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**RADIATION IN  
MEDICAL AND PUBLIC HEALTH RESEARCH**

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## RADIATION IN MEDICAL AND PUBLIC HEALTH RESEARCH\*

In accordance with the recommendation of the PAHO Scientific Group on Research in Radiation which met in May 1962, Dr. Frederick Stohlman, Jr., acting as PAHO Consultant, visited Peru, Venezuela, Brazil, and Chile to identify the areas of research capabilities in this field, with particular attention to problems unique to Latin America.

The Report of the Scientific Group, incorporating Dr. Stohlman's observations and outlines for research projects, was presented to the PAHO/ACMR Meeting in June 1962, and emphasized that "ionizing radiation could be looked upon both as an object of study with reference to its effects on living systems and as a tool for research" in many medical and public health fields.

## I

Studies of the Effects of Radiation on Living Systems

A.. Study of human populations residing in geographical areas of high background radiation in Brazil.

A proposal for a preliminary investigation of the potential public health significance to human populations living in geographical areas of high background radiation in Brazil was presented to the PAHO/ACMR at its First Meeting.

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\*Prepared for the Second Meeting of the PAHO Advisory Committee on Medical Research, 17-21 June 1963, by the Chief, Radiation and Isotopes Unit, PASB.

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Interest in this high background area by Brazilian scientists - who have been carrying out physical, clinical and geological studies over the past years - has continued.

Professor Merrill Eisenbud of the Institute of Industrial Medicine, New York University, made two consultant visits to the area to determine if there is a physical and measurable basis for what might be a hazard to the health of the population which resides there continually. He reported that high external radiation exposures had been measured by scientists in Brazil, but no measurements had been made of internal deposition. Chemical analyses of various radio-elements in the food chain, water, human tissues and excretions were suggested because the presence of radioactivity in abnormal amounts would be a good indicator of the body burden and of possible hazards to health. Also, to be analyzed for radioactive content would be public water supplies to cities and water from dug wells.

Samples collected in Brazil and analyzed in Professor Eisenbud's laboratory in New York show Radium-228 and Ra-226 to be present in food and water in appreciably increased amounts over samples taken from the City and State of New York. In Table 2 of Annex A results are reported concerning 52 food and water samples from high radioactive areas of Brazil and 6 samples from the USA. The milk samples ranged from the same as the USA to about 120 times as high with an average about 20 times higher. Foods were ten times above the normal value of 1 c/kg for Ra-226. Leafy vegetables and cabbage were very high, i.e. up to 1000 times. Cow bones from the radioactive areas are elevated by a factor of 10 to 20. Waters are higher by a factor of 30 over the average values reported in the USA, but not nearly as high as those from areas of Illinois, an area known for

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the high radium content of its well waters. Further study is needed.

Other measurements made in air (3 feet above the ground, at human gonadal height) indicate increased radiation exposure.

Data will be sought for:

1. Soil, plant, and small animals.
2. Field surveys
  - a. External radiation measurements to find new areas.
  - b. Food growing and distribution practices.
  - c. Demographic aspects: how long have individuals lived in these places; disease spectrum.
3. Radiogeology (soils, kinetics, distribution, and solubility).
4. Routine food and water sampling.
5. Urine and teeth analysis for radionuclides.
6. Catalogue of flora and fauna at Morro de Ferro.

A seventh area of study will be proposed in Brazil this August, where a tentative conference of Brazilian scientists, Professor Eisenbud as PAHO Consultant, a U.S. Atomic Energy Commission representative and PAHO staff will discuss (a) radioecology, and (b) human studies to be integrated into a projected two-year endeavor.

PAHO will continue to utilize the services of Professor Eisenbud as Consultant on a bi-yearly basis, as well as provide several fellowships for Brazilians for advanced study.

- B. Study of Radiosensitivity of Large Animals exposed to Ionizing Radiation at High Altitudes in the Peruvian Andes (hypoxia) and at Sea Level.

A project on the effects of whole body irradiation on large animals has been considered by the PAHO/ACMR at its first meeting. This is a study

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of the comparative sensitivity of llamas and burros to ionizing radiation at altitudes (hypoxia) and sea level. The studies will permit an evaluation of the effects of hypoxia in protecting the erythropoietic system and the recovery potential of stem cells in animals indigenous to altitude and in those native to sea level. The study location has the advantage of an existing high altitude laboratory. The project is being prepared for submission to one or more of the research granting agencies in the USA.

The study will be a collaborative one and will have as principal investigators Drs. Marek Rakower, Manuel Moro Somo, and Cesar Reynafarje at San Marcos University, Lima, Peru; Dr. Frederick Stohlman of St. Elizabeth's Hospital, Brighton, Massachusetts, and Dr. Eugene Cronkite of Brookhaven National Laboratory in the USA, with PAHO in a coordinating role.

