Developments in nuclear science in the past decade have demonstrated many ways of putting radiation to use in solving classic problems in such fields as hydraulics, water quality, insect control, food preservation, and air pollution.

Applications of Radiation in Sanitary Engineering

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DURING the past decade the sanitary engineer has frequently assisted in solving problems associated with environmental surveillance of radioactive materials and their management and disposition. Often his studies of such problems have indicated beneficial uses of these materials. For example, studies of specific radionuclides contained in radioactive wastes have provided information on groundwater flow. Similarly, application of water treatment methods to decontamination of radioactive liquid wastes has demonstrated mechanisms of water coagulation and softening.

Encouraged by such results, the sanitary engineer in more recent years has been making direct applications of radioactive materials to the solution of classic problems. Although use of radionuclides in sanitary engineering is still far from routine, a sizable number of applications have been reported and others are in prospect.

Hydraulics

Traditionally, flow characteristics imposed by pipes, tanks, and other boundary conditions are determined by use of a stable tracer material such as sodium chloride or fluorescein dye. Such material does not always yield measurements sufficiently sensitive for accurate tracing of flow paths. On the other hand, radionuclides, evaluated for use under widely varying conditions, provide a highly sensitive technique for this purpose (fig. 1). No single radionuclide has proved ideal for all purposes, selection depending on several key factors:

1. Half-life of the radionuclide. It should be sufficiently long for practical application and sufficiently short for safe disposal.
2. Suitability for measurement by laboratory or field equipment.
3. Safety of personnel conducting the study and others who may be exposed.
4. Physical, chemical, and biological compatibility with the fluid.

For convenience in reviewing the various hydraulics studies of radioactive tracers, the following broad groupings have been made.

Pipe Flow

Radionuclide tracers for measuring fluid flow in pipes have found wide application in the pe-

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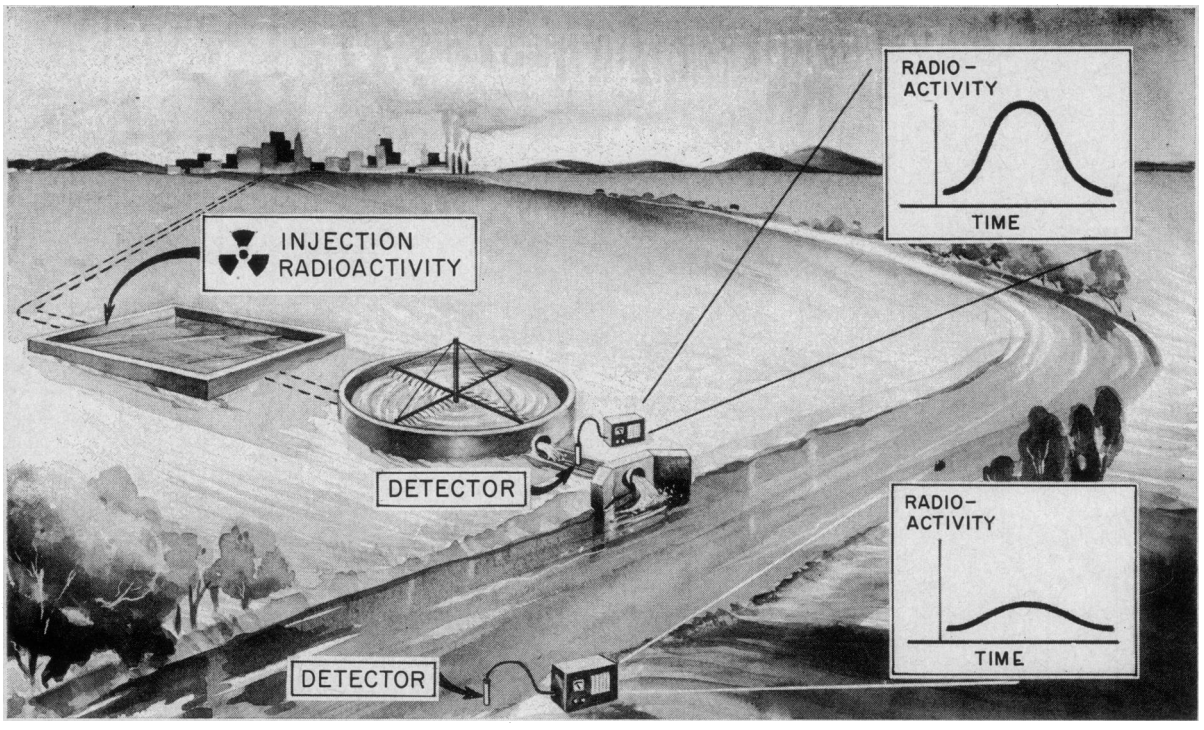


