12 material, waste disposal

not in database

ChemRisk Document No. 2526

# HANDLING Radioactive Wastes IN THE Atomic Energy Program

FILE COPY

UNITED STATES
ATOMIC ENERGY COMMISSION
OCTOBER 1949

UNITED STATES GOVERNMENT PRINTING OFFICE • WASHINGTON, D.C.

For sale by the Superintendent of Documents

## CONTENTS

| | Page |
|---|---|
| INTRODUCTION | v |
| I. THE MEANING OF RADIOACTIVITY | 1 |
| Half-life | 2 |
| Measuring Radiation | 2 |
| Effects of Radiation | 3 |
| Permissible Dose | 4 |
| AEC Practice | 4 |
| II. TYPES AND SOURCES OF RADIOACTIVE WASTES | 6 |
| Radioactive Waste Problem | 6 |
| Effects of Internal Radiation | 7 |
| Sources of Radioactive Wastes | 8 |
| Cooling Water | 8 |
| Cooling Air | 8 |
| Chemical Separation Residues | 9 |
| Solid Wastes | 9 |
| Handling "Hot" Laboratory Wastes | 10 |
| Development of Improved Waste-Handling Methods | 10 |
| III. SAFE HANDLING OF RADIOACTIVE WASTES IN THE ATOMIC ENERGY INDUSTRY | 11 |
| Methods for Handling Gaseous Radioactive Wastes | 12 |
| Material Processing, Metallurgy, and Machining | 12 |
| Air-Cooled Reactor Operations | 13 |
| Meteorological Surveys | 13 |
| Area Monitoring Program | 14 |
| Chemical Separation Operations | 14 |
| Laboratory Research | 15 |
| Incineration | 16 |
| Stack Gas Problem Working Group | 16 |
| Safe Handling of Liquid Radioactive Wastes | 16 |
| Reactor Cooling Water | 16 |
| Liquid Processing Wastes | 16 |
| Laboratory Wastes | 17 |
| Research and Development | 18 |
| IV. SAFE HANDLING OF WASTES RESULTING FROM RADIOISOTOPES DISTRIBUTION PROGRAM | 19 |
| Precautions Taken by Isotopes Division | 19 |
| Disposal of Laboratory and Clinic Radioactive Wastes | 20 |

## APPENDICES

| | |
|---|---|
| A. AEC ADVISORY COMMITTEES | 22 |
| B. WASTE DISPOSAL RESEARCH AND DEVELOPMENT SUPPORTED BY AEC | 27 |

# Introduction

The laboratory and production operations of the United States atomic energy program create a variety of potentially harmful waste materials which must be handled in special ways. The problem of waste disposal is not unique to the atomic energy industry. Many other large industries must dispose of noxious waste materials created in the course of their operations. In this respect, the atomic energy industry differs from other industries in that many of its wastes before treatment involve relatively large amounts of radioactivity, with which public-health officers, sanitary engineers, and others concerned with waste disposal have had little experience in the past.

Since improper handling of radioactive waste materials could endanger public health, the United States Atomic Energy Commission believes that the facts about this problem should be available.

This report describes radioactive waste materials, their sources in the atomic energy program, and the methods used in processing and storing or disposing of them at atomic energy installations and at laboratories and hospitals using radioisotopes. The appendices give more precise technical information on the research and development under way to bring about even greater safety, as well as to lower costs.

In carrying on its program for safe handling of radioactive wastes, the Commission relies heavily upon the individual programs of its prime contractors. In addition, it draws upon the talents and knowledge of other Federal agencies, of State and local health officials and sanitary engineers, and of specialized industrial consultants trained in engineering and health techniques. A number of agencies—notably the United States Public Health Service, the United States Weather Bureau, the Tennessee Valley Authority and the United States Geological Survey—are already cooperating with the Commission in the solution of specific problems.

