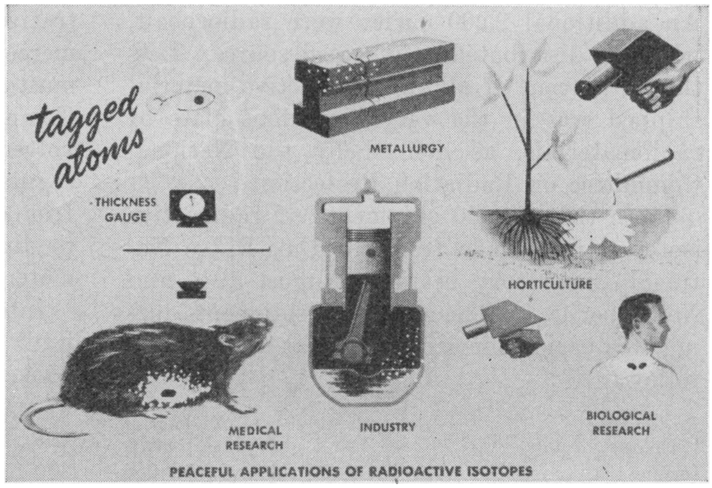
Radiation Exposure in the United States



Reactor-Produced Radioactive Isotopes

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RADIOACTIVE ISOTOPES "in the types and quantities producible in a nuclear reactor create health and safety problems which are not necessarily limited to the individual user, but are a matter of public interest as well." This statement was made by the United States Atomic Energy Commission (*1*), which is responsible for distributing and supervising the use of all reactor-produced radioactive isotopes in this country. It demonstrates the need for continual vigilance relative to these materials.

Although the radiation exposure received by persons using radioactive isotopes appears to be of a relatively low level, it is a fact that their use is becoming more widespread. Today more than 1,100 medical institutions, colleges and universities, industrial firms, Federal and State laboratories, foundations, institutes, and physicians have used or are using these materials. About 7,500 persons are directly involved in their use, besides the persons who are receiving medical applications of radioactive isotopes.

Reviewed here are data from the literature on the amount of radioactive isotopes in use, regulations concerning shipment and use, and levels of radiation exposure received by persons involved. These data supplement an earlier presentation by the authors on the principal sources of radiation exposure in the United States (*2*).

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Distribution

The Isotopes Division of the United States Atomic Energy Commission distributed only 96 curies of radioactive isotopes in fiscal 1947, the first year distributions were made. Each year since that date, the amount shipped has increased substantially. A total of 4,250 curies had been distributed by June 30, 1952. Of this amount, almost 1,800 curies were radioiodine and radiophosphorus, which decay rapidly.

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An additional 2,200 curies were radiocobalt, which is distributed as a sealed source. Less than 1 percent of all the radioactive material shipped was in the very hazardous class of radiomaterials, as defined by the National Committee on Radiation Protection.

More than 31,000 shipments of radioactive isotopes were made from the Oak Ridge National Laboratory between August 1946 and November 1952. The number of shipments during this period for each principal isotope is as follows (*3*):

Radioactive isotope	*Number of shipments*
Iodine-131	12, 058
Phosphorus-32	8, 784
Carbon-14	1, 381
Sodium-24	1, 218
Sulfur-35	680
Gold-198, -199	963
Calcium-45	468
Iron-55, -59	415
Cobalt-60	634
Potassium-42	506
Strontium-89, -90	234
Other	4, 033
Total	31, 374

The following data show the distribution of radioactive isotopes from August 1946 through June 1951 according to use (*1*):

Field of utilization	*Number of shipments*
Medical therapy	8, 981
Animal physiology	4, 328
Physics	1, 274
Chemistry	1, 040
Plant physiology	877
Industrial research	784
Bacteriology	321
Other	1, 300
Total	18, 905

