hypothesis explaining the disagreement between predicted and observed dose: The presence of a layer of bone, adjacent to the surface which is depleted in its radium content. We can determine whether or not the radium distribution is uniform by examining the spectrum shape. The shape also gives evidence as to whether a non-uniform distribution has a high or a low value adjacent to the bone surface. To date, we have found evidence of depleted layers in some bone samples and evidence of layers with enhanced concentrations in others. The relative frequency with which these types occur is yet to be determined.

The spectrum from a piece of radium bearing bone receives contributions from radium and each of its alpha emitting daughter products. In order to determine the concentration of radium or the dose rate from it, the radium contributions must be separated out. Because these spectra are quite complex, separation is a formidable task which we are attacking with computer methods and specialized measurement methods which allow us to determine the radium contribution directly but which require months of data collection. An example of a separated spectrum exhibiting the characteristics of enhanced surface concentrations is shown below.



0019755

Prepared by Robert A. Schlenker Argonne National Laboratory

Plutonium Distribution near Bone Surfaces

Alpha particle spectrometry can also be applied to the study of plutonium. Because only one radionuclide is present, separation of components is unnecessary. Using this technique, we have made the first measurements of the thickness of the plutonium surface deposit in human bone and found it to be less than 3 μm in two persons injected 15 and 17 months before death. When the burden is of many years duration, much of the plutonium has been built into bone volume by the remodeling process and the spectra reveal both the surface and the volume deposition. In a person with a 20.7-year burden, we have found the surface component to be less than 5 μm thick and the volume plutonium to be uniformly distributed within the bone.

Bone Remodeling

Appositional bone remodeling alters the target cell dose by covering the surface with a layer of bone nearly devoid of radioactivity. We are determining the extent to which this process has shielded the cells in persons exposed to radium. In several cases so far examined, the shielding in long bone midshafts appears to be less than expected for unexposed persons indicating a possible reduction in bone remodeling rate in radium exposed persons.

001975b

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Plutonium Microdistribution in Human Bone

With the cooperation of next-of-kin, we have exhumed the remains of 4 persons injected with plutonium in the mid-1940's. Three of these, a 20-year old woman with a 17-month burden (case 40-010), a 65-year old man with a 15-month burden (case 40-015) and a 79-year old man with a 20.7-year burden (case 40-001) have proven suitable for microdistribution studies. Our ultimate goal is to determine the dose or particle fluence to the cells at risk for sarcoma induction. To achieve this, we measure the plutonium concentrations in bone surface and bone volume deposits and also measure the deposit thicknesses. Two techniques are utilized, fission track autoradiography, to obtain data on concentration and volume deposit thickness, and alpha particle spectrometry, to obtain data on surface deposit thickness and the relative concentrations of surface and volume deposits. All three of the cases have been studied, 40-010 most extensively.

Several conclusions have been drawn from our data and observations:

(1) In the absence of bone remodeling, surface concentrations are not greatly different on endosteal, Haversian canal and periosteal surfaces in long bone midshafts 17 months after injection. Therefore, differences in the tumor susceptibility of these surfaces would be due to biological factors and not to differences in plutonium deposition.

(2) Endosteal surfaces in the axial skeleton show higher concentrations than in the appendicular skeleton at 15 and 17 months post injection. This partly explains the higher specific activities measured radiochemically (by Dr. Larsen) in the axial skeleton. Other factors which enter into the specific activity differences are the extent of bone remodeling and surface to volume ratio.

(3) The mean thickness of bone volume deposits formed by appositional growth exceeds the range of plutonium alpha particles. Thus, the deposits are "infinitely thick" for purposes of dose calculation and bone surface cells are completely shielded from deposits on buried surfaces lying at the lower boundaries of the volume deposits. This fact is of special importance since the buried surface deposits tend to be very intense.

(4) Surface deposits are so thin that, for purposes of dosimetry, they can be considered to have zero thickness. This greatly simplifies the dosimetric calculations.

(5) Surface deposits which begin to form when the blood level has fallen to a very low level are much less intense than the deposits which form when the blood level is high. However, the latter are in a position to irradiate cells for a much shorter time than the former. The less intense deposits are, therefore, of considerable dosimetric significance. They are an important source of dose even 20 years after injection.