## II

### Radiation as a Tool for Research in Medicine and Public Health

#### A. Iron absorption and loss.

The study of iron absorption and loss through various routes, being related to nutritional problems, was given a high priority by the PAHO/ACMR at its first meeting. The investigation of iron metabolism in normal and hookworm infested individuals at the Instituto Venezolano de Investigaciones Cientificas (IVIC), Caracas, Venezuela, is imaginative and is bound to yield important information. It will unfortunately require several more years for completion, and during most of this time a whole body radiation counter will be needed. Funds and training of personnel will be needed by IVIC. Personnel

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of Brookhaven National Laboratory could probably be made available to help in the initial instrumentation, while the head of the Electronic Department of IVIC would be trained in radiation measurement techniques.

For the study of iron absorption and loss, Drs. Marcel Roche and Miguel Layrisse of IVIC will be the principal investigators in Venezuela and Drs. Frederick Stohlman and Eugene P. Cronkite would be the medical scientist counterparts in the USA.

B. Irradiation Effects on the Biology of Rhodnius prolixus.

The use of ionizing radiation to modify the sexual physiology and the biotic potential of certain vectors, especially the reduviid bugs, was classified by the PAHO/ACMR as research of very high priority. The research is to be carried out by the principal investigator, Juan C. Gómez of IVIC, and Dr. William Baldwin of the Chalk River installation of the Atomic Energy Commission Limited of Canada. The frequency, duration, and reproductive effectiveness of successive copulations, and the number of eggs and their eclosion will be observed under varying environmental conditions, as well as feeding frequency, insect ages, and long term genetic effects. At IVIC the ecology of the reduviid bug will be studied in selected sites away from the laboratory using radionuclide tags as an aid to these observations. The biotic potential of sterilization by irradiation with cobalt-60 will be carried on after the basic physiology has been determined both there and at Chalk River. Dr. Baldwin will visit IVIC periodically to act as a consultant to the project. An application for research support has been submitted to a U.S. granting agency.

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- C. Lead poisoning as a means of studying the effects of hematopoietic stimulation (hypoxia) in persons with hematologic disorder (anemia).

A program directed at studying lead poisoning among workers in Peru has been proposed by Dr. Frederick Stohlman and Dr. Ramón Vallenás, Director of the Peruvian Institute of Occupational Health. Its fundamental objective will be to determine the effect of hematopoietic stimulation (hypoxia) in people with a hematologic disorder (lead poisoning anemia). A protocol for the lead study project is being prepared while a Peruvian scientist is being selected for a year's study in hematological and isotope techniques. Until this training period is finished and the project protocol written, no formal study will be started.

- D. Study of liver disease in Latin America using radionuclides, and an investigation of the effect of Schistosoma mansoni upon liver function, using similar means.

The study of hydatid cyst localization was reviewed by the PAHO/ACMR at its first meeting and a high priority was ascribed to it. To this end, Dr. George Taplin of the University of California Medical Center, Los Angeles, visited Chile and Brazil in January, 1963, to determine the interest and research potential for such a study.

The project initially confined to localizing hydatid cysts has now been proposed as a study of liver disease, which is found more frequently in Latin American hospitals than in hospitals in the USA. Patients in four main categories of liver disease (cirrhosis, metastatic liver disease, hydatid cyst, and amebic abscess as well as studies of the effect of schistosomiasis upon liver function) will be studied by radioisotope tracer techniques. The work will be divided into clinical investigation and

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refinement of photoscanning procedures in phantoms to be later applied to the clinical studies. A research grant application has been prepared for submission to a U.S. granting agency as a study coordinated by PAHO. The investigators are Drs. Ismael Mena, Santiago, Chile, Eloy Garcia, University of Pôrto Alegre, and Luiz Carlos Lobo, Institute of Biophysics, University of Brazil, Brazil, and Drs. George Taplin and Benedict Cassen of the University of California at Los Angeles.

E. Manganese poisoning, its metabolism, and the utilization of neutron activation analysis as a method of detecting tracer amounts.

Manganese as an essential nutrient has been studied by Dr. George Cotzias at Brookhaven National Laboratory, New York, utilizing a nuclear reactor for neutron activation analysis, a method suitable for the detection of tracer amounts. Manganese poisoning is an important world-wide industrial hazard that is no longer found in the USA. Chile, however, has many reported cases of this neurological disease. Clinical, physiological and biochemical investigations of the known cases are being conducted in a well-staffed university medical center in Chile. Dr. Cotzias, acting as PAHO advisor, visited Chile to determine the feasibility of research in this area. As the result of the capabilities for chemical analysis at Brookhaven National Laboratory and the patient availability in Chile, a study has been proposed which is specifically aimed at the elucidation of the mechanisms by which chronic industrial inhalation of manganese ores induces a schizophrenia-like syndrome followed by either Parkinsonism or "Wilson's disease-like" syndrome. It is proposed to bring to Santiago from the mining area for study acute cases of the disease, chronic cases with symptoms,



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chronically exposed individuals without symptoms and non-exposed persons free of this disease. Blood, urine, spinal fluid and hair or any other body reservoir will be forwarded to Brookhaven National Laboratory for analysis and study. Many useful phases of this study, not now known, will be expected to furnish guidelines for investigation as the five-year program progresses.

