Tritium in the Environment From Nuclear Powerplants

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TRITIUM, an isotope of hydrogen with an atomic mass number of three, is produced in nuclear reactors in substantial quantities. Although tritium is one of the least hazardous radioactive nuclides, its continued production and long half-life for radioactive decay may lead to increased levels in the environment. Because tritium is an isotope of hydrogen, it can be metabolized in the form of tritiated water and incorporated into body fluids and tissues. This source of population exposure requires that public health agencies be cognizant of the significance of tritium as an environmental contaminant.

The nuclear power industry has expanded rapidly during the past few years, and the U.S. Atomic Energy Commission predicts that this high rate of growth will continue during the next decade. Nuclear power reactors and fuel reprocessing plants release tritium to the environment under normal operating conditions.

Due to the stratospheric fallout from previous atmospheric testing of nuclear weapons, measurable levels of tritium are already present in the environment. An analysis of the effect of an expanding nuclear power industry on environmental tritium levels indicates that future tritium releases from reactors and spent fuel processing plants may surpass the quantity of tritium remaining from nuclear weapons tests.

The Bureau of Radiological Health's environmental surveillance activities provide a continuing source of data on tritium concentration in rivers on which nuclear facilities are located. There is, however, a need for more specific source-oriented information on tritium, and its potential for becoming a public health problem. This paper is intended as a general information guide on tritium for persons engaged in Federal, State, county, and local public health activities. The various sources and mechanisms for release of tritium and its pathway from nuclear facilities to the environment are described. This information is essential in assessing the requirement for environmental surveillance and in evaluating, from a public health viewpoint, the upward trend of tritium levels in the environment.

Radiological Characteristics of Tritium

Because of its relatively short biological half-time (12 days) combined with a relatively low disintegration energy, tritium is one of the least hazardous radionuclides produced in nuclear reactors. A single ingestion of tritiated water having an activity of 1 microcurie will produce a total dose to the body tissues of 0.21 millirems (mrem). Continuous ingestion of

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water having a specific activity of 1 microcurie of tritium per milliliter will produce a dose rate of 170 rem per year to body tissues. From this value the annual average discharge concentration limit for tritium in water can be calculated to be 3×10^{-3} microcuries per milliliter. This quantity is the concentration limit for tritium in radioactive waste discharges to the environment contained in the Code of Federal Regulations (*1*).

Tritium decays by the emission of a beta particle and an anti-neutrino to form stable helium-3. The half-life for this process is 4,500 days or approximately 12 years (*2*). The beta particle and the neutrino carry varying fractions of the energy liberated by the disintegration. When there are many tritium atoms present, this process produces a continuous spectrum of beta particle energies.

The maximum energy of the beta emitted by tritium is 18.6 kilo-electron volts (Kev) and the average energy is 5.6 Kev. These energies are considerably lower than those of most other beta emitters which are usually about 100 times greater.

Sources of Environmental Tritium

Naturally occurring tritium. Tritium is one of the three isotopes of hydrogen. Normal hydrogen consists of approximately 99.9 percent protium (hydrogen-1) and 0.015 percent of deuterium (hydrogen-2), although variations in isotopic concentration can exist in natural sources. Unlike protium and deuterium, tritium (hydrogen-3) is unstable because of radioactive decay and occurs naturally only in trace amounts.

Naturally occurring tritium is formed principally by the interaction of cosmic radiation with oxygen and nitrogen atoms in the upper atmosphere. Tritium produced by cosmic-ray interactions prior to 1952 contributed to environmental concentrations ranging between 16 to 35 picocuries of tritium per liter of water or 5 to 10 tritium units (*3*) where 1 tritium unit is equivalent to 1 atom of tritium per 10^{18} atoms of normal hydrogen. Because of a constant rate of production, the tritium from natural processes will accumulate until an equilibrium condition is reached. This condition is achieved when the rate of removal of tritium from the environment by radioactive decay equals the rate of tritium production. Since the earth is several billion years old, this equilibrium rate has existed for some time and the amount of tritium present from natural sources is essentially constant.