Figure 1. Hydraulics: Use of radiation in flow measurements aids study of tank design.

troleum industry. Their use enables flow measurement outside the pipe without disturbing flow conditions.

Studies on the longitudinal mixing of water in pipes, employing iodine-131, were reported as early as 1950 (*1,2*). The flow time within a milk pasteurization unit (short-time, high-temperature type) has also been evaluated with iodine-131 (*3*). Natural radon and added radium tracers have been used in studies of sewage flow (*4*) and outfall (*5*).

Leaks have been located in newly installed water mains through use of sodium-24. With this nuclide, a counting probe placed close to a pipe junction can detect leakage of as little as 100 milliliters (*6*). Unless the detector can be placed close to the leak, however, such methods are impractical. For example, to detect a leak 5 feet under ground would require a source strength equivalent to 3 curies of cobalt-60.

Tank Flow

Various radionuclides have been used successfully in determining detention time and dispersion in tanks. Radium was used by Hess in 1943 (*7*), but is no longer recommended because of its high cost and toxicity. Today, manmade radionuclides such as sodium-24 (*8*) and potassium-42 (*9*) are being used for measurement of detention time in industrial plant systems.

For tracing sewage flow, biological compatibility of the tracer material is a principal factor. Rubidium-86 is most commonly employed, the first report of its use appearing in 1953 (*10*). In a comparative study of rubidium-86 and bromine-82, the flow characteristics of an anaerobic sewage treatment plant were determined (*3*). Similar results were obtained with these radionuclides.

The dispersion of sewage in a 2-acre lagoon has also been determined. Here, with portable field instruments, iodine-131 tracer was measured (*11*).

Radionuclides are also being used in measureing silt at the bottom of large bodies of impounded water. The technique is based upon a density gauge which detects low-energy bremsstrahlung radiation (*12*).

Watercourse Characteristics

Many factors influence the diffusion characteristics of stream flow. Radionuclides have

proved effective in the determination of stream flow patterns. Use of radium for this purpose was first suggested by Joly in 1922 (*13*). In recent years, radioactive materials have been used for evaluating stream capacities for radioactive wastes. Studies on the Mohawk (*14*) using phosphorus-32 demonstrated the concentration of radioactive phosphorus by biota. In addition, certain hydraulic characteristics of the stream were revealed. Scandium-46 was used in tracing sewage effluent discharged into Santa Monica Bay (*15*). A study on the Ottawa River (Ohio) in which salt, fluorescein, and rubidium-86 were tried in flow measurements indicated that these tracer materials produced similar results (*3*).

Tritiated water, because of its chemical similarity to normal water, should be an ideal tracer for flow studies of this type. However, it has found limited application because of difficulties in measuring it. Tritium has been used successfully, nonetheless, in tracing flow through a model of the Savannah Tidal Estuary (*16*).

Ground Water

The cation exchange properties of soils are a principal deterrent in selecting effective tracers for ground-water movement. Although Fox (*17*) successfully employed rubidium-86, the soil studied was a porous, sandy type, atypical of most soils. Kaufman and Orlob (*18*) concluded that only anionic tracers, such as iodine-131, or non-ionic tracers are suitable for ground-water tracing. Chelation has been suggested as a means of converting radiocations to non-ionic form for use as ground-water tracers. The process has been demonstrated successfully in the laboratory (*19*).