The principal investigators are Dr. Ismael Mena, Division of Nuclear Medicine, Catholic University of Chile, Santiago, Chile, and Dr. George C. Cotzias, Chief, Physiology Division, Brookhaven National Laboratory, Upton, New York, with the Chief of the Radiation and Isotope Unit, PAHO, as project coordinator. An application for a research grant has been submitted to a U.S. granting agency.

F. Normal and abnormal copper metabolism and the use of radio-nuclides in the study of the plasma copper protein (ceruloplasmin).

As a result of the visit of Dr. George Cotzias to Chile, it has been proposed that a study be made of workers exposed to copper in Chilean mines, especially copper toxicity cases. Normal and abnormal copper metabolism has been studied by Dr. I.H. Scheinberg and his staff at the Albert Einstein College of Medicine, New York, and they have demonstrated that abnormal copper metabolism in human beings is associated with Wilson's disease. As a result, Dr. Scheinberg has proposed a study of copper metabolism in those miners in Chile with chronic toxicity, and a comparison study of how humans exposed to high concentration of copper avoid copper poisoning.

In conjunction with Dr. José Barzelatto, of the University of Chile,

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Dr. Scheinberg would like to make a thorough physiological, chemical and physical study of ceruloplasmin, the plasma copper protein. This investigation is only in the very preliminary stages of becoming a research proposal.

#### Conclusion

The PAHO/ACMR recommendation that an effort be made to spread knowledge of useful radioisotope techniques is being carried out, or planned for, in all research projects under consideration by the Radiation and Isotopes Unit of PAHO.

A N N E X    A

NATURALLY OCCURRING RADIONUCLIDES IN FOODS AND WATERS  
FROM THE BRAZILIAN AREAS OF HIGH RADIOACTIVITY

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NATURALLY OCCURRING RADIONUCLIDES IN FOODS AND WATERS  
FROM THE BRAZILIAN AREAS OF HIGH RADIOACTIVITY

The levels of external radiation in the Brazilian areas of abnormally high radioactivity have been described thoroughly by Roser and his associates (1,2) who have shown that the levels of ambient gamma radiation in the inhabited areas range as high as 1 mr/hr, and are more than twice this value in uninhabited regions.

As it has been known for a long time that radioactive elements present in the soil, like other trace elements, are absorbed by plants and animals and eventually find their way to man, a pilot study was undertaken to determine the extent to which the naturally occurring radionuclides are present in typical foods and waters of these regions of high radioactivity. This report summarizes the findings of these pilot studies.

It was known at the outset that the area is rich in thorium-232, and the presence of the decay products of this nuclide in foods and waters was therefore anticipated. It was also considered likely that the radioactivity in biota would be due primarily to absorption of radium-228 (mesothorium)

and its daughters, rather than the thorium isotopes, which have been found to be relatively unavailable to plants (3). However, radiochemical studies of the minerals in these areas (4) had shown traces of uranium to be present, a finding that suggested Ra-226 might also be found in the biota of the area. Preliminary radiochemical analysis of the foods indicated that this nuclide was, in fact, present and it therefore became necessary to develop procedures for differentiating Ra-228 from Ra-226. These procedures will be outlined later in this report.

#### Potential Sources of Exposure to Radioactive Internal Emitters

Human assimilation of nuclides in the uranium and thorium chains can occur in a number of ways including:

- a. inhalation of radon and thoron and their daughter products
- b. adventitious ingestion of dust
- c. ingestion of food and water.

It is possible that diffusion of radon and thoron from the rocks and soils occurs at a greater rate than normal, but the atmospheric concentrations of these gaseous decay

products in these areas have not as yet been investigated.

The opportunities for adventitious ingestion of radioactive dusts exist in the villages, in the country, and in the recreational areas. Figure 1 shows a group of children who, a short while before the picture was taken, were playing soccer on a dusty unpaved street in which the radiation levels ranged from 0.1 to 0.25 mr/hr. One of the boys can be seen with sugar cane that he chews from time to time, but when the soccer game is in progress the piece of sugar cane is laid to rest on the dusty street!

