House of Representatives Judiciary Committee
Sub-Committee on Administrative Law and Governmental Relations

Summary of Testimony of John Rundo, Ph.D., D.Sc.

I retired in 1991 from Argonne National Laboratory (ANL) as a Senior Biophysicist after 22 years employment. I had previously worked for 20 years at the Atomic Energy Research Establishment at Harwell in England. By far the largest part of my professional life has been devoted to research involving radioactivity in man.

In 1973 scientists under my direct supervision determined the plutonium excretion rates of three persons who had been injected with plutonium in the 1940s. The results are tabulated in my full testimony. Both the urinary and fecal excretion rates for two persons were much higher than predicted by the equations used to relate body contents to the excretion rates. Those prediction equations had been derived from the urinary and fecal excretion rates of all the persons injected, including these two, using the data obtained in the first 4½ months after injection. Excretion of plutonium by the third person was too low to be used.

The macroscopic and microscopic distributions of injected plutonium in the skeleton of an exhumed body were determined.

Regarding the question of harm, the evidence is that all the persons injected with plutonium died of causes unrelated to their injected radioactivity. There were no bone or liver cancers, the expected biological effects of injected plutonium.

The purpose of the injections (not done at ANL) was to enable health physicists to determine the body contents of plutonium in workers from their urinary excretion rates. This information was urgently needed in the 1940s when many persons were exposed occupationally to plutonium and the results from animal studies were strongly species-dependent. Thus, these persons derived benefit from the injections. A benefit of the follow-up studies in 1973 is that it is now possible to use the urinary excretion to determine with some confidence the body content of plutonium in an individual as long as 30 years after intake to the blood. This could be important from a legal standpoint. To summarize, the result of the follow-up studies has been to add significantly to human knowledge about the biological behavior of an element which may well play an important role in world-wide energy production in the future.

In my full testimony, I list a number of published studies in which radioactive materials were administered to humans by researchers at various institutions. In many of these studies the researchers themselves were the subjects; they are identified with an asterisk. The radionuclides and numbers of subjects were: palladium-103 (1 man*); niobium-93 (1 man*); radium-226 (41 hospital patients); radium-226 (2 men*); radon-222 (1 man*, 1 woman*); sodium-24 (1 man*, 2 persons); radium-226 and strontium-85 (1 man*); potassium-42 (more than 28 persons); and radium-224 and thorium-234 by ingestion (3 men, 3 women) and by injection (4 men, 2 women). In almost every case the absorbed radiation doses were so small that no radiation effects would be expected. The injections of radium-226 in 41 hospital patients were a notable exception to this. My testimony concludes with a list of references to the published literature describing the experiments.

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PERSONAL BACKGROUND AND EXPERTISE

My name is John Rundo; I am married and have three grown children. I was born and educated in England, and I graduated in 1949 with the degree of B.Sc. in chemistry from the University of London. That year, I joined the Health Physics Division of the Atomic Energy Research Establishment, Harwell in England where I remained until 1969, except for a three-year period (1952-1955) when I was on leave of absence at the Finsen Institute in Copenhagen, Denmark. The University of London awarded me the degree of Ph.D. in radiation biophysics for a thesis on my work in Copenhagen on measurements and dosimetry of thorium [a radioactive element] in man.

In 1969 I joined the Radiological Physics Division of Argonne National Laboratory (ANL) as a Biophysicist, to participate in the work of the newly formed Center for Human Radiobiology (CHR), the initial purpose of which was to consolidate and continue studies of the late effects of radium in man ("dial painters", who were exposed occupationally, and others who were administered radium on medical grounds) in a long-term project funded by the U.S. Atomic Energy Commission and its successors. My original role was to lead a group responsible for making measurements of the radium contents of the persons under study. Later my responsibilities were broadened to cover all measurements of radioactivity. By 1973 I had more than 70 publications in the open literature, dealing with the measurement and metabolism of radioactive isotopes in man. In 1974, I was promoted to Senior Biophysicist, a title I held until my retirement in 1991; by that time I had roughly doubled the number of publications. In 1980, I was awarded the degree of D.Sc. (a "higher" doctorate, not an honorary degree) by the University of London, based on my published work in the field of Low-level Radioactivity in Man. I must emphasize that I am not a physician. On a part-time basis, I continue with some professional activities (e.g., consulting) in my retirement.