Use of tritium as a ground-water tracer is being studied. Its concentration in ground water is also being used to determine the water's age (*20*).

Flow of Solids

Settling or scouring of solids from liquid media can frequently be measured directly. In some instances, however, information regarding the interchange of solids is desirable. For example, the movement of silt in the River Thames has been studied through use of sand particles tagged with scandium-46 (*6*).

Floc particles bearing radionuclides have been used to determine removals by filtration media. In one such study, the effective depth of penetration of floc particles in sand filters was observed by use of iodine-131 tracer (*21*). In another study, iron-55 and iron-59 were used to evaluate graphite, anthracite, and sand as filtration media (*22*).

Water Quality

Analytical procedures employing radioactive tracers have been developed for both chemical and bacteriological contaminants in water. In many instances these procedures have markedly increased the sensitivity of measurement and have simplified assay methods as well. Radioactive tracers have been used also to determine removal mechanisms and related factors in various treatment processes designed to improve water quality.

Chemical Assay

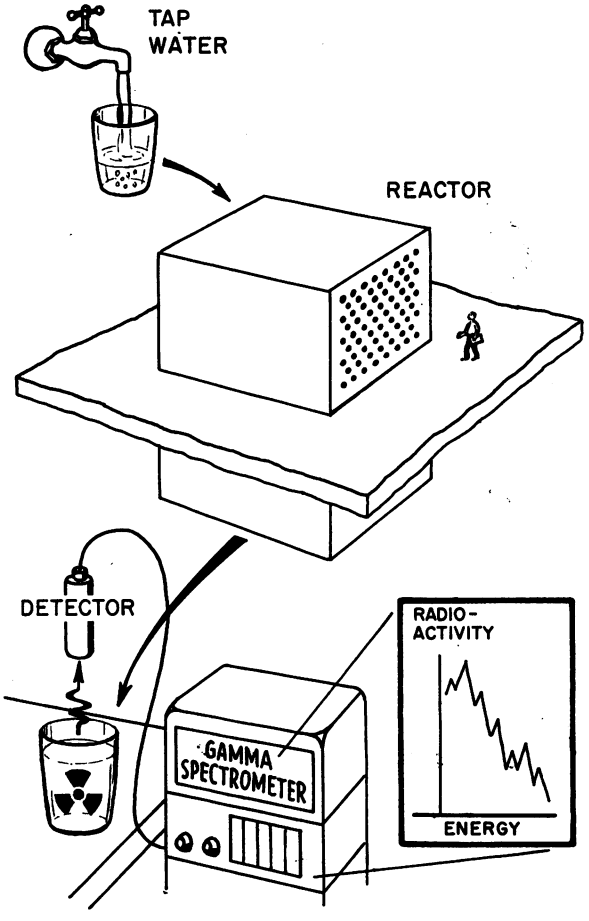
For chemical assay, two basic approaches have been explored: radiometric titration methods and neutron activation analysis.

Radiometric titration techniques using nuclide tracers to sensitize the end point have been specified for chloride and sulfate determinations. Many other applications have been suggested (*23*).

Activation analysis has been widely accepted in many fields for the determination of trace quantities of more than half the known elements (*24*). The technique is based on the fact that most elements when subjected to neutron bombardment give rise to radioactive species of the same element. The radiations emitted by these materials are characteristic of the particular element. Through study and measurement of emitted radiations, it is possible to determine the quantities of stable elements originally present in the sample.

The recent application of the neutron activation technique to the analysis of drinking water promises to broaden and extend knowledge of water quality (fig. 2). Typical elements readily determined in water by this procedure include chlorine, bromine, iodine, copper, arsenic, manganese, barium, strontium, and sodium. Concentrations in the range of 1 part in 10^9 are easily detected (*25*).

Figure 2. Chemical Assay: Neutron activation provides an analytical method for both qualitative and quantitative determination of stable elements.