Transportation

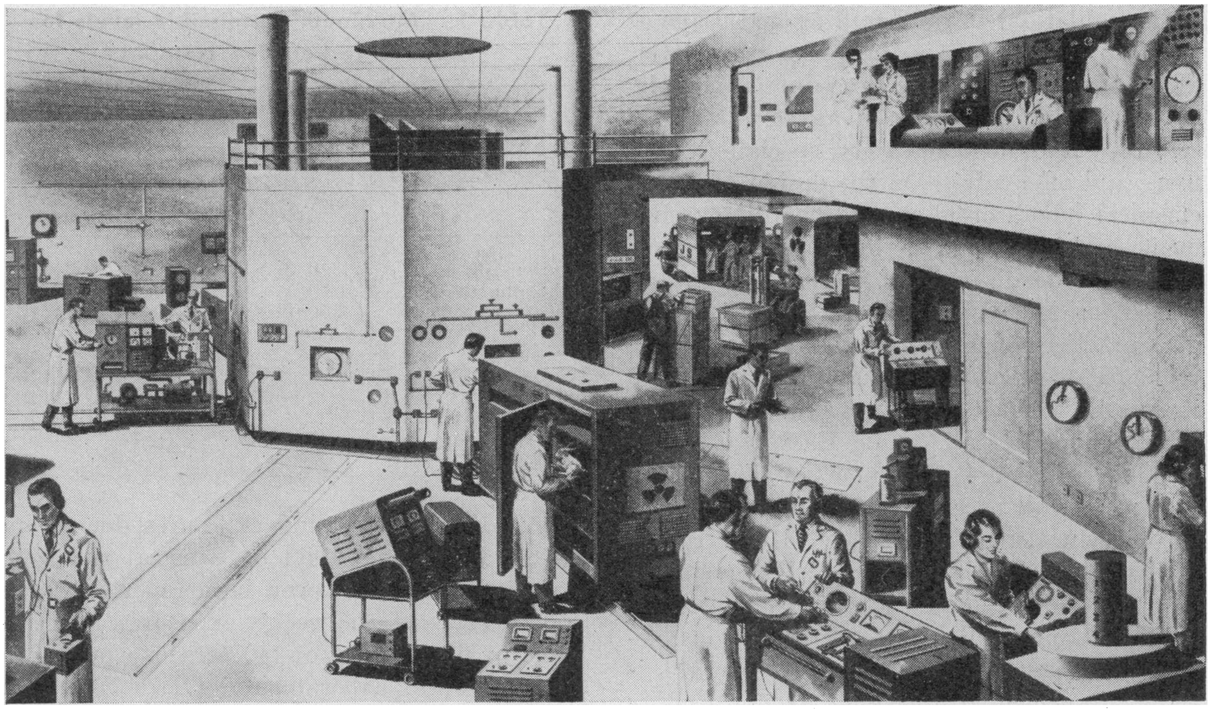
The Interstate Commerce Commission is empowered to formulate rules and regulations to assure the safe interstate transportation of radioactive materials by commercial motor vehicle, rail, and water carrier. They cooperate in the formulation of regulations with the American Association of Railroads, the United States Coast Guard, and the Civil Aeronautics Board, which act as the enforcement agencies in their respective fields. Regulations governing postal shipment of radioactive materials are both formulated and enforced by the United States Post Office Department and are administratively independent of the Interstate Commerce Commission. However, the Post Office must collate their regulations with those of the Commission since several carriers may be involved in any one shipment process. These regulations attempt to protect people and films from exposure to radiation and at the same time to limit the cost and burden of shielding materials (*4*).

Interstate Commerce Commission regulations limit the quantity of radioactive substance packed in 1 outside container to 2 curies, except by special arrangement. They limit the allowable radiation from the shipping container to 200 milliroentgens per hour at the surface and 10 milliroentgens per hour at a distance of 1 meter. Both of these requirements must be satisfied. Shipments are exempt from these regulations if they contain 0.1 millicurie or less of radioactive material and meet other special requirements that overcome the radiation hazard. The Atomic Energy Commission has reported approximately 95 percent of all shipments have had an external radiation level of less than 0.015 roentgen per hour at the surface of the cointainer.