Figure 2 shows one of the popular beaches at Guarapari that is exploited for its radioactive sands. The radioactive minerals are concentrated in the darker sands, above which the gamma radiation intensities are as high as 2 mr/hr. As in many parts of the world where exceptionally high radioactivity exist, the radioactive properties of this and other radioactive areas in Brazil are exploited for their allegedly curative values, and many thousands of Brazilians take their vacations at these areas where they come in contact with the monazite sands and drink mineral waters of high radioactive content (Figure 3). We see that there is relatively close contact with the radioactive soil of these regions, but the extent to which this results in assimilation of the naturally

occurring radioactive materials has not been studied.

The most important means by which the heavy radionuclides are absorbed by man in these areas is possibly through the ingestion of food and water. In Figure 4 are shown milk cattle grazing on grass growing in an areas where the ambient gamma radiation levels range from 0.05 to 0.25 mr/hr. Figure 5 shows coconuts growing in a backyard, in which the radiation level is 1.0 mr/hr, and in Figure 6 we see extensive farming in a region in which strip mining of radioactive minerals is under way. Figure 7 is a photograph of a shallow well from which both the stock animals and their owners derive drinking water.

The pilot study that will be described in this report was designed to determine the extent to which the heavy radionuclides are absorbed by the food and water in these regions of abnormally high radioactivity.

#### Some Properties of the Thorium and Uranium Series

The uranium and thorium series originate in the radioactive decay of U-238 and Th-232, and consist of fourteen and eleven radioactive nuclides respectively. The two chains include isotopes of ten elements, each of which

has its own metabolic properties. The twenty-five nuclides have half-lives that range from  $4.5 \times 10^9$  years for U-238 to microseconds for polonium-214. From the point of view of its movement in biological systems, an element can be regarded as nonexistent if the time from its formation to its decay is so short that it does not translocate from its place of formation. Thus, the biological action of the radio-nuclides are strongly influenced by not only their chemical properties, but also their half-lives.

Table 1 lists the nuclides of both the radium and thorium series, broken down into sub-chains having parents with half-lives of a few days or longer. This arrangement assists one to visualize the clusters of nuclides that are apt to be found together at various steps of the food chain. Thus, if the Ra-224 having a 3.6 day half-life, should separate from the Th-228 which has a 1.9 year half-life, then the Ra-224 would be expected to be in equilibrium with six radioactive daughters whose lives are so short that translocation of the nuclides of this sub-chain is unlikely. Little is known about the kinetic behavior of the ten elements of the uranium and thorium series, but as a first approximation one can assume that isotopes having half-lives of



less than a day do not live long enough to translocate, but that those with half-lives greater than a few days may translocate within the organism.

The relative insolubility of the long-life thorium and uranium isotopes in the upper portions of the two chains suggest that the first isotopes to be absorbed by plants in significant amounts would be Ra-226 in the case of the uranium series, and Ra-228 in the case of the thorium series. This assumption established the rationale for our analytical procedures which were directed primarily at measurements of Ra-226 and Ra-228, but Th-228 was also separated and determined.

#### Normal Values of Ra-226 and Ra-228 in Food and Water

Several previous investigators have analyzed foods and waters for Ra-226, but there have been very few published values for Ra-228 and Th-228. In 1955, Stehney and Lucas (5) estimated the mean daily intake of Ra-226 to be 1.6 pc in the United States. More recently, Hallden, Fisenne, and Harley (6) have analyzed the Ra-226 content of the foods of New York, Chicago, and San Francisco, and concluded that the average daily intake in the three cities was 2.3, 2.1 and 1.7 pc Ra-226 respectively.

The Ra-228 content of foods in the United Kingdom has been studied by Hill (7) and Turner et al. (8). The latter investigator made the important suggestion that the beta emitting nuclide, Ra-228 is absorbed by plants to a greater degree than its alpha emitting granddaughter, Th-228. In Table 2 are shown the Ra-228 and Th-228 content of a few New York foods.

The data of Hursh (9), and Stehney and Lucas (5) indicate that the normal range of the Ra-226 content of public water supplies is very variable, ranging from less than 0.000 pc/l to 0.17 pc/l. The mean concentration of Ra-226 in the forty-one water supplies samples by Hursh was 0.04 pc/l. Stehney and Lucas have found that water from deep sandstone wells in Illinois contain as much as 37 pc/l, which may actually exceed the maximum values currently recommended as permissible for continuous consumption.

#### Analytical Methods

Sample Collection and Preparation - The Brazilian localities from which samples were taken include Guarapari, Meaípe, Araxá, Taquiri, Tapira and Rio de Janeiro, which was used as a control. The radiogeological features of

these areas have been described by Roser et al. in his earlier presentation (1).

All of the samples were collected in the field, on the farm of origin. The water samples were collected in plastic jars in which they were stored until they were received in the laboratory at New York University where all analyses were performed. The food samples, immediately after collection, were placed in individual plastic bags in which they remained until they reached the laboratory in Rio de Janeiro within two to five days after collection. Here the samples were first reduced to char by infrared and were then ashed at 600°C prior to being shipped to New York for analysis. In some cases the ignition of the samples was not completed until after the samples were received in New York.