Prepared by R. A. Schlenker Argonne National Laboratory

0019757

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Excretion of ^{210}Pb Following Occupational or Medical Exposure to ^{226}Ra

Knowledge of the excretion rates of ^{226}Ra and its long-lived decay product ^{210}Pb (22 yr) of persons with significant amounts of these nuclides is important to evaluation of their radiation doses. The excretion rates are useful in determining the parameters of the nuclide retention functions and, especially in our studies, the dose to contaminated subjects over long periods of time. ^{210}Pb, as an isotope of lead, is of particular interest because subjects with large amounts of ^{226}Ra excrete ^{210}Pb well in excess of that derived from environmental sources. Determination of the excretion rates of this nuclide makes possible estimation of some metabolic parameters of endogenous lead not otherwise available, such as urinary-to-fecal ratios and skeletal turnover rates.

The urinary and fecal excretion rates of ^{226}Ra and ^{210}Pb were determined for 46 subjects who had been exposed to ^{226}Ra; 22 had been radium dial painters, 12 received radium iatrogenically and 12 had been radium chemists. The body contents ranged from 8 to 8600 nCi ^{226}Ra. Those of ^{210}Pb are not directly determinable *in vivo*, but they are estimated from the radioactive growth and decay and retention functions to be about 30% of the ^{226}Ra levels for long-term exposures. This value is consistent with extensive measurements on autopsy bone specimens from three dial painters, but it is substantially lower than those in some other cases studied in this laboratory (ANL-7760, pp. 22-34, 1970) and found in some more recent measurements. The mean ages at exposure were 21, 28 and 31 yr for the three groups respectively, the dial painters being significantly younger than the two other groups at the mean time of exposure. The mean total coefficients of elimination (CE) (percentage of the body content excreted annually) for ^{226}Ra were significantly lower for the medical cases and chemists (0.97 ± 0.08 and 1.24 ± 0.26 %/yr, respectively), than for the dial painters (2.15 ± 0.33 %/yr), where the mean body contents of the respective groups were 1330, 127 and 416 nCi.

The differences in the CE's between the groups appear not to be due to differences in either sex or ^{226}Ra body content; there were no significant differences in CE between the 7 males and 9 females in the medical group, and the CE's did not correlate with ^{226}Ra body content within the groups. However, the age at acquisition of the ^{226}Ra may affect the CE: the dial painters (the group with the highest level of excretion) were first exposed to ^{226}Ra at a mean age significantly lower than were the other groups.

The coefficients of elimination (total of urinary and fecal CE's) for ^{210}Pb (relative to the ^{226}Ra body content) were much higher for the chemists (9.2 ± 5.0 %/yr) than for the dial painters (1.42 ± 0.56 %/yr) and the medical cases (0.38 ± 0.09 %/yr). Both the urinary and fecal excretion rates taken separately for each of the groups show similar trends. Excretion of ^{210}Pb is divided approximately equally between urine and feces. For radium, on the other hand, only about 3% of the excretion is urinary.

Prepared by R. B. Holtzman Argonne National Laboratory

0019758

A value of the CE for ^{210}Pb based on its body content may be estimated from the data for the medical cases if it is assumed that all of their ^{210}Pb has grown in from the ^{226}Ra in the body. Thus, at 40 yr after intake the ^{210}Pb activity is about 30% that of the ^{226}Ra and the CE is about 1.3 %/yr.

If we assume that the medical cases had a minimal exposure to ^{210}Pb or its radon and daughter precursors, then the substantially enhanced excretion rates of ^{210}Pb for the chemists indicate body content of ^{210}Pb in excess of that grown in from the ^{226}Ra present in the body. The radon parent of ^{210}Pb may have emanated from radium solutions and mixtures in the laboratory of factory. The short-lived daughters would have been inhaled and deposited in the lungs where they formed ^{210}Pb, which would have translocated via the blood to the bone. The somewhat higher excretion rate of the dial painters over that of the medical cases indicates that they, too, had some additional exposure to precursors of ^{210}Pb, but to a lesser degree than the chemists.

The additional ^{210}Pb produces a dose to the skeleton through its alpha-emitting daughter, ^{210}Po, that may be comparable to, and in some cases substantially greater than, that from small body burdens of ^{226}Ra. Thus, in one recent case for whom bone specimens were available (01-208, ^{226}Ra content 818 nCi), the $^{210}Pb/^{226}Ra$ ratio was about 0.5, a much higher value than would be expected ($\sim$ 0.2) about 20 years after mid-exposure. The average dose to the skeleton from the excess ^{210}Pb was estimated to be about 12% of that from the ^{226}Ra series (107 rads/900 rads).

In addition, the fraction of the increased ^{210}Pb derived from the inhaled short-lived radon daughters is indicative of a dose to the lungs, one that may be comparable to that received by uranium miners at levels known to produce somatic effects.