I should say that preparation of this testimony has been hampered by the unavailability of all the records of the CHR (including the involvement in the plutonium injection cases) consequent upon the closing of the radium project.

Before discussing the involvement of Argonne National Laboratory with the persons injected with plutonium, I would like to make two points. Firstly, to the best of my knowledge, no persons were ever injected with plutonium at Argonne National Laboratory, and secondly, I have never conducted, nor would I ever conduct, experiments on humans without first obtaining their informed consent.

INVOLVEMENT WITH PLUTONIUM INJECTION CASES

Because of the expertise existing in my CHR group in the area of radiochemical analysis of biological samples for very low levels of radioactivity, and appropriate expertise in other groups of the CHR, we were the laboratory of choice to study some of the persons who had been injected with plutonium in the 1940s. In 1973, we were advised by Dr. Patricia Durbin of Lawrence Berkeley Laboratory that some of the people were still living and we were able to locate two of the three in the Rochester area through the courtesy of Dr. Christine Waterhouse of Strong Memorial Hospital, Rochester, in whose care they were. They agreed to our request that they be hospitalized on a metabolic ward for collection of all excreta for analysis by us. I do not know what background information they were given.

A third subject was located by us in a different part of the country and he also agreed to participate. On the way to Rochester, this man visited Argonne National Laboratory. Records indicate that unsuccessful attempts were made to detect plutonium in the body by external measurement while he was at Argonne.

The three subjects were hospitalized on the metabolic ward for various periods (at least eight days); all urine and feces and some blood samples were collected and sent to Argonne for radiochemical analysis. [During the hospital stay of one subject, I and a colleague took special equipment to Rochester and made an attempt to detect plutonium and americium (a product of the radioactive decay of one isotope of plutonium) in the body by external measurements. We were unsuccessful in this endeavor.]

RESULTS AND COMMENTS

Table 1. Measured excretion rates of plutonium.

Subject	Days since injection	Urinary excretion		Fecal excretion	
		days sampled	pCi/day*	days sampled	pCi/day*
Mr. E.A.	9,474	3	0.06	-	No analyses
Mrs.E.C.	9,934	14	7.60	6	3.17
Mr. J.M.	10,008	8	4.68	8	1.77

*1 pCi (picocurie) corresponds to a disintegration rate of 2.22 atoms per minute. It is the same as a trillionth of a curie, which itself is the radioactivity of one gram of radium.

The results of the analyses of the excreta are summarized in Table 1. The urinary excretion rate for Mr. E.A. was so low that it was necessary to process the whole of a day's collection and count the extracted activity for about a week.

This is why only three urine samples and no fecal samples were analyzed. The amount injected into this man's left calf muscle was less than one third of the amounts injected intravenously into the two other persons, and much of it remained at the site of injection after the leg was amputated. Almost half of the amount injected was found in tissue around the site of injection; there may very well have been more in the surrounding muscle. These findings introduced a large element of uncertainty into our knowledge of the actual amount in Mr. E.A.

For the other two subjects the activity was relatively easy to measure. The urinary excretion rates for these two persons were six to twelve times higher than predicted by the equation then used to calculate body contents from urinary excretion rates, while the fecal excretion rates were 19 to 38 times higher than the similarly predicted rates. Note that those prediction equations were derived from the urinary and fecal excretion rates of all the persons injected, including these two, using the data obtained in the first 4½ months after injection. They were certainly valid for that early time period, but should not be used at very long times after acquisition.

The blood samples from these two persons were also analyzed for plutonium, with the following results:

Mrs.E.C.	97 pCi/liter plasma
Mr. J.M.	39 pCi/liter plasma

These data can be used with the excretion results to calculate a quantity called the excretory plasma clearance; this number reflects the rate at which plutonium is removed from the blood to the excreta. We obtained 0.11 liter/day and 0.17 liter/day for the two persons, respectively; these results were similar to those found shortly after injection.

To the best of my knowledge, all the results for these two persons were given to Dr. Christine Waterhouse in Rochester; I remember having at least one telephone conversation with her, but I cannot recall the matter we discussed. The records show that the results for Mr. E.A. were given to his physician (name unknown to me). I do not know what these physicians told their patients.

The excretion results have been published in conference proceedings[1]; the results of the blood analyses were presented at a scientific meeting and only the abstract has appeared in print[2].

