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Merril Eisenbud, Director
Health and Safety Laboratory

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Roy E. Albert, M. D., Medical Officer
Health and Safety Laboratory

MINUTES OF STRONTIUM METABOLISM MEETING AT THE WASHINGTON DIVISION OF BIOLOGY AND MEDICINE, WEDNESDAY-JANUARY 13, 1954.

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Approximately 25 people attended this conference and the chairmanship was divided between Drs. Bugher and Claus. The purpose of the meeting was to discuss the current concept of tolerable strontium burden and also the status of information on strontium metabolism in relationship to the tolerable burden in persons exposed to fallout material.

Dr. Brues opened the discussion and distributed a set of notes covering the pertinent details on strontium and radium toxicity in humans and animals. He mentioned the study currently in progress at Argonne on the long-term follow-up of individuals who received radium for therapeutic purposes. On the basis of this study and others on radium dial painters, the permissible burden of 0.1 uc still seems like a good number. He quoted Evans as saying that those cases with less than 1 microgram of radium body burden and with bone changes probably were exposed to mesothorium originally. The mesothorium is more toxic than radium because thoron is not released from the body. The long-term radium retention is about 1% of the initial dose. One year after exposure, the retention was about 4% so that the integrated dose is about 2 times the long-term body burden. Dr. Brues is also carrying out a study on the radium burden of inmates in the Joliet Prison who have been drinking water containing 5 uuc/liter. The body burdens of these individuals is at least 10^{-3} microcuries. There are a number of cities in Illinois whose water contains the above concentration of radium and studies are now under way to estimate the incidence of bone sarcoma in this population. The Aurora Hospital has about 1 bone sarcoma per year for a population of about 30,000. This does not seem to be excessively high.

Mouse studies were discussed indicating that the comparative carcinogenicity of strontium to radium is from 1:8 to 1:15. These studies were done on a type of mouse which has a high susceptibility to benign tumors. It is not known whether the high incidence of malignant tumors represented only a conversion of benign tumors to a malignant form. There is evidence that the latent period in the development of cancer is a function of life span in animals. The bone changes seen in humans following ingestion of radium seem to progress very rapidly after they once become apparent, also suggesting a latent period.

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Dr. Bowers presented some retention data for radium in dogs. He noted that 60% was retained in 24 hours in adults and 86% in a 5-months old animal. Twenty per cent of the dose was in the skull and vertebrae.

Dr. Morgan reported lower values for inert strontium in bone than have been previously reported, i.e. 7 ppm in vertebrae instead of 60. These analyses were made with a neutron activation technique whereas the old ones were based on spectrographic analyses. Comparisons of the two techniques have not yet been done adequately.

Comar noted that strontium excretion in milk is about 0.1 of calcium. The strontium calcium deposition ratio in the fetus is 0.2 and in the adult 0.3. Strontium excretion in cows is about 0.4% per day after it becomes constant. The problem of mobilizing toxic materials from the bone is complicated by the fact that recrystallization is so rapid that the material tends to be fixed deeply within the bone in a short time. After sectioning bone in which Ca^{45} was fixed in-vivo, only 50% of the Ca^{45} could be liberated by in-vitro exchange. The excretion of strontium in sheep and cattle is quite similar to the few excretion data available on humans but the comparison is inadequate because of the paucity of human experiences. Dr. MacDonald suggested that stable strontium may be present in an irregular distribution as indicated by the radio-autographs of animal bones pretreated with radioactive strontium. Dr. Comar thought that the presence of stable strontium in the body was not an important consideration since strontium probably exchanges with calcium. The spottiness of strontium deposition may be a function of the irregular ingestion.

The "hot spots" obtained after injection of radioactive calcium are 6 to 15 times the average level of radioactivity in the bone. This is also true for C^{14}. This consideration may be important from the point of view of tumor production although Dr. Brues recalled the experiments indicating that diffuse radiation is more efficient in tumor production than equivalent amounts of radiation delivered in pinpoint fashion, at least on skin.

Dr. Hoecker reported some of his experiments which indicated that the removal of calcium from an immobilized limb was accompanied by a reduction in the radium content suggesting that the radium is deposited in association with calcium. He also noted that "hot spots" occurred in human cases of sarcoma from radium.

In a discussion of the pathological changes produced by strontium, Dr. Comar reported that hematopoietic changes were observed at 10 times tolerance and bone trabecular "severance" was seen at 100 times MAC. There was no evidence of permanent damage. Dr. Hamilton mentioned that Dr. Friedell administered 10 millicuries of Sr^{89} to a patient which was about a lethal dose. This evoked a searching of minds for cases of accidental exposure in humans and a number of such instances were recalled. Dr. Hamilton also mentioned a monograph on strontium

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excretion by Pecher printed by the University of California Press in 1945 which contains a great deal of useful information on human strontium metabolism. He will attempt to get reprints of this monograph for distribution since it is largely unavailable. The type of experimental animal came under discussion and it was brought out that mice and rats, unlike man, dogs and rabbits do not have haversion systems. As the size of the bone increases, the distance between trabeculi also increases, possibly changing the radiation geometry. Probably the animals most closely related in bone structure to humans are the chimpanzee and the burro. Dr. Hamilton suggested the use of a number of types of animals with varying life spans in order to confirm the relationship between tumor dose and latent period.

In passing, it was mentioned that materials other than strontium would constitute a hazard in the event of the destruction of a reactor including Barium^{140} and Neptunium^{239}, and the problem under these circumstances would be the hazard of a single dose rather than the chronic exposure to fallout material.

Dr. Larson mentioned some of the activities found in kangaroo rats living within the area of heavy fallout near the test site. He found 327 d/m/gm of bone ash of total strontium. Of this, 45 d/m/gm was accounted for by Sr^{90}. The lungs contained 1400, liver 82, gut 108,000 d/m/gm of ash. The fallout strontium close to the test site is very insoluble (about 0.5%) whereas further away, i.e. Brookhaven, it is about 50% soluble. Uptake in radishes in the test site area was about 1:2 on a gram-for-gram basis (i.e. radishes to soil). After 3 crops, there is no further uptake. A higher uptake of strontium in plants is observed in plants on the eastern coast. There was a question as to whether this was related to the available calcium since it is possible that larger quantities of calcium might increase the strontium intake in a similar fashion to lead.

In discussing the possible studies on humans, Dr. Hamilton mentioned that Sr^{85} would be useful as a pure gamma emitter in studies dealing with the uptake of strontium measured by external counting. It is cyclotron produced from rubidium.

Dr. Claus then directed the discussion toward the strontium burdens which would produce the various pathological responses. It was agreed that these relationships which are expressed on the basis of a 70 kilogram man are crude but at least they serve the purpose of establishing some limits to the relationships.

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Relationship Between Long-Term Adult
Burden of Strontium in 70 Kilogram Man

Effect	Body Burden (uc)
Barely discernable	5
Serious hazard (hemopoietic)	35
Bone Sarcoma	50
LD_{50}	2-3 mc

Distribution:
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