# I. The Meaning of Radioactivity

Radioactive materials are those materials which release energy, either in the form of small, fast-moving nuclear particles, or as energy rays similar to light. The rays and particles released by radioactive materials are collectively called "radiation." When radiation passes through other materials, such as air, metal, or animal tissue, it has the property of electrifying the materials along its path. This process is called "ionization," and the radiation itself is then called "ionizing radiation." In living tissues the ionizing effect of radiation causes the injury and death of cells. Ionizing radiation, therefore, if applied in amounts large enough to kill many cells, can do great harm to a plant, an animal, or a human being.

We are familiar with three common types of nuclear ionizing radiation: *alpha particles, beta particles,* and *gamma rays.* All three produce ionization when passing through other materials. Each fast-moving alpha particle bears a positive electric charge and is the nucleus of an ordinary helium atom. Beta particles also travel at high velocities, but in this case the particles—which are electrons—are very much lighter and have a negative, rather than positive, charge. Gamma radiation, unlike alpha and beta particles, is radiant energy similar to light or X-rays. There is no associated particle and no electrical charge. Even sunlight in sufficient intensity will burn unprotected skin. The far more energetic and penetrating gamma rays can injure cells deep within the body.

Relatively few of the substances found in nature are radioactive. In the atomic energy program, however, large quantities of materials are made radioactive through artificial means. These are the materials that create the radiation hazards associated with the processing and handling of radioactive waste. Some idea of the size of this problem may be gained by realizing that an operating nuclear reactor generates radiation equivalent to several hundred tons of the naturally radioactive element, radium. In contrast, only 3 pounds of pure radium have been made available in the whole world during the last 50 years.

## HALF-LIFE

A radioactive material is radioactive because its atomic nuclei are disintegrating—that is, they are undergoing a process of radioactive "decay" by shooting out particles or gamma rays. The length of time that a material will remain radioactive is measured in terms of "half-life," which is the period required for one-half of its atomic nuclei to give off a particle or gamma ray and become more stable. Radioactive materials with very short half-lives are said to be very unstable, while those with long half-lives are said to be relatively stable. A completely stable material is, of course, nonradioactive. An unstable material continues to "decay" until every atomic nucleus has reached a point of nuclear stability. When this point is reached the material is no longer radioactive. The half-lives of radioactive materials that can be measured range from less than a millionth of a second for one type of radioactive polonium to more than a million million years for a radioactive form of the rare metal rhenium. In the case of any radioactive material, after 6 half-lives have elapsed only 1.6 percent of the original radioactivity remains.

Since radioactivity involves the nuclei of atoms, the rate of decay cannot be modified by any ordinary means. Even temperature, at least in the ranges with which we are most familiar, has no perceptible effect on the half-life. Our inability to change the decay rate sharply limits the methods at our disposal for controlling and handling radioactive materials.

## MEASURING RADIATION

Scientists use two common units in measuring radiation. One is the "curie," which is an amount of radioactive material in which 37 billion nuclear disintegrations per second occur. This is approximately the number of disintegrations that takes place each second in one gram of radium. A millicurie is one-thousandth of this amount, or 37 million disintegrations per second; and a microcurie is one millionth of this amount, or 37 thousand disintegrations per second. While the curie was arbitrarily based on radium disintegration, it continues to serve as a convenient measure of the amounts of different radioactive materials required to provide a fixed amount of radioactivity.

To give some indication of radiation's ionizing effect on other materials, scientists use another unit of measurement. This unit is called the "roentgen." The roentgen measures the amount of energy absorbed by material receiving radiation. It is a unit based on the amount of X-rays or gamma rays required to produce ions equivalent to one electrostatic unit of charge in one cubic centimeter of air under standard conditions. Similar units have been developed to measure the amount of energy lost by any type of radiation in producing ionization in any material. These are termed roentgen equivalents.