OTHER STUDIES AT ANL OF THE PLUTONIUM INJECTION CASES

Some other studies of the plutonium injection cases were made in the Center for Human Radiobiology. With the permission of their next-of-kin, the remains of four of the persons who had been injected with plutonium were exhumed for analysis of the skeleton to determine the

retention, and also for examination by autoradiography to determine the microscopic distribution of the plutonium in the skeleton. The skeletons of two of the four had suffered so much natural decomposition after burial that they could not provide much information. A third person had been cremated. The fourth person, a young woman with Cushing's syndrome, had died at age 20 some 17 months after injection in November 1945 with 0.3 microcurie* plutonium-239. The results of the analyses were presented at scientific meetings and have been published in the proceedings[3,4]. The hair of this woman was also found to contain plutonium and the variations in the concentration along the hair were shown to match the contemporary levels in the blood[5].

RISKS AND BENEFITS

Because of the toxicity of plutonium, an important question is whether any of the 18 persons who were injected with the element suffered any harm as a result. The known effects of internal alpha-particle emitting radioactivity in man are cancers of the bone (from radium) or liver (from thorium administered in the form of Thorotrast) and possibly leukemias or anemias (from very high doses of radium). Causes of death of 14 of the 18 plutonium-injected persons (the other four were still alive) were reported at a meeting held in October 1975 and the paper was published in the proceedings.[6] I can do no better than to quote from the abstract of the paper: "The liver doses do not appear to be high enough to be carcinogenic, but comparison of the bone-surface doses with radium doses that have induced bone tumors indicate that six of these cases have received doses high enough to be considered carcinogenic. However, no bone tumors have yet appeared." Those members of the group who were still alive in 1975 have now died. I am not aware that any had a bone cancer. Thus, three persons (I exclude Mr. E.A. because the amount injected was much less and was at least roughly halved by the amputation) survived about 30 years or more after injection with about 0.3 microcurie (about 5 microgram) plutonium-239, a substance often referred to as "the most dangerous substance known to man." The absence of a biological effect shows that the protection standard had been set conservatively.

There are two important questions concerning possible benefits of the injections or of the follow-up studies. It has to be understood that the purpose of the injections was to determine the relationship between the body content of plutonium and its excretion rate, especially the urinary excretion rate. This relationship must be known to permit calculation of the body content. Those members of the general public who worked with plutonium, whether in the laboratory or in bomb-manufacturing plants, derived great benefit from the results of the injections, in that their body contents of plutonium could be estimated with reasonable confidence by their health physicists. "Action levels" were set for the urinary excretion rate (at which point further exposure was stopped), based on the known excretion patterns, and programs of regular urine sampling and analysis resulted in early indications of significant body contents.

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*A microcurie is a millionth of a curie, which is the radioactivity of 1 gram of radium. 16 grams of plutonium-239 have a radioactivity equal to 1 curie.

As far as the follow-up studies are concerned, I note the following benefits. One result of our findings was that the radiochemists at Los Alamos National Laboratory reviewed their results from 1950, and detected some errors associated with a change in the analytical method. When the urinary excretion results for 1950 were corrected, they gave values which were higher than our results, as would be expected. The originally published (erroneous) results for 1950 were actually lower than our results for 1973.[7] A less obvious benefit is that it is now possible to use the urinary excretion to determine with some confidence the body content of plutonium in an individual as long as 30 years after intake to the blood. Another benefit is that these follow-up studies and the scientific enquiry they engendered, have resulted in a much better understanding of the detailed behavior of plutonium in the human skeleton[3,4], and have provided evidence that no correlation exists between cause of death and injected plutonium.[6] To summarize, the result of the follow-up studies has been to add significantly to human knowledge about the biological behavior of an element which may well play an important role in world-wide energy production in the future.

OTHER TESTS INVOLVING HUMAN EXPOSURE TO RADIOACTIVITY

I know of several experiments that have been carried out at various times in the past in which radioactive materials were administered to people. However, with two exceptions, my knowledge is limited to what has been presented at scientific meetings or published in the open literature, so I am not able to give details. I should emphasize that, with one notable exception, I specifically exclude those cases where administration of radioactivity was for medical purposes. The three exceptions that I mentioned are as follows.