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Distribution of Plutonium in Hair and Its Relation to Concentration in Blood

The concentration of plutonium has been determined along the length of the hair of a female subject (Case no. 40-010) who received 11 kBq (0.3 μCi) of ^{239}Pu by intravenous injection in 1945. The subject succumbed to her pre-existing illnesses 518 days post injection, and her remains were exhumed by the Center for Human Radiobiology in 1973.

The subject's hair, 280 mm in length for the longest strands, was divided into 20-mm long sections and the plutonium concentration (Bq/kg hair) was determined in each section by alpha spectrometric isotope dilution. The concentration ranged from 22 Bq/kg (0.59 pCi/g) at the distal end to 3 Bq/kg (0.08 pCi/g) at the proximal end. The distance of each section from the distal end of the longest hair was then converted to an estimated time in days post injection by dividing it by the growth rate of the hair indicated for this individual.

The plutonium concentration as a function of time could be well-fitted (in the least-squares sense) by either of two functions, as shown in the figure. The first function was the sum of a single exponential whose half-time was 81 ± 16 days, and a constant term (Eq. 1). For other individuals in the same series of injections, Durbin found that the longest-lived of five exponential components of the plutonium concentration in the blood had a half-time of 88 ± 13 days (Du72). Thus the hair reflects the time dependence of the amount of plutonium in the blood.

The second function which fitted the hair data was the sum of two exponentials, whose half-times were 32 ± 18 and 260 ± 80 days, respectively (Eq. 2). These values overlap the half-times of 42 and 300 days found by Durbin for components of the urinary excretion of plutonium by man (Du72). This agreement is expected in view of the agreement of the hair and blood data, since urine is a plasma filtrate.

The concentration ratio of plutonium in hair to plutonium in blood can be determined by comparing the intercepts of Eq. 1 and of Durbin's fifth blood component. This latter value is 0.44% of the injected dose, which leads to a value for the concentration in blood of 11.3 Bq/kg for this subject. Since the intercept of Eq. 1 is 18.2 Bq/kg, the concentration ratio is 1.6.

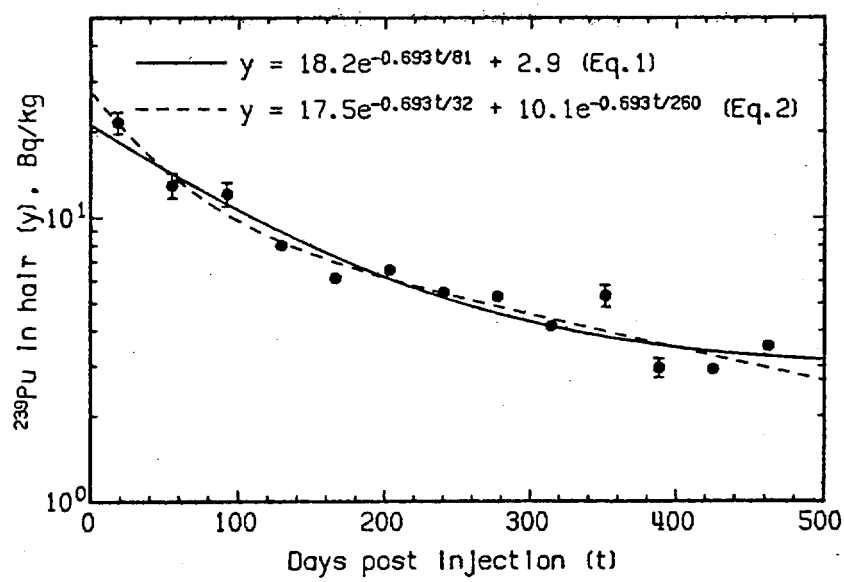
This analysis raises the intriguing possibility that human hair may serve as a bioassay material for the determination of plutonium in vivo. Some of the advantages of hair compared to urine would include ease of sample collection, preservation of time-dependent information in a single sample, relatively little organic material present to interfere with chemical analysis, and a much higher concentration of activity in the sample. In addition, analysis of hair could be used to confirm excreta analyses and also offers a method of determining the integrated plutonium exposure over a period of time. An obvious disadvantage is the delay between the time when plutonium is deposited in the hair and the time the sample

Prepared by R. E. Toohey Argonne National Laboratory

0019760

can be collected. The amount of hair which can be collected at any one time would also depend very strongly on the personal preferences of the subject. Although the sensitivity of the analytical technique is the same for hair and urine (i.e., about 3 mBq, or 0.1 pCi/sample) the amount of plutonium excreted in the urine is two orders of magnitude greater than that deposited in the hair on a daily basis.

It should be emphasized, however, that 40-010 was extremely ill at the time of injection, and her medical history indicated that neither her circulation nor kidney function were normal. Many more analyses of plutonium in the hair of subjects with known body burdens of plutonium will be required before the usefulness of hair as a bioassay material can be established.