Nuclear weapons tests. Past tests of nuclear weapons in the atmosphere are the greatest single source of tritium present in the environment today. Tests by both the United States and the Union of Soviet Socialist Republics, before the Atmospheric Test Ban Treaty in 1962, greatly increased the amount of tritium in the environment. Thermonuclear (fusion) weapons produce tritium from neutron interactions with lithium and deuterium with a production rate of 6.7 megacuries of tritium per megaton of fusion yield (*4*). This source contributed about 1,700 megacuries of tritium to the environment compared with an equilibrium value from natural sources equivalent to approximately 69 megacuries.

A large fraction of the tritium produced by these detonations was injected into the stratosphere. This part of the atmosphere does not mix rapidly with the lower portion of the atmosphere; therefore, the tritium is introduced into the troposphere over many years. Tritium in the lower atmosphere is rapidly removed by precipitation. Tritium removed from the atmosphere by precipitation will accumulate in the surface layers of the oceans and inland waters. Rainfall that follows periods of nuclear testing has several hundred times the tritium content normally present from natural tritium. The estimated time for these processes to remove half of the tritiated water from the lower atmosphere is 35 to 40 days (*3*).

Tritium From Nuclear Reactors

Tritium may be produced in nuclear reactors by the following five mechanisms: (*a*) fissioning of uranium, (*b*) neutron capture reactions with boron and lithium added to the reactor coolant, (*c*) neutron capture reactions with boron in control rods, (*d*) activation of deuterium (hydrogen-2) in water, and (*e*) high energy neutron capture reactions with structural materials.

The relative magnitude of tritium production by these sources is influenced by the reactor type, operating history, design characteristics, and materials of construction. The amount of tritium and manner in which it is released to the environment will also be affected by these parameters.

During the processing of spent reactor fuel, tritium, which has been produced in the fuel rods, is released to the environment and may be a significant source of environmental tritium contamination. A detailed discussion of this source, however, is not within the scope of this report.

Fission-product tritium. During the fission process the uranium nucleus usually splits into two more or less equal fragments plus several neutrons. About once in every 10,000 fissions, however, the nucleus is split into three portions (ternary fission) one of which may be a tritium nucleus. It requires 3.1×10^{16} fissions per second to produce a power level of 1 megawatt of thermal energy (Mwt).

Most nuclear powerplants generate electricity at a rate of approximately one-third of the thermal energy production rate. Therefore, approximately 10^{17} fissions per second are required to produce 1 megawatt of electrical energy (Mwe). This production rate corresponds to the production of about 10^{13} atoms of tritium per second or 50 millicuries of tritium per day for each megawatt of electrical energy generated. This tritium normally remains in the fuel unless it diffuses through the cladding material or a leak occurs.

A second source of fission-product tritium in nuclear reactors is due to traces of uranium on the outer side of fuel elements which remain from the fuel fabrication process. This "tramp" uranium may be only a few micrograms per square inch of fuel surface, but because of the large surface area provided by the many fuel rods in a reactor it can produce detectable fission-product concentrations in the coolant.

The reactor fuel is usually uranium oxide and is contained in tubes made of stainless steel or an alloy of zirconium (zircaloy). The primary function of the cladding material is to prevent the escape of fission products from the fuel element. These fission products would otherwise leak from the fuel and contaminate the primary coolant. Sometimes, because of a lack of uniformity in manufacturing, damage during shipment or handling, or as a result of unequal corrosion rates or temperature gradients, the cladding develops pinhole failures or defects through which fission products such as tritium may escape.

All new water-cooled power reactors being built in the United States are using zirconium-clad fuels; however, several older reactors use stainless steel clad fuel. Stainless steel is being replaced by zircaloy cladding because of the increased corrosion resistance and more favorable nuclear properties.

Experience has shown that the fraction of tritium escaping from fuel which is clad with zircaloy-2 is significantly less than that escaping from stainless steel clad fuels. This loss of tritium may be due to fewer defects in zirconium cladding or the ability of zirconium to combine chemically with hydrogen, thus limiting diffusion through the cladding and, consequently, limiting the release of tritium to the coolant.

Tritium produced by activation. Tritium is produced in water reactors by the activation of the naturally occurring deuterium present in the cooling water. Because of the small amount of deuterium in water and the low probability of its capturing a neutron to form tritium, this source of tritium in light water reactors is insignificant. In heavy water reactors which are cooled or moderated with deuterium oxide (D_2O), however, activation is the major source of tritium. Heavy water reactors for power production are not used in the United States at the present time but may be developed at some time in the future. There are, however, several heavy-water plutonium production reactors and small heavy-water moderated research reactors in operation.