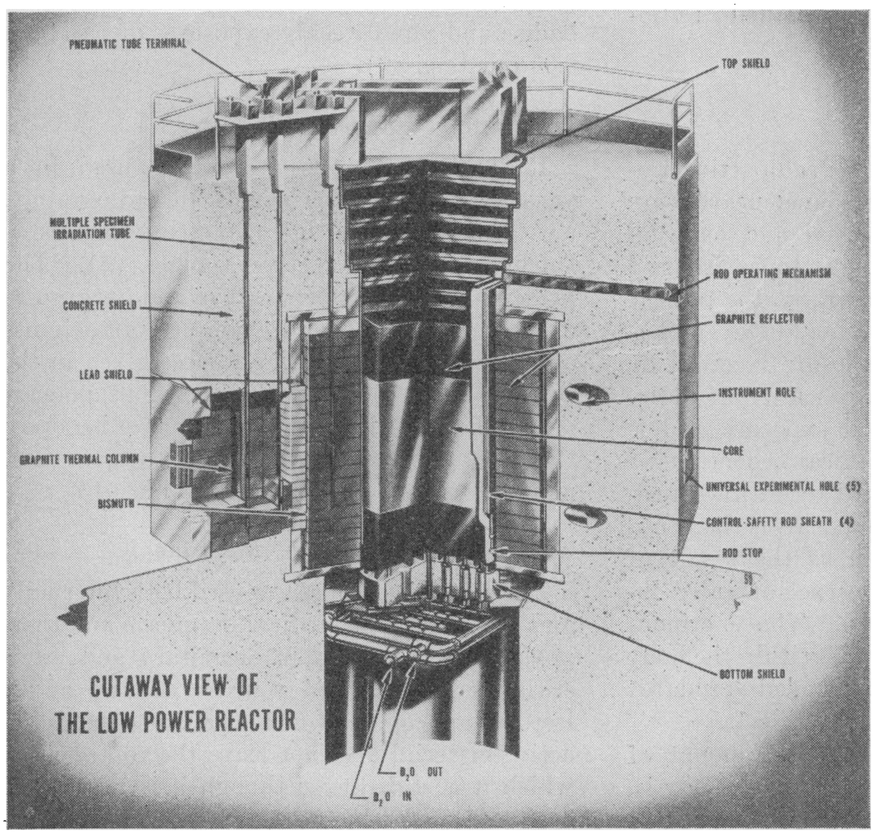
The contractor at the Atomic Energy Commission installation assumes responsibility for packaging isotopes, in accordance with the regulations. Generally, the only concern is transporting the material to the user from the installation. However, the recent trend for the prime receiver of radioactive isotopes, such as a large central hospital, to process and redistribute them to secondary receivers, such as smaller hospitals, creates additional transportation problems.

Control of Utilization

The Atomic Energy Commission, exercising its responsibility under the Atomic Energy Act of 1946 (Public Law 585, 79th Cong. 2d sess.), has to date accomplished control of radioactive isotope distribution and use by an allocation or "licensing" procedure. The radioactive materials distributed by the Commission have been made available only to those who have the necessary prerequisites in training and equipment to handle the materials safely (*1*). A secondary receiver is, of course, subject to the



Production of Artificial Radioactive Isotopes in a Low Power Atomic Reactor



The top sketch shows the reactor housing, control stations, and other equipment as they would appear in use by industry, universities, and other research institutions. At left is a cutaway drawing of the reactor. This "atomic furnace" can be operated at a rate of 8 hours a day, 5 days a week, for 10 years before being recharged. It was designed for the Atomic Energy Commission. (Illustrations courtesy of North American Aviation, Inc.)

same regulations in the handling and usage of the radioisotopes as is the primary receiver.

