Survey of Medical Radium Facilities in Minnesota in 1965

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RADIUM, which in this report means the specific isotope radium 226, is a naturally radioactive element present in nature as a member of the uranium decay series. It decays by alpha particle emission to radon, a noble gas, which is also an alpha emitter. Radium is a bivalent metallic element, chemically similar to barium, strontium, and calcium. Accordingly, if it enters the body it will be deposited in the bone and produce biological damage because of its long effective half-life and alpha decay (*1, 2*). Studies of the effects of radium on radium-dial painters have shown that body burdens as low as 1 μg. of radium will produce significant biological damage (*1, 2*). The maximum permissible body burden has been set at 0.1 μg. of radium 226 by the National Bureau of Standards Handbook No. 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure."

Radium is chemically active and consequently difficult to isolate in its metallic state and to keep pure after isolation as it reacts with air, forming the oxide and nitride and finally the carbonate. Because of this chemical reactivity, it is produced in the form of radium salts, principally the soluble bromide and chloride and the insoluable carbonate and sulfate (*3*). Since solubility is an important factor in the absorption of radium by the body, it is believed that all radium produced in recent years has been in the form of the insoluble sulfate (*4*).

Radium has been used for medical purposes since 1901, 3 years after its discovery by the Curies. Initially, radium was applied as a powder to the skin or injected as a solution into the treatment area. Severe local reactions in tissue, caused by the alpha and beta radiation, led to the development of filtered sources that permitted only the gamma radiation to strike the tissue. Observation of the long-term effects (leukopenia, lymphocytosis, osteomyelitis necrosis, and osteogenic sarcoma) resulting from deposition of radium in the body has been one factor in limiting medical applications to contained sources.

Radium and radon are primarily alpha emitters, and the gamma emission associated with their decay is not generally considered significant. The gamma radiation associated with radium sources is emitted principally in the beta decay of the daughter products radium B (lead 214) and radium C (bismuth 214). Therefore, radium and radon must be in equilibrium with their gamma-emitting daughters to be useful in medicine (*5*). Equilibrium is maintained by placing the radium salts in a hermetically sealed container.

Control of Radium Hazards

Sealing the sources of radium to insure equilibrium has been a major factor in controlling the inhalation or ingestion of radium and its daughter products. It is also the means to pre-

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vent the occurrence and spread of radioactive contamination. Inhalation, ingestion, and contamination problems still arise, however, under the following conditions:

1. The manufacturer of the radium source fails to completely seal the container.

2. The container loses its hermetic seal through rough handling.

3. The container material deteriorates.

4. The radium source ruptures from a buildup of gas pressure within the container (*6*). A leak in the source container may release the extremely fine radium salt or permit the release of only the gaseous radon. Particulates of the radon daughters may then adhere to the surface of the source, the lead storage container, and other objects that are near or in contact with the source.

The primary concern in a radium control program is the exposure of persons to unnecessary or excessive doses of radiation. External exposure to radiation is controlled by using three basic radiation protection principles: time, distance, and shielding. Internal exposure to radiation is controlled by preventing the release of radium or its daughter products. Careful handling, periodic examination, periodic reencapsulation and testing for leaks to check the integrity of the hermetic seal of the capsules are measures that should be taken by all users of radium sources to prevent contamination from radon daughters, to reduce the chance of an accidental spill of the salt, and to insure the expected gamma dose per milligram of radium content (*5*).

Minnesota Radium Control Program

The protection of the public health and safety from the hazards associated with the use of radium is the responsibility of State and local governments. Consequently, the use of radium has not generally been subject to the same rigorous controls that the Atomic Energy Commission maintains over sources of radiation under its jurisdiction.

To fulfill its responsibility in the control of radiation sources, the State department of health, on December 4, 1958, adopted regulations on ionizing radiation. The requirements of these regulations pertaining to radium facilities include the registration of sources and a provision to allow radiation safety surveys of all facilities by health department personnel. Thirty-seven radium facilities are registered in Minnesota. The following tabulation shows the distribution by type of user and radium inventory.

Type of radium user	*Number of users*	*Milligrams inventory*
Medical inventory	27	3, 829
Hospitals	15	1, 649
Clinics	6	1, 788
Physicians	4	45
Rental services (to medical users only)	2	347
Nonmedical inventory	10	243
Industrial	7	208
Educational	3	35
Total	37	4, 072

Safety surveys of radium facilities were started in June 1963. These early surveys included an evaluation of the gamma radiation hazard in the storage and handling areas with a Nucor CS–40A ionization-type rate meter (*A*) and an alpha contamination survey with an Eberline PAC–1S scintillation-type alpha detector (*B*). Several facilities had high-level alpha contamination, many facilities had no adequate gamma protection, and there was a complete absence of periodic testing for leaks at the source. Steps to reduce the hazards associated with the use, handling, and storage of radium were recommended in the report of the survey sent to the owner or user.

Survey of Radium Sources

Contacts with the owners and users of radium showed that they did not have the capability of testing their own sources. Many did not fully understand the necessity of testing for leaks, and there was a lack of convenient commercial leak-testing facilities in Minnesota. These factors caused the Radiation Safety Advisory Committee of the Minnesota Department of Health to recommend that the department's radiation control unit survey all radium facilities and leak-test all radium sources in the State.

If deemed necessary, the committee recommended that a program be set up to test periodically for leaks. Accordingly, when the radiation control unit surveyed the radium facilities, they incorporated a leak test into the survey procedure.