A comparison of the tritium concentrations in the primary coolant of light and heavy water reactors is shown in the following table:

Reactor type	*Tritium concentration (microcurie per milliliter)*
Heavy water	7200
Pressurized water reactor	1.5
Do	.14
Do	.044
Boiling water reactor	.015

SOURCE: reference 5.

Tritium is also the product of neutron capture reactions in boron-10, boron-11, lithium-7 and lithium-6. Lithium-7 is usually formed by the $^{10}\mathrm{B}(\mathrm{n},\alpha)^{7}\mathrm{Li}$ reaction when boron is used in nuclear reactors for reactivity control.

In the past, lithium-6 was used in the coolant for pH control or in coolant purification demineralizers. This use of lithium-6 resulted in the production of elevated tritium concentrations in the primary coolant.

The use of lithium-6 has been abandoned for this reason and replaced by ammonia or lithium-7. Tritium may also be formed by the $^{14}\mathrm{N}(\mathrm{n},\mathrm{T})^{12}\mathrm{C}$ reaction with ammonia in the coolant or nitrogen in the containment atmosphere. The magnitude of these sources has not been fully assessed.

In boiling water reactors (BWR) boron is used for control in the form of boron carbide either as cruciform control rods or as absorber plates (curtains). Weaver and Harward (*6*) describe the differences in design between this reactor and a pressurized reactor. The rods are movable and function to control the power level of the reactor. Boron absorber curtains are generally used during the first fuel cycle to compensate for the lack of buildup of neutron absorbing fission products (poisons) and are then removed.

Both the absorber plates and the fuel rods are clad in similar fashion so that tritium which is formed from the boron must escape through the cladding by the same mechanism as the fission-product tritium.

Pressurized water reactors (PWR) use boron for reactivity control in the form of boric acid dissolved in the primary coolant. This chemical shim is used to obtain a more uniform power distribution and to compensate for long term changes in fission-product poison buildup, uranium burnup, and changes in neutron flux levels. The initial concentration of boron ranges from several hundred to several thousand ppm and decreases during the operating life of the fuel. Table 1 shows estimated tritium production rates in a typical 1,000 Mwt light water reactor for various irradiation times (*7*).

The production of tritium can also occur in high temperature gas-cooled reactors by ternary fission and by activation of helium-3 found in trace amounts in the helium coolant. The following table shows the estimated tritium production rates in a 120 Mwt air-cooled reactor (*5*).

Source	*Production rate (curies per year)*
Ternary fission	605
^{3}He activation in coolant	91
Total	696

SOURCE: reference 5.

Tritium release mechanisms. The tritium concentration in the primary coolant system is strongly dependent upon the coolant makeup rate or residence time of the coolant in the reactor. The effect of the average residence time of the coolant in the reactor system on coolant tritium concentrations is shown for boiling water reactors in table 2 and for pressurized water reactors in table 3. In both tables, the contribution of fission-product tritium is shown as a function of the fraction of the tritium which passes through the fuel cladding. The tritium produced by activation of the boron encased in the control rods of a boiling water reactor (BWR) has been assumed to remain within the rod and does not contribute to tritium levels in the coolant (*7*). The tritium level from the use of boron in a PWR varies with the boron concentration in the coolant and consequently shows a considerable range as shown in table 3.

Table 4 shows tritium levels in the primary coolant of several operating light water reactors. These measurements were obtained by the staff of the Northeastern Radiological Health Lab-

Table 1. Tritium production rates in a 1,000 Mwt light water nuclear reactor [1]

Irradiation time	Tritium produced (curies) Activation of deuterium in coolant	Ternary fission	Boron and lithium reactions [2]
1 day	0.0003	13	50
1 week	.002	90	400
1 month	.008	400	1,600
1 year	.09	5,000	20,000

[1] Reference 7.

[2] These estimates represent upper limit production rates assuming boron control rods, boron chemical shim, and lithium-6 purification resins.