The two functions fitted to the hair data, as described in the text. For each function, y is the concentration of plutonium in hair (Bq/kg) and t is the time post injection in days, calculated from an estimated growth rate of 0.54 mm/d.

Reference

Du72 Durbin, P. W., 1972, "Plutonium in Man: A New Look at the Old Data," in Radiobology of Plutonium, B. J. Stover and W. S. S. Jee, eds. J. W. Press, Salt Lake City, pp. 469-537.

0019761

October 1979

CENTER FOR HUMAN RADIOBIOLOGY

Fact Sheet on

Environmental Contamination from Uranium Mill Tailings

This project was undertaken on behalf of the Division of Environmental Impact Studies and funded by the Nuclear Regulatory Commission to evaluate the impact on the environment of uranium ore processing mills and particularly of mill tailings piles.

A survey is being made of possible contamination of the biosphere that could affect humans in the neighborhood of uranium ore processing mills in New Mexico. This contamination is due to uranium and its long-lived decay products, ^{230}Th, ^{226}Ra and ^{210}Pb, as shown in the uranium series decay table (overleaf). Major factors (food chain, water and air) in human uptake of these materials are being studied and compared to those in control areas distant from the mill. Contamination may result from dust from the ore and processed uranium, and from dust and water from the tailing piles, which contain the residual activities from the processed ore. Radium-226 decays to the gas ^{222}Rn, which may then emanate from the tailings. The short-lived daughters of radon may contribute a relatively large dose to the lungs of people in the vicinity of the source, and the levels of ^{210}Pb deposited in the body may then be a measure of this dose.

The major emphasis has been on determination of ^{226}Ra and ^{210}Pb levels using well-established analytical techniques in our laboratory. These nuclides were determined in various biota: rabbits, cattle, vegetables and grass were collected on or near two uranium mill sites. For controls, similar samples were obtained from areas distant from mining and milling operations. For the onsite rabbits the ^{226}Ra concentrations in various tissues were substantially greater than those in control animals. The levels of ^{210}Pb and ^{210}Po did not differ significantly for a given tissue between the two groups, except that the ^{210}Pb level in the kidney was greater in the onsite group.

For cattle the results are less complete, but the data indicate no great differences between the concentrations of ^{226}Ra and ^{210}Pb in the soft tissues of animals grazed near the tailings and controls. However, the levels of both nuclides are higher in the bone from animals near the piles. Vegetables from a residential area on a mill site contained substantially greater concentrations of ^{226}Ra and ^{210}Pb than those reported for standard New York City diets; no local control samples were available for comparison. Grass and cattle dung from land irrigated by water containing 60 pCi/ℓ ^{226}Ra from uranium mines had concentrations of ^{226}Ra and ^{210}Pb 50 and 8 times, respectively, those in control samples.

From these studies we can ultimately estimate the levels of contamination in the human food chain produced by a mill. The results on the concentrations of these nuclides in various components of the food chain, soil, fodder and cattle tissues will make possible improved estimates of transfer coefficients for these nuclides, parameters which are necessary for mathematical models describing the transfer of radionuclides and trace elements from the environment to man. These, in turn, allow estimates of the dose to man from environmental contamination from a mill, which could be significant. Thus, it is estimated that a doubling of the

0019762

Prepared by R. B. Holtzman Argonne National Laboratory

normal concentrations of uranium and daughter products in meat and vegetables could increase the dose equivalent rates to the bones of persons consuming these foods by 30 mrem/yr or more, a value which exceeds the limit of 25 mrem/yr set by the U.S. EPA.

Principal nuclides in the uranium series

Sub-series (1)	Element (2)	Mass number	Major mode of decay	Radioactive half-life
Uranium	Uranium	238	α	4.51×10^9 yr
	Thorium	234	β	24.1 days
	Protactinium	234	β	1.17 min
	Uranium	234	α	2.47×10^5 yr
Thorium-230	Thorium	230	α	8.0×10^4 yr
Radium-226	Radium	226	α	1.60×10^3 yr
Radon-222	Radon	222	α	3.82 days
	Polonium	218	α	3.05 min
	Lead	214	β	26.8 min
	Bismuth	214	β	19.7 min
	Polonium	214	α	1.64×10^{-4} sec
Lead-210	Lead	210	β	22 yr
	Bismuth	210	β	5.01 days
	Polonium	210	α	138 days
	Lead	206	none	stable

(1) Sub-series or radionuclides, based on half-lives or other properties.

(2) Each radionuclide is the parent of the following one.

0019763