Bacteriological Assay

Basic knowledge regarding the metabolism of various food essentials by organisms has been expanded in recent years as a result of tracer techniques. A development which shows promise in the field of water quality assay is a rapid technique for the presumptive coliform test. This technique is based on the metabolism of lactose labeled with carbon-14 to form radioactive carbon dioxide (*26*). This metabolite, indicating a presumptive test, can be detected in as short an incubation time as 15 minutes (fig. 3).

Water and Waste Processing

Corrosion and scale formation have concerned the sanitary engineer for many years. Today studies employing radioactive materials promise to help him gain a better understanding of these conditions. Studies employing calcium-45 have yielded information regarding the mechanism of scale formation (*27*).

The mechanism by which phenol is adsorbed and desorbed from activated carbon has been investigated by using phenol labeled with carbon-14 (*28*). The fate of a detergent subjected to activated sludge treatment was studied by use of detergent tagged with sulfur-35 (*29*). With phosphorus-32 tracer, the phosphate cycle, including biota uptake and circulation, has been studied in lake water (*30*).

Gamma radiation for disinfection of water or sewage is frequently mentioned. Use of waste fission products in treating the material has been suggested; also sterilization of sewage by using it as a reactor coolant (*31*). Studies have indicated that high exposure levels (about 1 million roentgens) are required for disinfection (*32,33*). Hence, the feasibility of such irradiation methods is doubtful because of

Figure 3. Bacteriological Assay: Radiotracers may provide a rapid and sensitive method for the presumptive coliform test.

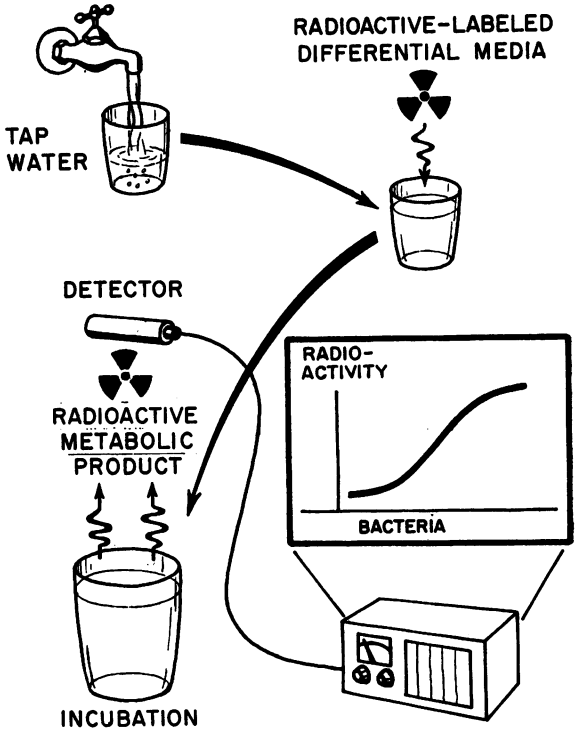
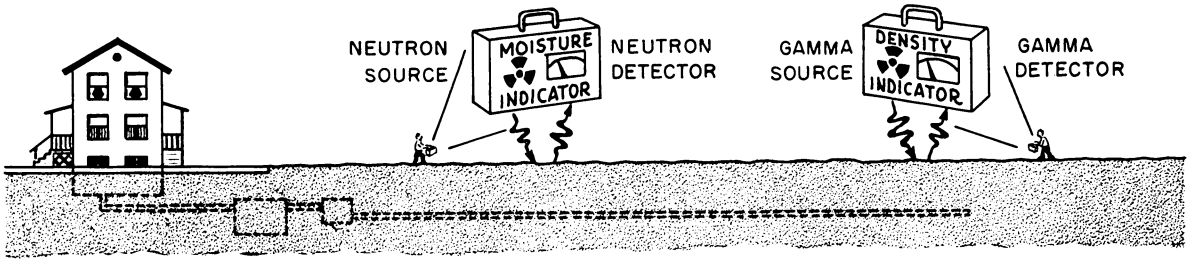


Figure 4. Soil Properties: Field measurements of soil moisture and density show promise for use in designing household sewage disposal systems.



safety considerations. The neutron activation problems associated with the latter proposal might be particularly troublesome.