The allocation control procedure is complemented by the activities of an advisory field service. Radiological safety specialists visit users and offer advice on the design of radiochemical laboratories, remote handling equipment, and shielding, decontamination procedures, standardization of measurements, and the safe use and disposal of radioactive isotopes. The practices, equipment, and records of the users are reviewed with particular emphasis on factors involved in radiation safety (5).

According to the Atomic Energy Commission, increased use of radioactive isotopes in the future will necessitate supplementation of the present centralized method of control by supervision at the point of use. The responsibility of the Commission for the control of the hazards from "byproduct materials," as described in the Atomic Energy Act of 1946, is being supplemented by a joint Atomic Energy Commission-Public Health Service program of assisting state and local health organizations to assume responsibility for the day-to-day surveillance of Commission-distributed radioactive isotopes.

Exposures to Radiation

In handling and preparing radioactive isotopes, the user and the personnel nearby are potentially exposed to internal and external radiation. When radioactive isotopes are used for medical diagnosis and therapy, the patient too receives exposure. It should be emphasized, however, that the exposure received by the patient in the medical application of radioactive isotopes is a planned exposure and is administered for his net medical benefit.

The most persistent hazard to health associated with the use of these materials is the possibility of internal radiation as the result of radioactive substances being accidentally ingested, inhaled, or absorbed. The enormous potency of very small amounts within the body is emphasized by the recommended standards (6), which are summarized in table 1.

Since the determination of the amount of radioactive material within a person's body is, at present, a complicated procedure, few data

Table 1. Maximum permissible levels for specific radioactive isotopes

Radioactive isotopes	In the body (microcurie)	In liquid media (microcurie per ml.)	In air (microcurie per ml.)
Iodine-131	0.3	3×10^{-5}	3×10^{-9}
Phosphorus-32	10	2×10^{-4}	1×10^{-7}
Carbon-14	250 (fat)	3×10^{-3}	1×10^{-6}
	1,500 (bone)	4×10^{-3}	5×10^{-7}
Sodium-24	15	8×10^{-3}	2×10^{-6}
Cobalt-60	3	2×10^{-2}	1×10^{-6}
Strontium-89	2	7×10^{-5}	2×10^{-8}
Strontium-90 (+Yttrium-90)	1	8×10^{-7}	2×10^{-10}

are available regarding exposures due to internal radiation. Data on external radiation exposures have, however, been reported. One report concerns the weekly exposures, as measured by film badges, of 140 persons working in radioisotopes laboratories. Of 4,750 film badges worn by these persons during an 8-month period, only 1 indicated a weekly exposure greater than 0.3 roentgen, the maximum permissible weekly dose. More than 4,700 badges indicated weekly exposures of less than 0.05 roentgen (7).

Radioactive Isotopes in Industry

Radioactive isotopes are being used in a variety of research problems, in radiography, and in such testing and measuring devices as thickness and liquid level gauges (2). The principal radioisotopes used in industry, some of their properties, and examples of their use are listed in table 2. The figures given in the third column illustrate the enormous potency of small quantities of the radioactive isotopes; they are not necessarily related to the quantities actually used in the examples cited.

Radioactive Isotopes in Medicine

Radioactive isotopes are used both internally and externally for medical diagnosis and therapy. In this report, intracavitary and interstitial uses of sealed sources of radioactive isotopes are considered external since the radioactive material does not leave the container in which it is sealed even though it is within the body. Some of the better known medical applications of radioactive isotopes are as follows (*8*):

Sodium-24—Correlation of sodium turnover with congestive heart failure; differentiation of normal and restricted blood flow; radiocardiography (determining pumping qualities of the heart).

Phosphorus-32—Determination of extent of tumor mass in brain tumor surgery; treatment of polycythemia vera and chronic leukemia.

Iodine-131 in diiodofluorescein—Location of certain brain tumors.