Table 2. Calculated tritium concentrations in the coolant of a 1,000 Mwt boiling water reactor [1]

Residence time of coolant	Coolant tritium concentrations (µCi per liter)				
	From deuterium activation	From ternary fission [2]			
		100 percent	10 percent	1 percent	0.1 percent
1 day	0.002	70	7	0.7	0.07
1 week	.01	500	50	5	.5
1 month	.04	2,000	200	20	2
1 year	.5	30,000	3,000	300	30

[1] Adapted from table II, reference 7.

[2] As a function of percent tritium leakage through cladding.

Table 3. Calculated tritium concentrations in the coolant of a 1,000 Mwt pressurized water reactor [1]

Residence time of coolant	Coolant tritium concentrations (µCi per liter)					
	From deuterium activation	From ternary fission [2]				From boron in coolant [3]
		100 percent	10 percent	1 percent	0.1 percent	
1 day	0.002	70	7	0.7	0.07	3–300
1 week	.01	500	50	5	.5	200–2,000
1 month	.04	2,000	200	20	2	800–8,000
1 year	.5	30,000	3,000	300	30	10,000–100,000

[1] Adapted from table II, reference 7.

[2] As a function of percent tritium leakage through cladding.

[3] Varies with boron concentration which decreases with time since last refueling.

oratory of the Bureau of Radiological Health. If the data for the three boiling water reactors are compared with the calculated tritium concentrations shown in table 2 for a residence time of 1 month, it can be estimated that approximately 1.0 percent of the fission-product tritium diffused through the stainless steel cladding, whereas only about 0.1 percent diffused through the zirconium cladding.

A similar comparison of the primary coolant tritium activities in PWR plants shown in table 5 with the calculated values in table 3 indicates that boron in the coolant appears to be the predominant source of tritium in the primary water. Based on a residence time of approximately 1 month, the only other source which could produce the observed levels would have to be leakage of almost all the fission-product tritium from the fuel. There is no apparent basis for assuming a higher tritium leak rate from the fuel of a pressurized water reactor than that estimated for a boiling water reactor.

Discharges From Nuclear Powerplants

Tritium which has entered the coolant of a nuclear reactor can reach the environment by several pathways. The number of pathways available and the relative amount of tritium discharged by each route depend upon the reactor design and reactor type.

Boiling water reactors. In a boiling water reactor the primary coolant flows through the reactor core, is converted to dry steam and then is fed to the turbine generator to produce power. The coolant is returned to the reactor through a condenser which removes the excess heat still remaining in the steam. The condenser cooling water and the reactor coolant are in close proximity in the condenser. This interface is maintained under a vacuum so that any leakage would be into the reactor and not to the environment.

Air ejectors on the condenser remove the oxygen and hydrogen produced by the dissociation of water in the reactor, air which has leaked into the condenser, and residual water vapor. The air and noncondensable gases are discharged to the plant stack through the off-gas system. Tritium in the form of elemental hydrogen gas may be discharged through the air ejector but a major part of the tritiated water vapor will be removed by condensation. Because of the long radiological half-life of tritium, its concentration in the gaseous stack effluent is not reduced by the 30-minute delay of waste gases in the system.

Pressurized water reactors. A pressurized water reactor consists of two coolant systems. The primary system conducts superheated water through the reactor core to steam generators and returns it to the reactor. The steam generator consists of rows of U-shaped tubes through which the heated primary coolant passes. Surrounding the tubes is the secondary coolant.

Because of a pressure difference between the primary and secondary system (2,000 pounds per square inch in the primary as opposed to about 1,000 pounds per square inch in the secondary) it is possible to convert the secondary coolant into steam. The secondary system then follows a path similar to the primary coolant of a BWR going through turbines and the condenser.

An important difference between boiling and

Table 4. Tritium in operating power reactors [1]

Reactor and type	Power level (Mwt)	Type of fuel cladding	Boron used in coolant	Tritium concentration μCi per liter		
				Primary coolant	Secondary coolant	Discharge canal water
A. Pressurized water reactor	600	Stainless steel	Yes	1,560	0.41	0.024
B. Pressurized water reactor	585	do	No [2]	2–44	(3)	.007
C. Pressurized water reactor	80	do	No [4]	145	(3)	(3)
D. Pressurized water reactor	50	Aluminum	No	116	.45	.019
E. Boiling water reactor	256	Stainless steel	No	8.8	(5)	.009
F. Boiling water reactor	240	do	No	13.3	(5)	.002
G. Boiling water reactor	700	Zirconium	No	[6] 1.6	(5)	[6] .0006

[1] Data from Northeastern Radiological Health Laboratory, Bureau of Radiological Health.