In 1969, at the time I immigrated to the United States I had in my lungs a small amount of protactinium-233 that I had inhaled while at Harwell in England. The experiment was designed by me and approved by the local Human Uses Committee. The purpose was to provide calibration possibilities for the assay of plutonium in the lung by external counting. At that time the only Laboratory that I knew of in this country with any capability for that kind of measurement was Los Alamos Scientific (now National) Laboratory and I travelled there for them to take advantage of the situation. I am not aware of any publication of the results. In the 1970s on separate occasions, I and a colleague inhaled small amounts of palladium-103 and niobium-93, respectively, at Harwell for the same purpose. These experiments were certainly conducted with informed consent.

The single exception in connection with medical purposes, mentioned above, was in 1931 when 41 patients at the Elgin State Hospital in Illinois were injected with very large amounts of radium (between 70 micrograms and 450 micrograms) as a putative treatment for schizophrenia. This group of patients yielded important data on the long-term retention of radium in man[9,10], comparable to the importance of the data obtained from the plutonium injection studies.

By the mid- to late 1950s, measuring equipment had become so sensitive that the presence in a person of more than a few microcuries of a gamma-ray emitter overwhelmed the recording equipment; this limited the amount that could be administered in most cases. By "a few

microcuries", I mean in the range of 1-10. I should also say that in a number of the experimental studies outlined below, the subjects receiving radioactivity were the experimenters themselves.

I now list in chronological order the studies that I know of through publications in the literature where a radioactive substance was administered to one or more volunteers for research purposes. The earliest report is from 1915 when a paper appeared describing the fate of radium administered both by intravenous injection of 100 micrograms on two separate occasions in one of the authors, and by mouth of 50 micrograms also twice in another author[11]. Since two of the authors of the paper were the subjects we can safely assume that there was informed consent. (I might note in passing that about 50 years later these two men retained 0.7 percent and 0.15 percent of the amounts administered, respectively, the difference arising because only a fraction of ingested radium is absorbed into the blood.)

Turning to more recent times, I note that a study was published in 1951, in which two persons inhaled radon at the Health and Safety Division (Laboratory?) of the Atomic Energy Commission's New York Operations Office[12]. The purpose was to determine the retention of inhaled radon, and the delay needed between work with radium and breath sampling for estimation of radium content. On several occasions, the subjects inhaled radon at a concentration of "about 5×10^{-10} curies per liter" (i.e., about 500 pCi per liter) for periods "from 20 minutes to 8½ hours." Thus, there was more than one exposure of two individuals. The question of informed consent was not mentioned, but the subjects were among the researchers themselves.

In 1955 a paper was published[13] which had been presented at the International Congress of Radiology held in 1953 in Copenhagen, Denmark, which I attended. In this work, three persons were administered "a few microcuries" of sodium-24 (half-life 15 hours). They were identified by their initials: L.D.M. (the senior author of the paper), T.T. and J.W. There was no mention of the route of administration or of informed consent.

In about 1961, radium and strontium-85 were injected into an 80-year old man to determine the early retention[14]. I do not know the amounts injected, but there must have been informed consent because the subject was listed as a co-author.

Several papers published between 1958 and 1962 refer to the use of the short-lived radioactive potassium-42 as a calibrator for the measurement of naturally radioactive potassium in the human body. (I had used this on myself and colleagues in Copenhagen in 1953.) The first reports[15] were not specific, but the second[16] described the measurement and calibration procedure but without specifying the amounts. It was stated only that "a solution containing a small amount of K^{42} is divided into equal parts; one of these is administered to the subject and the other is diluted . . ." The third publication[17] described the experimental procedure in more detail; potassium-42 was administered to as many as 28 persons and numerous measurements were made of their body radioactivity in different measuring systems. There was no mention of informed consent.

Finally, at a 1967 meeting in Sun Valley, Idaho, a report was given of experiments in which mock luminous paint containing short-lived radioactive isotopes of radium and thorium was ingested by three men and three women, all aged between 63 and 83, and the same isotopes were injected intravenously in a similar group[18]. The purposes of the experiment were to determine the fractions of radium and thorium that are absorbed into the blood after ingestion, and the retentions of these elements after injection The report gives no information on the amounts of either radionuclide and informed consent was not mentioned.

I cannot think of other experiments of this nature, although there may well have been some, and this concludes my testimony.

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