The water samples were acidified and evaporated to a small volume. From this point the analysis of water samples and aliquots of the food residues were analyzed by the same procedures.

Gamma Spectrometry - Prior to radiochemical analysis the ashed samples were examined by gamma-spectrometry,

using a four inch sodium iodide well crystal in a steel cave having six inch walls. Depending on the amount of sample, it was counted either in the one inch well or in a plastic petri dish mounted on top of the crystal.

Th-228 was measured quantitatively by this technique by measurement of the 2.62 Mev Tl-208 peak. The presence of Ra-228 and Ra-226 could be qualitatively established in some samples by the presence of well defined peaks at 0.92 Mev in the case of Ra-228 and 1.76 Mev in the case of Ra-226. Quantitative estimates of Ra-228 and Ra-226 are not made because of interferences from the K-40 1.4 Mev peak, and also because the outgassing factor for Rn-222 was unknown.

Standards were prepared by extracting a known amount of aged (42 year) Th-232  $\text{NO}_3$  and all its daughters into a solution of di(ethylhexyl) phosphoric acid in heptane. A portion of this solution was standardized by stripping Ra-224 from the solvent and alpha counting. The observed alpha count was within one percent agreement with the calculated concentration of Ra-226. A known portion of this solution was mixed with warm paraffin and permanent standards were prepared for each geometrical configuration.

These standards gave calibration factors of 0.039 c/m/pc in the vial and 0.019 c/m/pc in the petri dish.

Background over the thirty channels used for measuring the Tl-208 peak was 2.62 cpm. The minimum significant count for 95 percent confidence is 0.69 cpm, corresponding to a minimum significant activity of 17.6 pc in the vials and 36.5 pc in the petri dish.

Radiochemical Analysis - After being examined by gamma spectrometry, the ash samples were first decomposed by treatment with hydrobromic, hydrofluoric, or perchloric acids, depending on the properties of the residue being examined.

After sample dissolution, the following steps were followed in order to determine Ra-226, Ra-228 and Th-238.

1. Polonium, lead, and bismuth were extracted into a quaternary amine (Aliquat 336, General Mills Company) as bromo-complexes.

2. Thorium was then extracted into an acidic-organo-phosphorous compound, di (2-ethylhexyl) phosphoric acid (EHPA - Union Carbide Chemical Company). This thorium

bearing solvent was then aged for a known period to allow in-growth of Ra-224 and other Th-228 alpha emitting daughters. These daughters were stripped from the solvent with dilute acid, and alpha counted. From the observed alpha count and the period of alpha in-growth, the Th-228 content of the sample was determined through use of the Bateman equation.

3. After removal of thorium, the radium isotopes were collected on a lead sulfate precipitate. The lead sulfate was dissolved and lead removed by solvent extraction into Aliquat 336. After aging, this radium fraction was analyzed for Ra-228 by measurement of its Ac-228 daughter, and for Ra-226 by the emanation technique. A low background beta counter was used to detect the separated Ac-228, and Rn-222 and its daughters were collected in a ZnS coated bottle and counted by an alpha scintillation technique.

By saving the radium and thorium fraction, these analyses can be repeated as often as desired. Furthermore, the thorium present in each sample has been preserved so that Th-232 and Th-230 analyses can be performed, if and when it should seem desirable.

A detailed description of the method will be published elsewhere. It is derived from the procedures of Petrow, et al. (12,13,14,15) and from the radon procedure of Stehney et al. (16).

The sensitivity of these methods is, of course, a function of detector background and reagent blank. For the Th-228 procedure, background was five counts per hour and the reagent blank, three counts per hour. Since at equilibrium, a maximum of four alpha disintegrations are obtained for each Th-228 disintegration, as little as 0.1 pc of Th-238 is readily detectable. The nature of the procedure is such that the weight of sample ash should not exceed 10 grams. With the maximum sample size, the procedure is sensitive to about 3.3 pc/kg of wet bone and 0.1 pc/kg of fruit, vegetable, or dairy products.

For the Ac-228 determination, the detector background was 1.2 cpm and reagent blank 0.4 cpm. Thus, about 0.5 pc of Ra-228 is the minimum detectable amount. For a ten gram ash sample, this provides a sensitivity of 0.5 pc/kg of raw vegetables or 15 pc/kg of wet bone. This limitation in sensitivity for bone samples could be a serious handicap

when analyzing bones of normal Ra-228 content, where a burden of 10 to 20 pc of Ra-228/kg is considered normal. However, Ra-228 contents of the Brazilian samples were far in excess of the limiting amount.