Studies have been made on the transport of sewage sludge through a digestion tank using raw sludge labeled with radioactive phosphorus (*34*). Beneficial information has resulted, particularly with regard to methods for stirring, adding, and withdrawing sludge from such systems. Use of radiation to develop new strains of biota for better oxidation of sewage has been proposed. This suggestion is based on the known ability of radiation to produce genetic changes. Through such changes improved strains of biota might result.

Other Applications

Applications of radiation in sanitary engineering cover a wide variety of other subjects.

Hydrology

Accurate predictions of runoff from snow packs are readily accomplished through use of gamma sources (*35*). Attenuation of the radiation by the snow itself permits accurate determinations of its depth. For example, with a 40-millicurie cobalt-60 source, depths having a water equivalent up to 55 inches can be measured and the information automatically reported from remote locations by means of a telemetering system (*36*).

Soil Properties

Density and moisture content of soils are amenable to measurement by use of radiation, and such measurements can be made directly in the field. In early studies, soil density was determined by the degree of gamma ray attenuation (*37*). In more recent developments,

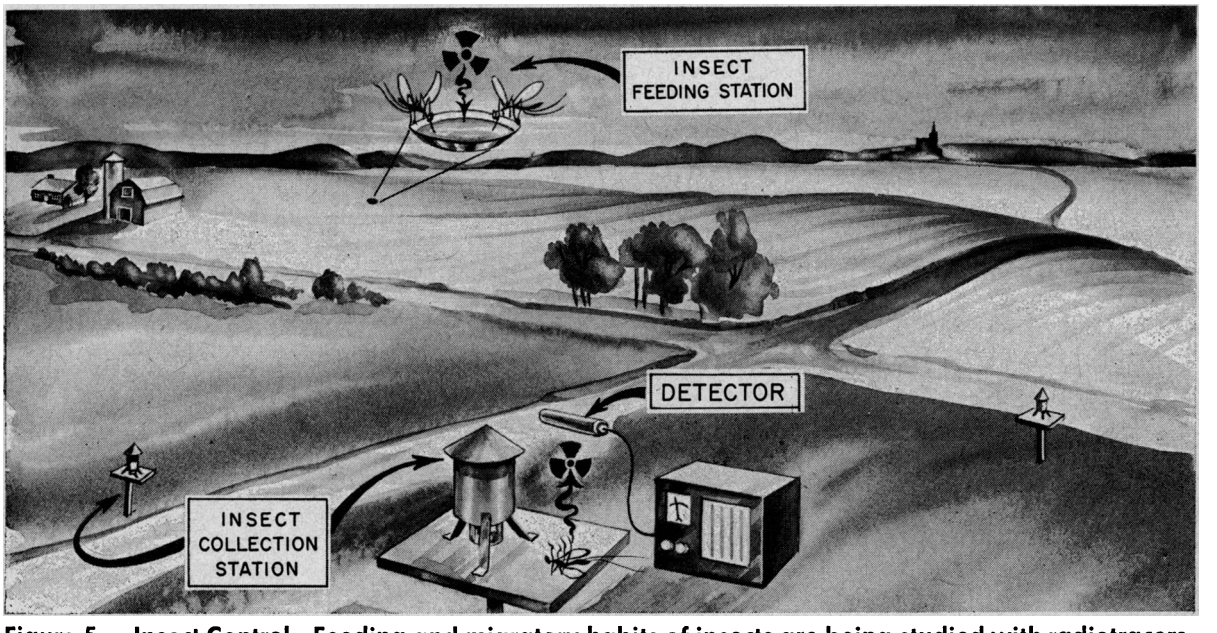


Figure 5. Insect Control: Feeding and migratory habits of insects are being studied with radiotracers.

density is measured by correlation with the amount of scattering of gamma radiation when a radiation source is placed in contact with the soil (*38*). Moisture-content measurements are based on the neutron-moderating properties of soils. A source of fast neutrons is used in conjunction with a slow neutron detector. For most soils, the number of slow neutrons detected is proportional to the hydrogen or water content (*12*). These techniques offer promise in establishing design criteria for rural sewage disposal systems (fig. 4).