## EFFECTS OF RADIATION

Present knowledge of radiation effects is based largely on scientists' observations of the changes that take place in the cells of plants and animals exposed to X-rays and the gamma radiation from radium. However, the kind of damage done to living cells of plants or animals by all types of radiation—alpha, beta, gamma, or X-ray—is identical. In an examination of tissue damaged by radiation, it is usually impossible to tell by the kind of damage just what type of radiation caused it.

In discussing the amounts of radiation that the human body can stand, it should be remembered that all living things on the earth are being bombarded continually by cosmic rays, which are very penetrating ionizing radiations. Persons living near sea level probably receive about two roentgens of cosmic radiation during the course of a normal lifetime. Persons living in mountainous areas, on the other hand, may receive from 10 to 20 times as much. At these higher altitudes, the thin blanket of air absorbs only a small amount of radiation from outer space.

A person can take a much larger dose of radiation in a single part of his body than he can in his body as a whole. As an example of the amount of radiation that can be applied safely to a small area of the body, it might be pointed out that a dose of 5,000 roentgens (usually referred to as simply 5,000 r) is not infrequently used to treat a small skin cancer. There will be a scar after this type of treatment, but probably no serious or lasting harm is done. A tenth of that total, if given to the whole body in a short time, would be enough to cause death in most human beings.

The effect of total body radiation given to an individual will be less severe if it is spread over several applications than if the same amount is given in a single dose. The rest period between doses allows for an appreciable recovery. It is possible that no deaths would occur if a group of persons were exposed to 100 roentgens each day on 3 successive days. The same dose in a single application of 300 roentgens would probably kill some out of a large group of people so irradiated. It is believed that a dose of about 400 roentgens would kill half the people exposed to it. This is called a 50 percent lethal dose (LD–50) or a dose sufficient to kill 50 percent of the population receiving it.

There are also enormous differences in species. The little animalcules called paramecia that swim around in a fresh-water pond have an LD–50 of 300,000 roentgens. In other words, if we were to radiate a population of paramecia, it would take about 300,000 roentgens to kill half of them. In a population of the pupal stage of some insects, the LD–50 is about 150,000 roentgens. In the rat, it runs somewhere between 825 and 900 roentgens, and in the guinea pig, one of the most sensitive animals to radiation, only about 250 roentgens. Plants, in general, are far more resistant than animals to radiation.

861092°—49——2

Persons sub- tting to an ordinary chest X-ray will receive from four-tenths to 2 roentgen. aring the short course of their exposure to the X-ray machine, while persons submitting to a complete gastro-intestinal series of X-ray pictures may receive as much as 40 to 75 roentgens. Remembering these facts helps keep perspective in discussing radiation problems.

## PERMISSIBLE DOSE

Many years ago medical scientists agreed that a normal human being could sustain a continuous day-in-and-day-out whole-body external exposure of one-tenth roentgen per day without any detectable effects. Accordingly, this figure has come to be known as the "permissible dose." More recently, experts in the field of biology and medicine have found that this accepted permissible level does not have as large a safety factor as once thought. For this reason, the National Committee on Radiation Protection, an advisory committee to the National Bureau of Standards, the body which sets radiation standards in the United States, has recommended that the "permissible limit" for continuous exposure be reduced to about three-tenths roentgen per week.

Eight subcommittees of the national committee have been formed to study particular problems of radiation protection. These groups are trying to formulate systematic codes of protection recommendations in each of the following eight fields:

1. External Permissible Dose.
2. Internal Permissible Dose.
3. X-rays Up to Two Million Volts.
4. Heavy Particles (Neutrons, Protons, and Heavier Particles).
5. Electrons, Gamma Rays, and X-rays, Above Two Million Volts.
6. Safe Handling of Radioactive Isotopes.
7. Monitoring Methods and Instruments.
8. Decontamination and Waste Disposal.

Subcommittees 2, 6, 7, and 8 are concerned in part with phases of the problem of treating and handling radioactive wastes. (The membership of the national committee and Subcommittee 8 is given in Appendix A.)