[2] Converted in late 1965 to a stainless steel fuel with full chemical shim (boron in coolant).

[3] Not reported.

[4] Boron is used for shutdown but not during routine operation.

[5] Not applicable.

[6] Data from Nuclear Engineering Laboratory, Bureau of Radiological Health.

NOTE: J. C. Drobinski, Jr., and E. J. Troianello of the Bureau's Northeastern Radiological Health Laboratory analyzed the tritium samples.

Table 5. Liquid radioactive waste discharges from operating power reactors [1]

Reactor and type [2]	Total annual discharge (curies)		Condenser cooling water available for dilution (gallons per minute)	Fraction of AEC discharge limit concentrations (percent) [3]	
	Gross activity less tritium	Tritium		Gross activity [4]	Tritium [5]
A. Pressurized water reactor	0.01	1,300	14,000	0.001 –0.13	0.16
B. Pressurized water reactor	11.1	500	260,000	.03 –4.7	.03
E. Boiling water reactor	.01	10	28,000	.0002– .05	.006
F. Boiling water reactor	1.3	20	100,000	.3 –1.2	.0035
G. Boiling water reactor	4.1	5–10	167,000	.3 –3.8	.001

[1] Reference 8.

[2] Corresponds to reactor designations in table 4.

[3] Reference 1.

[4] Applicable limit for continuous discharge for mixtures for radionuclides averaged over 12 months was 10^{-6}μCi per ml.

[5] Applicable limit is 3 × 10^{-3}μCi per ml.

pressurized water reactors for consideration of tritium releases is that in a PWR, leakage between the primary and secondary coolants must occur before the secondary system will be contaminated by tritium or other fission products. As shown in table 4, the tritium concentration in the secondary coolant of pressurized water reactors is only a small fraction of the primary coolant concentration. Thus, a much smaller amount of the tritium will be discharged in the form of elemental hydrogen through the condenser air ejector of a PWR as compared with a BWR.

Release of gaseous tritium. The amount of tritium discharged from both boiling and pressurized water reactors in a gaseous form is only about 1 percent of the total tritium discharge (*7*). Most of the tritium is released as tritiated water together with the liquid radioactive waste. In both types of reactors, a small part of the primary coolant water is continually drawn off, depressurized, cooled, and purified to remove fission and activated corrosion products.

The coolant stream is purified by filtration and demineralization which remove insoluble and soluble radionuclides. Gaseous activity, mainly noble gases and coolant activation products, is removed during coolant depressurization and then transferred to the gaseous radioactive waste processing system. Traces of tritiated water vapor and gaseous tritium are released from the coolant during this process.

Release of tritium in liquid wastes. Because tritium is in the form of tritiated water, it is not removed from the coolant by either filtration or ion-exchange. The purified water containing tritium may be transferred back to the reactor coolant system, stored for future use, or transferred to the liquid radioactive waste processing system.

The primary coolant is not continuously discharged to the waste disposal system. Leakage of the coolant from reactor coolant pumps and other components, however, can occur. This waste will be collected by the plant drainage system which drains to the liquid holdup tanks of the waste processing system.

The largest discharge of primary coolant to the waste treatment facility usually occurs after the reactor has been shut down for fuel reloading or maintenance. During fuel loading, water is added to the reactor cavity to provide radiation shielding and heat removal for the spent fuel elements as they are transferred from the reactor to the spent fuel storage pit.

The refueling water can mix freely with the reactor coolant and before startup this excess water must be drained from the reactor vessel. This excess water represents a considerable volume of the liquid processed by the radioactive waste system. It also contains considerable boron and, therefore, leads to additional tritium production after startup of the reactor. Liquid displaced by expansion of the reactor coolant as the plant power level increases during startup is also carried over to the waste processing system.