Iodine-131—Detection of hyperthyroidism; location of thyroid cancer offshoots, or metastases; treatment of hyperthyroidism, thyroid cancer, and metastases.

Cobalt-60—Interstitial sources for treating accessible tumors and teletherapy units for deep-seated tumors.

Strontium-90—Beta-ray source for treating surface lesions.

Gold-198 (*colloidal*)—Treatment of subsurface tumors of lymphoid system and chronic leukemia.

Internal Sources

Iodine-131 is the most widely used radioactive isotope for medical purposes, and phosphorus-32 ranks second. A medium-sized hospital (150 to 300 beds) participating in the isotopes program will have some 35 millicuries of radioactive iodine on hand. A large hospital (400 to 700 beds) may have 200 to 300 millicuries of this material, according to the January 1951 report of the Joint Fire and Marine Insurance Committee on Radiation of the major private underwriting and insurance associations.

Radioiodine given orally is rapidly absorbed from the gastrointestinal tract and distributed throughout the body. In normal persons, the thyroid gland will fix 10 to 25 percent of the dose and the remainder will be excreted in the urine within 24 hours. In patients with hyperthyroidism, 50 to 80 percent of the dose may be fixed by the thyroid (*9*).

Radiophosphorus is given either orally or intravenously. About 75 percent of the oral dose is absorbed and the remainder is lost in the feces. Of the amount reaching the circulatory system, whether the dose is administered orally or intravenously, 20 to 40 percent is excreted quickly through the kidneys, and the rest is distributed throughout the body (*9*).

Thus, in the medical application of radioactive isotopes the whole body is subjected to some radiation, most of which occurs during the first day or so after the dose is given. For example, for each millicurie of radioactive phosphorus administered to a patient, the resultant total-body irradiation is 10 roentgen equivalents physical, taking into account the half life of the isotope and the excretion of part of the dose (*9*).

Table 3 presents the range of the usual doses of iodine-131 and phosphorus-32 and the theoretical exposure resulting in the critical organ of the body. Calculations were made from published data, as indicated.

Table 2. Radioactive isotopes in industry

Radioactive isotope	Half life	Millicuries of radioactive isotope per gram of total element as available	Example of use
Cobalt-60	5.3 years	34 to 5,000	Radiography.
Selenium-75	127 days	3.3 to 100	
Tantalum-182	117 days	105 to 1,500	
Carbon-14	5,720 years	250 to 1,500	Thickness gauge.
Strontium-90	25 years	[1] 160,000	
Barium-140	12.8 days	[1] 72,000,000	Mark interfaces and measure intermixing in pipelines.
Antimony-124	60 days	12 to 1,500	
Iron-59	46.3 days	500 to 1,500	Measure engine wear.
Calcium-45	152 days	0.2 to [1] 19,000,000	Evaluate detergents.
Yttrium-90	2.54 days	115	Used as tracer in dyeing process.
Lanthanum-140	40 hours	525	Determine sulfuric acid content in chromium plating solutions.

[1] Approximate.

Table 3. Range of radiation exposures from diagnostic and therapeutic doses of radioactive phosphorus and iodine

Radioactive isotope	Disease	Average total oral dose [1] (microcuries)		Selected critical organ	Total radiation exposure to selected critical organ [2] (roentgens or roentgen equivalents physical)	
		Diagnosis	Therapy		Diagnosis	Therapy
Iodine-131.	Hyperthyroidism.	100 to 300 (usually 100).	3,000 to 10,000.	Thyroid.[3]	[4] 100 to 1,100.	[4] 11,000 to 40,000.
	Thyroid cancer.	1,000 to 3,000.	[5] 50,000 to 250,000.		[4] 4,000 to 11,000.	[6] 24,000 to 300,000.
Phosphorus-32.	Blood dyscrasias.	100 to 500.	3,000 to 10,000.	Bone.[7]	2 to 7.	40 to 130.
				Muscle.	1 to 3.	20 to 65.