Finally, the sensitivity of the Ra-226 procedure is approximately equal to that for Th-228, that is, about 0.1 pc.

As regards water samples, the largest samples received were two liters in volume, and the minimum detectable amount of Ra-228, Ra-226, and Th-228 were 0.2 pc/l, 0.05 pc/l and 0.05 pc/l respectively.

Calcium Analysis - Many of the ash samples were also analyzed for their calcium content by titration with standard EDTA solution in the presence of an indicator, Eriochrome Schwarz T.

#### Findings

Our data are given in Table 2. It is seen that the water samples are higher by a factor of about 30 than the average values reported by Hursh in this country, but the values are not nearly so high as those reported by Stehney



in the areas of Illinois known for the high radium content of its well waters.

The Ra-226 content of the foods is elevated by a factor of ten over the normal value of about 1 pc/kg, but the Ra-228 levels are even higher, being more than 20 times normal, on the average.

A surprising finding has been the high radium content of the leafy vegetables such as lettuce and cabbage. The lettuce from Tapira was found to have 965 pc/kg of wet weight, and Araxa cabbage was 71 pc/kg. The high value of the lettuce from Rio de Janiero can not be explained. It could be due to contamination in the laboratory, or to the possibility that the lettuce was grown in a high radiation area. It is interesting that the lettuce sample from New York was also somewhat higher than the other foods samples. The cow bones from the radioactive areas are elevated by a factor of approximately 10 to 20.

#### Discussion

In reviewing the above data one must bear in mind that this was a pilot study designed to approximate the extent to which the natural radioactivity of the foods and waters are elevated above the levels considered to be normal

elsewhere in the world. The data revealed considerable scatter and this plus our present lack of knowledge as to the food production of the areas, and the dietary practices of the local populations, would make it imprudent to attempt to assess the dosimetric implications of these observations so far as these local populations are concerned. The principal conclusion one can draw from the above data is that additional information is badly needed.

The excellent studies of Roser and Cullen, accomplished under very difficult conditions over thousands of kilometers of poor roads were aimed at mapping areas in which the external radiation levels were elevated, and in which large numbers of people lived. These regions must now be re-surveyed in order that the food growing practices in the area can be understood. More information is needed on the kinds and amounts of food that are grown and the manner in which it is distributed.

Estimating Ra-226 and Ra-228 in the Human Skeleton - It would of course be useful to develop a program of human measurement so that the body burdens from Ra-228 and Ra-226 can be estimated directly. Such estimates can be made by methods of total body counting by radiochemical analysis of bone or

teeth by measurement of radon and thoron in exhaled breath and, finally, by radiochemical analysis of urine.

The use of total body counting to estimate the body burdens of the inhabitants of these areas is contraindicated at the present time because evidence is lacking that the body burdens are elevated to a level sufficiently high to enable one to obtain useful data by methods of total body counting. A well designed instrument in expert hands can barely detect  $10^3$  pc of Ra-228 or Ra-226. The required instrumentation would include a six inch steel shield sufficiently large to accommodate the patient, a crystal at least eight inches in diameter by four inches thick, and the associated electronic equipment which would include a multi-channel analyzer and readout apparatus. A shield for total body counting could probably be improvised in the field by stacking bags of refined sugar which in its purified form is relatively free of potassium and radium. However, the logistic problems associated with measurement of this kind would at best be quite serious because of the large geographical areas involved and the poor condition of the roads. Total body counting should only be attempted if other methods of estimating the body burden indicate that positive data would be forthcoming. It would

be wasteful to undertake an expensive program of total body counting only to find that all of the measurements are below the detectable limit of the instrument.

A more practicle way to screen a population is by sampling bone or teeth. Bone samples will be difficult to obtain because of the primitive state of medical practice in these areas and local prejudices against autopsies. However, it is possible to obtain teeth, and Dr. Penna Franca, of the National University of Brazil, has recently collected such samples and we will await the results of anlaysis with interest. In this connection it is interesting to note in Table 3, that the estimates of Ra-226 and Ra-228 in the cattle teeth agreed with the values obtained for other bones of the skeleton within a factor of two.

A number of methods are available by which the radon and thoron concentrations of exhaled breath can be used to estimate the body burden of Ra-226 and Ra-228. Of the two radioisotopes, Ra-228 would be expected to be present in the bones of residents of these areas in higher amounts than Ra-226 and, for this reason, the methods developed by Evans (10) for estimating the thoron (Rn-224) content of the human

breath has been adapted for use in the field. A few measurements have been made on residents of Guarapari, but the results to date are equivocal and additional measurements are required. The recent development by Hursh (11) of a new and somewhat simplified method of measuring breath thoron may have application to this problem and such an instrument is currently being constructed for use in the field during the coming year.