If the radioactivity level is sufficiently low, as determined by radiochemical analysis, the purified coolant may be discharged to the environment with the condenser cooling water. Liquid radioactive wastes consisting of purified reactor coolant, laundry wastes, and leakage from pumps and valves are stored in holding tanks before treatment. Treatment processes may include filtration, demineralization, or evaporation.

Although these processes are effective in reducing the concentration of other radionuclides by several orders of magnitude, generally they have no effect on tritium removal. The tritium is discharged to the condenser cooling water at almost the same concentration as in the reactor coolant except for a small amount of dilution by nontritiated wastes. The effluent concentrations are much lower, however, because of the large amount of dilution provided by the condenser cooling water.

Table 5 shows annual liquid radioactive waste discharges for several operating nuclear reactors. Tritium may comprise between 50 and almost 100 percent of the total amount of radioactive material discharged as liquid waste. Tritium discharge concentrations, however, are usually much less than 1 percent of the discharge limit as specified by the Code of Federal Regulations (*1*).

Tritium Detection

Tritium is undetectable by conventional methods of gross radioactivity analysis. Because tritium is usually in the form of tritiated water, it is usually evaporated during the procedures used to prepare water samples for radioactivity analysis. In addition, because of the low energy of the beta particle emitted during the decay of tritium, it is not detected by conventional gross beta counting techniques or in-line plant monitors.

As a result of these limitations, special analytical techniques such as liquid scintillation counting must be used to measure tritium.

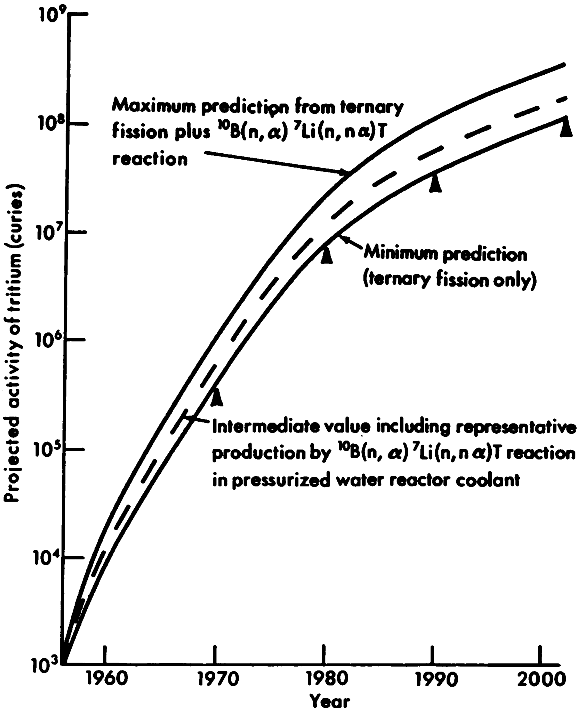
Limits for the discharge of unidentified mixtures of radionuclides cannot be correctly applied to tritium and due to the lesser biological hazard resulting from tritium, would be unnecessarily restrictive. The analytical techniques used to measure the activity of these mixtures usually include gross beta analysis, and since this technique is insensitive to tritium it would not be detected. Tritium may be separated from most other radionuclides by distillation of tritiated water. Tritium analysis can be made on the distillate using liquid scintillation counting. Conventional gross beta counting techniques can be used for the residue. The discharge limit can be calculated by ratioing the measured concentrations to the appropriate discharge limits ($3 \times 10^{-3} \mu$Ci per ml. for tritium and $3 \times 10^{-8} \mu$Ci per ml. for unidentified activity measured by gross beta analysis) and summing them. The limit $3 \times 10^{-8} \mu$Ci per ml. may be raised to $10^{-7} \mu$Ci per ml. if ^{129}I, ^{226}Ra, and ^{228}Ra are known to be absent. If the sum of the ratios is less than 1.0, the mixture may be released to the environment. If greater than one, further analysis or dilution is necessary before the liquid can be released.

Tritium Surveillance by BRH

Since 1964, the Radiation Surveillance Branch of the Bureau of Radiological Health has been operating a tritium sampling network which collects weekly samples of water for tritium analysis from 10 locations throughout the United States. Eight stations are downstream from nuclear facilities, and the other two serve to establish baseline levels. Samples from this network are analyzed monthly by the Bureau's Southeastern Radiological Health Laboratory.