[1] Source: Medical physics, edited by Otto Glasser. Chicago, the Year Book Publishers, Inc., 1950, vol. II.

[2] Sources: Marinelli, L. D., Quimby, E. H., and Hine, G. J.: Dosage determination with radioactive isotopes. II. Practical considerations in therapy and protection. Am. J. Roentgenol. 59: 260–280 (1948).

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See also footnote 1.

[3] Average thyroid weight of 30 grams used in calculations.

[4] Assumes 75 percent absorption of oral dose in thyroid.

[5] Usually consists of a series of smaller doses.

[6] Assumes 10 to 30 percent absorption of oral dose in thyroid.

[7] Weight of bones in average man assumed to be 7,000 grams.

As can be seen from these data, exceptions to the standards established for permissible levels of radiation are made when radioactive isotopes are used clinically since the intent here is to produce or measure biological changes rather than to avoid them. In certain therapeutic applications of radioactive isotopes, the total-body irradiation may be 75 to 100 roentgens.

Powell (*10*) reports that patients who have received internal applications of radioactive materials do not ordinarily constitute a significant source of external radiation. However, when a therapeutic dose of a gamma-emitting isotope, such as iodine-131, has been given, the maximum permissible dose level, 0.3 roentgen in air per week or 7.5 milliroentgens per hour for a 40-hour week, may be found as far away as several feet from the patient. It has been recommended as a public health precaution that "patients who receive large doses of iodine-131 or gold-198 should be hospitalized until the total residual activity in the body is not over 30 millicuries" (*11*).

Periodic radiation surveys of the areas in the hospital where these patients are located may be required, and the wearing of film badges by the nurses caring for them is recommended (*12*). The external radiation hazard may be minimized through use of the protective measures—distance, time, and shielding.

The patient who has been given one or more doses of a radioactive isotope requires special supervision and handling if nurses and other personnel are not to become contaminated. It is recommended that rubber gloves be worn while bathing the patient (*12*). In addition, such problems as the contamination of bed linen must be considered. These articles may require special storage or laundering procedures (*10*).

External Sources

Strontium-90 and cobalt-60 are the principal radioactive isotopes used in medical therapy as external sources of radiation. Beta-ray applicators (strontium-90) are available for the treatment of certain eye conditions. Cobalt-60 is available in the form of large shielded concentrated sources for deep therapy and in the form of small needle sources for intracavitary and interstitial therapy. The Atomic Energy Commission has authorized 12 applicants to use teletherapy units, amounting to a total of some 16,000 curies. Three of these units are already in operation. Twenty-two applicants have been authorized to use small sources, such as needles, totaling some 7,600 millicuries.

Dosages administered to the patient are of the order of 6,000 to 7,000 roentgens. Such therapy, however, is used only for conditions demanding drastic measures, and the exposure is limited to a small section of the patient's body.

Wastes

Wastes from the use of radioactive isotopes by industry, the medical profession, and research laboratories could create health hazards to persons outside the installations using them. However, if the recommendations for the disposal of the wastes from the use of phosphorus-32 and iodine-131 made by the Subcommittee on Waste Disposal and Decontamination, National Committee on Radiation Protection (*13*), are followed, few, if any, hazards should arise. Ruchhoft and Feitelberg (*14*) have shown that the dilution needed to reduce the activity of liquid isotopic wastes from hospitals to safe limits is generally available, and, therefore, their disposal is not a major problem. Radioactive isotopes, such as cobalt-60, which are distributed as sealed sources normally have no waste disposal problems.

Conclusion

It would appear that the radiation exposure in the United States due to reactor-produced radioactive isotopes distributed by the Atomic Energy Commission is currently limited to relatively few people and is of a relatively low level. However, there is no indication of a decline in the use of these materials, but rather there is a strong probability that their use will become much more extensive. Further study of radiation exposure from this source as data become available may be required.

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