Several leak-test methods were considered for use in the survey. The Radioactive Materials Section of the Division of Radiological Health, Public Health Service, was asked for advice, and on the basis of the section's recommendations the decision was made to use the jar test (*7*) whenever this method was applicable. The method is simple and requires minimum handling of the source. Each source is placed in a 2¼-inch-diameter, 1-inch-deep glass jar that has a bare metal cover. If the source is leaking, the radon daughters will collect on the inside surface of the cover. After a 24-hour collection period, the alpha activity on the cover is checked with an alpha detector.

Before being used in the field, this leak-test method was tried on several leaking and nonleaking sources at the University of Minnesota. The jar test was compared with an electrostatic test similar to the one described by Gallagher and associates (*5*). A good correlation of results was found between the two methods, although the electrostatic test was slightly more sensitive in detecting extremely low leakage rates.

The comparison of the jar and electrostatic tests and the field surveys indicated that radon leakage from a sealed radium source generally was an "all or nothing" condition. Our tests showed that for most sources the activity on the cover varied from 0 to 1,000 counts per minute. This activity was found to result from contamination in the storage container and not from leakage at the source. The contamination was attributed to a leaking source in the existing inventory or to leaking sources that had since been replaced. All the leaking sources produced activities on the cover ranging from 10,000 to 300,000 counts per minute.

Survey Findings

We surveyed 19 medical radium facilities with a combined inventory of 1,552 milligrams. Included were 10 hospitals, 2 clinics, 5 physicians, and 2 radium-rental companies. A total of 214 needles and tubes, 11 plaques, and 1 applicator were tested for leaks. The facilities were evaluated on the basis of the standards recommended by the National Bureau of Standards Handbook No. 73, "Protection Against Radiation from Sealed Gamma Sources."

Adequate shielding during storage was found in 15 of the 19 facilities. The four facilities that lacked shielding owned two unused radium plaques, one seldom-used 50-mg. nasopharyngeal applicator, and four unused needles.

Adequate protection of personnel during radium-applicator loading procedures was provided in 6 of the 19 facilities. The other facilities either did not have an L-block or similar shielding or the shielding was not used because it was inconvenient to the storage area. Some of these facilities lacked the proper source-handling instruments. In several instances physicians were seen handling the source with their fingers. This procedure was particularly prevalent among users of plaques.

Alpha contamination of more than 2,000 disintegrations per minute (dpm.) per 60 square centimeters ($cm.^2$), as measured with the Eberline PAC–1S alpha scintillation-type detector, was found in 15 of the 19 facilities. Contamination of more than 20,000 dpm. per 60 $cm.^2$ was found in 11 facilities; contamination of more than 200,000 dpm. per 60 $cm.^2$ was found in 6 facilities. Leaking sources were found in 7 of the 19 facilities; however, only 3 of 214 needles were found to be leaking, while 6 of 12 plaques leaked.

Only six users of radium periodically surveyed for the presence of contamination, and five of the six used instruments capable of detecting only beta and gamma radiation. There seemed to be a general lack of awareness of the contamination hazards associated with the use of radium, and it is fortunate that with this lack of normal precaution the contamination problems were not more serious than they were.

When contamination was found, the report sent to the user concerning the survey contained recommendations for decontamination by a qualified person with suitable detection instruments. When this report was written, the three facilities with the greatest problem from contamination had been decontaminated. One of the facilities, a rental agency, operating from the home of an owner who had been renting radium for 18 years, decided that the radium business had decreased to the extent that it was no longer worthwhile staying in business. This facility had operated without owning a radiation detection instrument; instruments were borrowed on isolated occasions but only to find misplaced sources. Contamination levels as high as 800,000 dpm. per 60 cm.^{2} were found on old plaque boxes and equipment, and levels greater than 100,000 dpm. per 60 cm.^{2} were found in the work areas and in the radium safe. One needle, in an inventory of 22, and 3 plaques were found to be leaking. The owner indicated, however, that the plaques had recently been replaced and that bent needles had occasionally been sent to a radium company for resealing.

The other two decontaminated facilities were hospitals. In one the radium storage room was in the surgical ward. There had been alpha contamination on the order of 200,000 dpm. per 60 cm.^{2} on the floor and 1 million dpm. per 60 cm.^{2} in the storage container. The contamination had spread into the corridor. Decontamination procedures included removing the tile from the floor of the radium room and from isolated spots in the corridor. It is interesting that in this facility none of the present sources were leaking. Investigations indicated that the contamination had been caused by a 10-mg. radium plaque which had been donated to the hospital about 1945. This plaque was unnoticed among the hospital equipment for several years until it was tracked down and placed in the radium-storage room. The plaque was returned to the radium company about 1 year before our survey, and it was found that only 0.5 mg. of radium remained in the source. No contamination survey had been made before we surveyed the facility. The other hospital had extensive contamination in the storage and handling areas caused by two leaking plaques.

Summary and Conclusions

Radium sources can cause internal as well as external radiation hazards. A preliminary survey of radium in Minnesota indicated the need for a comprehensive survey incorporating a leak test. After adopting a suitable leak-test method, 19 medical radium facilities, with a combined radium inventory of 1,552 milligrams, were surveyed. Alpha contamination was found in 15 of the surveyed facilities; some required extensive decontamination. Leaking sources were found in 7 of the 19 facilities.

The protection of personnel from exposure to external radiation was usually found to be inadequate. The surveys demonstrated that most users of radium lack the knowledge and even a basic concern for the hazards of radium usage. Finding excessive exposure to contamination by and leakage of radium is only a beginning. Good management and use of radium will develop only as survey programs such as this demonstrate to the user that care is necessary and that relatively simple precautions can minimize the hazards associated with the use of radium.

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