Results of the analysis of samples from the tritium sampling network are reported periodically in *Radiological Health Data and Reports* (*9*, *10*). A special project to study tritium in surface waters of the western States is currently being conducted by the Southwestern Radiological Health Laboratory.

Projected cumulative activity of tritium produced in power reactors in the United States



▲ Total free world activity predicted by Cowser and co-workers, reference *12*.

Environmental tritium concentrations reported by the tritium sampling network for 1964–66 ranged between 2×10^{-6} and 2×10^{-5} microcuries per milliliter (2–20 nCi per liter) (*9*, *10*). Population exposure rates from continuous ingestion of this water would range from 0.33 to 3.3 mrem per year. The maximum concentration reported would contribute less than 3 percent of the normal average population exposure rate of 125 mrem per year from all natural sources of radioactivity (*3*).

The results obtained from this sampling network indicated, with one exception, that waters downstream from nuclear facilities did not show any significantly higher tritium concentrations than streams which did not have operating nuclear reactors on them (*9*). The one exception was a plantsite with several operating heavy-water moderated reactors on it. Releases of tritium in the liquid wastes from this plant did elevate tritium concentrations in the adjacent river above background levels. Tritium concentrations, however, amounted to less than 1 percent of the Atomic Energy Commission's discharge limit of $3 \times 10^{-3} \mu$Ci per ml.

A study by the nuclear engineering department of the University of Cincinnati, under a contract with the Bureau of Radiological Health, is developing projections of future radionuclide inventories based upon predicted growth trends in the nuclear power industry (*11*). The estimated tritium activity produced by increasing utilization of nuclear energy for electric power production forecast from this study is shown in the chart together with estimates made by the Oak Ridge National Laboratory (*12*). Based upon these projected levels, the total tritium produced from nuclear power facilities in the year 2000 will be more than 10^8 curies or approximately 5 percent of the maximum tritium activity present in 1963. At present, tritium releases from operating power reactors are only a small fraction of the discharge concentrations permitted by the Code of Federal Regulations and do not constitute a danger to health. The Public Health Service will continue to monitor the environment in the vicinity of nuclear reactors and fuel reprocessing plants and will evaluate any buildup of tritium in terms of a future hazard to health.

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Pain. *September 1968; 15 cents; 16 pages. Published by the National Institute of General Medical Sciences, National Institutes of Health.* Explores the nature of pain and man's attempts through the ages to endure it, cure it, explain it, and at times, use it for his own purposes. Makes a strong case for research in the nature of pain, for special training for physicians, and the development of new diagnostic and treatment techniques, including analgesics that control chronic pain over long periods without producing addiction.

Common Laboratory Instruments for Measurement of Radioactivity, April 1967. Interlaboratory Technical Advisory Committee Report No. 2. *PHS Publication No. 999–RH–32; June 1968; 104 pages.* Prepared by the Subcommittee on Physics and Instrumentation. Clarifies requirements and characteristics of instrumentation used to measure levels of ionizing radiation experienced by man in his environment. Assists responsible radiological health agencies in selecting optimum surveillance and counting systems.

Social Welfare Expenditures Under Public Programs in the United States, 1929–1966. *Social Security Administration, Office of Research and Statistics Research Report No. 25. By Ida C. Merriam and Alfred M. Skolnik; 1968; 254 pages; $2.* Presents data in 3 parts. Part I contains historical and trend data that measure one significant aspect of recent social change—the growing involvement of government, and increasingly the Federal Government, in social welfare programs and activities. Part II describes the public programs included in the the social welfare expenditure series. Each section contains a brief history of a particular program and its development. Explains the nature and basis of data included and summarizes the sources of data used. Part III presents statistical data of expenditures from 1929–66.

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INFANT AND PERINATAL MORTALITY IN ENGLAND AND WALES. *PHS Publication No. 1000, Series 3, No. 12; November 1968; 77 pages; 75 cents.*

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VARIATIONS IN BIRTH WEIGHT, LEGITIMATE LIVE BIRTHS, United States, 1963. *PHS Publication No. 1000, Series 22, No. 8; November 1968; 35 pages; 45 cents.*

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