Measurement of the urinary content of the two radium isotopes should provide a satisfactory method of screening the populations to determine if additional work would be warranted. The urinary content of the radium isotopes would reflect both the dietary intake of radium and the amount stored in the skeleton and other tissues of the body, but it is to be expected that the former would mask the latter and that the primary purpose of urine analysis would be to estimate the daily intake of the two isotopes. Pooled samples of the urine of residents of the various areas and from controlled areas should be analyzed to determine if any difference does exist.

Atmospheric Radioactivity - In view of the fact that the soils contain abnormally high amounts of the two radium

isotopes it is to be expected that their gaseous daughter products radon and thoron may diffuse from the earth at a more rapid rate than normal in these areas. Under normal conditions of atmospheric turbulence the additional contribution of radon and thoron to the atmosphere of these localities would be flushed out of the region in a matter of minutes and any significant buildup of these gases would probably be prevented. However, during periods of inversion when the normal mixing processes of the atmosphere are greatly restricted, the radon and thoron concentrations could conceivably rise sufficiently to represent another significant source of exposure to the local inhabitants. Whether or not this is the case can only be answered by future measurements.

Opportunities for Radioecological Studies - The above discussion has been concerned primarily with uptake of the radionuclides by human foods. In addition, a number of localities seem to offer attractive opportunities for radioecological studies. In particular, the Morro de Ferro near Pocos de Caldas, a hill with an area of 0.35 km<sup>2</sup> offers the opportunity to investigate a number of interesting questions

at a site that is essentially undisturbed by man. The external radiation levels at the top of the hill are more than 1 mr/hr, or about 10 r/yr. The soil of the hill is low in calcium, and preliminary measurements of the grasses indicate the Ra-228 and Ra-226 levels to be 10 to 100 times the levels observed in the foods. The skeletal dose to small mammals, the radon and thoron exposure of underground organisms, the partitioning of radionuclides from tissue to tissue, and finally the radiation effects on the flora and fauna are numerous, fascinating and useful among the questions that can be investigated at this and other sites.

Table 1

## Nuclides of the Uranium and Thorium Series

<u>Uranium</u>			<u>Thorium</u>		
U-238	$4.5 \times 10^9 \text{y}$	$\alpha$	Th-232	$1.3 \times 10^9 \text{y}$	$\alpha$
Th-234	24d	$\beta$	Ra-228	6.7y	$\beta$
Pa-234	1.2m	$\beta$	Ac-228	6.1h	$\beta\gamma$
U-234	$2.5 \times 10^5 \text{y}$	$\alpha$	Th-228	1.9y	$\alpha$
Th-230	$8.0 \times 10^4 \text{y}$	$\alpha$	Ra-224	3.6d	$\alpha$
Ra-226	$1.6 \times 10^3 \text{y}$	$\alpha$	Rn-220	52s	$\alpha$
Rn-222	3.8d	$\alpha$	Po-216	0.16s	$\alpha$
Po-218	3m	$\alpha$	Pb-212	10.6h	$\beta\gamma$
Pb-214	26m	$\beta$	Bi-212	60m	$\alpha\beta$
Bi-214	20m	$\beta$	Po-212	0.3s	$\alpha$
Po-214	160 $\mu$ sec	$\alpha$	Tl-208	3.1m	$\beta\gamma$
Pb-210	20y	$\beta$	Pb-208	S T A B L E	
Bi-210	5d	$\beta$			
Po-210	138d	$\alpha$			
Pb-206	S T A B L E				



Table 2

Ra-228, Th-228 and Ra-226 Content of Food and Water  
pc/k or pc/l.

<u>Type of Sample</u>	<u>Sample No.</u>	<u>Place</u>	<u>Ra-228</u>	<u>Th-228</u>	<u>Ra-226</u>	<u>Gamma Radiation (mr/hr)*</u>
Milk	Ta-7	Tapira	6.5	1.5		-
"	T-2	Taquiri	4.6	0.33		-
"	M-12	Meaipe	11.2	0.4		-
"	G-14	Guarapari	7	1.2	1.0	-
Cheese	T-3	Taquiri	37.9	3.1	34.2	-
Milk	C-4+	USA	0.32			-
<b>Fruit:</b>						
Bananas	A-7	Araxa	7.4	8.8		0.04
"	G-2	Guarapari	10.5	2.7	9.2	0.18
"	G-15	"	4.0	3.6	1.5	0.15
"	G-17	"	2.5			0.05
"	Puc-3	Rio de J.	< 0.5			-
Papaya	M-4	Meaipe	2.7			0.25
"	M-5	"	4.0			0.15
"	G-16	Guarapari	5.5		NIL	0.08
<b>Coconut:</b>						
Milk	M-3a	Meaipe	< 0.2#			-
Meat	M-3b	"	13			-
Husk	M-3c	"	19	9.3		-
<b>Coconut:</b>						
Milk	M-6a	Meaipe	< 0.2#			-
Meat	M-6b	"				-
Husk	M-6c	"	3.1			-
<b>Vegetables:</b>						
Tomatoes	A-3	Araxa	6.1	1.4		0.04
Cabbage	A-5	"	71	28.8	18.3	0.04
Corn Cobs	Ta-1b	Tapira	69	46		0.18
Lettuce	Ta-2	"	965	190		0.18
Potatoes	T-4	Taquiri	17	5.5		0.01
"	T-6	"	15	1.8	8.3	0.05
Corn	M-2a	Meaipe	10	1.3	5.1	0.01
Corn Cobs	M-2b	"	61	14	8.9	0.01
Cabbage	M-7	"	57			0.18
Bertalha	G-3	Guarapari	38	41	10.1	0.09
Abobora	G-4	"	4.6	4.1		0.20
Tomatoes	G-5	"	5.4			0.20
Couve	G-6	"	12	1.9		0.05
Potatoes	C-6+	N.Y. State	< 1			-
Lettuce	C-7+	" "	6.5			-
"	Puc-2	Rio de J.	76			-
Corn	C-2+	N.Y. State	2			-
Spinach	C-3+	N.Y. State	2.5		5.2	-