Insect Control

Radionuclide tracers are providing information on the travel of insects, their feeding and parasitic habits, and other factors affecting disease transmission (fig. 5). As an example, the dispersal of mosquitoes and flies has been studied using phosphorous-32 and zirconium-95 tracers (*39*).

For control of certain insects, particularly the screwworm fly, gamma radiation is being used to sterilize the males and thereby interrupt the reproduction cycle (*12*). It is envisioned that within the next few years complete eradication of the screwworm fly in southeastern United States will be possible by this means.

Another approach to insect control is the use of gamma radiation to reduce insect infestation in packaged materials. Irradiation with cobalt-60 and fission products has been studied as a technique for ridding packaged foods of various species of beetles and flies (*40*). Exposures of about 65,000 roentgens are required to kill, 16,000 to 32,000 to inhibit reproduction. Irradiation has certain inherent advantages over chemical fumigation, particularly the ease of application and completeness of control (*40*).

Food Preservation

Research indicates that all types of food can be sterilized by radiation, regardless of the species or numbers of contaminating organisms. Certain side reactions, however, may make the food less wholesome, cause changes in taste or texture, or create toxic products (*41*).

Transmission of trichinosis through pork products is of particular public health importance. Studies of gamma irradiation of raw pork, with cobalt-60 or fission products, have shown that transmission of this disease can be prevented without producing detectable taste changes (*42*). Radiation exposure levels of about 20,000 roentgens are sufficient to inhibit the maturation of trichina larvae (*43*).

Food Sanitation

Cleansing abilities of detergents are being evaluated through use of radionuclide-tagged soils and bacteria. Methods for the preparation of the soils have been formulated (*44*). Among a variety of radionuclides tried, phosphorus-32 has proved good for tracing bacteria. Through such applications, the relationship of cleansing efficiency to type of utensil, surface conditions, and type of organism has been evaluated (*45*).

Air Pollution

Radionuclides have proved successful in providing data on the dispersion and dilution of air contaminants and the effectiveness of control measures. A unique method of using a radioactive gas to trace dust aerosols has been reported (*46*). If a radioactive gas, such as thoron, is added to a dust aerosol, the radioactive atoms of the decay products will be adsorbed by the dust particles. The resultant radioactivity of the aerosol may then be used to characterize the finest suspended matter. Dusts, so labeled, have provided information on filter efficiencies, the structure of filter media, and the mechanism of operation of sampling and control equipment.

Another application in the field of air pollution investigation is neutron activation. For example, the dispersal of nonradioactive antimony oxide from a stack was traced through irradiation of collected air samples in the reactor at the Oak Ridge National Laboratory (*47*). With this technique, as little as 3×10^{-9} gram of antimony per cubic foot can be detected. This is a sensitivity exceeding that of the best chemical method. It is also interesting to note that under the conditions of the experiment no radioactive material was released to the atmosphere.

Conclusion

Essentially every phase of sanitary engineering has benefited from nuclear technology, and the potentialities of the applications appear to

be endless. Hence, nuclear science is assisting substantially in attainment of the goal of sanitary engineering: the improvement of the public health, principally through the control of man's environment.

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Coordinator of International Affairs

A new position, Departmental Coordinator of International Affairs, has been established in the Department of Health, Education, and Welfare.

The new position will coordinate international activities related to health, education, vocational rehabilitation, social insurance, social welfare, and other areas within the Department and provide liaison with other Government departments and agencies having international concerns. The Department's operating agencies will continue to hold direct administrative responsibility for the international aspects of their programs.

Robert A. Kevan has been named to fill the new post. He served as special assistant to the chief medical director of the Veterans Administration and for 2 years was assistant chief of the Formosa field office of a management consultant firm before coming to the Department in March 1958 as assistant to the Assistant Secretary.