Table 2 (Cont'd)

<u>Type of Sample</u>	<u>Sample No.</u>	<u>Place</u>	<u>Ra-228</u>	<u>Th-228</u>	<u>Ra-226</u>	<u>Gamma Radiation (mr/hr)*</u>
Water:						
Spring Water	A-1	Araxa				-
Sulfur Well	A-2	"	1.5			-
Spring Water	A-8	"	3.2		1.65	-
" "	Ta-4	Tapira	<0.2			0.18
Tap Water	Ta-12	"	1.5		0.78	-
Well Water	Ta-13	"	3.1			-
" "	T-1	Taquiri	<0.2			0.02
Spring Water	T-8	"	<0.2			0.01
Tap Water	M-8	Meaipe	1.6		0.78	-
Well Water	M-9	"	<0.2			1.0
" "	M-14	"	1.4			-
" "	G-7	Guarapari	1.4			0.04
Tap Water	C-5+	N.Y. State	<0.2			
Steer Bones:						
Leg Bone	T-9	Taquiri	2250	3300	1290	-
Jaw Bone	T-10a	"	2550	1320	1450	-
Teeth (low.)	T-10b	"	1470	2640	835	-
Low. Jaw Bone	T-11	"	2370	1700	932	-
Leg Bone	G-8	Guarapari	1566	1030	262	-
Teeth	G-13	"	1467	1160	368	-
Leg Bone	C-1+	N.Y. State	140		152	-

#Insufficient weight of ash.

\*Measured 3 feet from ground, using a scintillation counter.

+Controlled group.

Table 3

Comparison of Th-228 by  
Radiochemical Analysis and by  
Gamma Spectral Analysis  
pc/kgm

Sample	Type	Radio Chemistry	$\gamma$ Spect.	Ratio $\gamma$ Spect. Radio Chem.
A-3	Tomatoes	1.4	NIL	-
A-5	Cabbage	28.8	39.6	1.38
A-7	Banana	8.8	NIL	-
Ta-1a	Corn	-	NIL	-
Ta-1b	Cobs	46.0	68.7	1.49
Ta-2	Lettuce	190	163	0.86
Ta-7	Milk	1.5	NIL	-
T-2	Milk	0.33	NIL	-
T-3	Cheese	3.1	NIL	-
T-4	Potatoes	5.5	NIL	-
T-6	Potatoes	1.8	NIL	-
T-9	Bones	3300	1830	0.55
T-10a	Jaw Bone	1320	1820	1.38
T-10b	Teeth	2640	1570*(P) 2400*(V)	0.59 0.91
T-11	Bone	1700	1570	0.92
M-1	Cow Dung	-	1350	-
M-2a	Corn	1.3	NIL	-
M-2b	Cobs	13.5	NIL	-
M-3c	Coconut Husk	9.3	10	1.08
M-12	Milk	0.4	NIL	-
G-2	Banana	2.7	NIL	-
G-3	Bertalha	41	84	2.05
G-4	Abobora	4.1	NIL	-
G-5	Tomatoes	-	NIL	-
G-6	Couve	1.9	NIL	-
G-8	Bone	1030	851	0.83
G-13	Teeth	1160	676	0.58
G-14	Milk	1.2	NIL	-
G-15	Banana	3.6	29.1+	8.08
G-16	Papaya	-	NIL	-
G-17	Banana	-	NIL	-

\* Teeth measured both in vial and in petri dish. No teeth sample was homogeneous as it was difficult to grind them.

+  $\gamma$  results gave count just above MDA. Small amount of sample may account for large difference.

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