## AEC PRACTICE

The radiation exposure permitted employees in the atomic energy program is generally held much lower than the standard permissible levels. In this connection, the Atomic Energy Commission's Safety and Industrial Health Advisory Board reported in 1948: "History affords no parallel to the thorough study of and protection against radiation hazards to workers, from inception of the project to the present."

There were only 2 deaths and 13 injuries caused by accidents involving external radiation in the Manhattan Project, the organization which produced the atomic weapons of World War II—a remarkable record, in view of the fact that the quantities of radiation were thousands of times greater than any heretofore encountered, and that tens of thousands of employes worked with radioactive materials. In contrast, more than 70 deaths of people working in the Manhattan Project were caused by construction accidents and other common industrial hazards. Even this rate was far below the national average for similar work.

# II. Types and Sources of Radioactive Wastes

There are two main sources of radioactive wastes which must be given special handling to assure safety:

1. The production phases of the national atomic energy program—the huge separation plants and nuclear reactors.
2. The laboratories and hospitals where radioactive materials are used as research tools or for medical treatment.

The radioactive wastes from the operations in the national atomic energy program may be gases, liquids, or solids. The substances in the air or water that carries away the heat generated in nuclear reactors become radioactive as they pass through. Varying amounts of radioactive materials remain in the liquid residues from the chemical processes used to separate plutonium from uranium and the fission products. Metal containers, pipes, vents, and other equipment exposed to radiation over long periods of time may become contaminated with radioactive materials.

At hospitals and laboratories using radioisotopes, the radioactive wastes that cause disposal problems are chiefly liquids containing residues of the radioactive material used in experiments or treatment of patients. Scientists and physicians generally use only minute amounts of these materials, which with a few exceptions, notably radiocarbon (carbon 14), have short half-lives. Handling wastes from these sources is not nearly so difficult as handling the wastes from atomic energy production installations and reactors.

## RADIOACTIVE WASTE PROBLEM

From the beginning of the atomic energy program, a cardinal operating principle has been that workers and the public should be protected at all times from *external* radiation—that is to say, from radiation that strikes only the outer surface of the body. In handling radioactive wastes, however, the principal problem to guard against is *internal* radiation. Radioactive materials discharged as waste must not be permitted to find their way into the body and subject it to an internal bombardment of radiation.

Radioactive gases discharged from some atomic energy installations might be potentially harmful to human beings if not well controlled. These gases are usually discharged from tall stacks. Normally, radioactive gases and



particles carried by the gases will be quickly scattered and very little radioactivity will be found in the air. Under unusual atmospheric conditions, however, these gases might be carried rapidly to the ground where they could be inhaled or the radioactive particles could be deposited on plants or on the soil. Contaminated vegetation, in turn, might be eaten by animals or by people, or fall to the ground in the form of leaf litter.

Liquid wastes which find their way into streams are also potential hazards for they might be swallowed by animals or absorbed by algae or other micro-organisms and in turn be consumed by fish. In either case, the internal radiation hazard would be similar to that from air-borne wastes.

### Effects of Internal Radiation

In animals and human beings, the effects of internal radiation depend largely upon the particular material involved. Different materials are handled by the body in different ways. The amount and character of damage done by any specific material is governed mainly by four factors:

1. *The quantity of the material that is absorbed in the body.* One of the very dangerous radioactive substances is plutonium. But if plutonium is swallowed, only a very small fraction ever remains in the body; the bulk of it is not absorbed.
2. *The distribution of the material in the body.* If a small amount of radioactive sodium is swallowed, it will be distributed widely throughout the body, so that a gram of shoulder or upper arm muscle will contain about as much radioactive carbon as a gram of lung or spleen. On the other hand, radioiodine is absorbed in highly selective fashion; roughly seven-eights of it normally goes to the thyroid gland. In a 150-pound man, the thyroid will probably weigh only about half an ounce. This tiny size, compared to the whole body, and the localization of nearly 90 percent in the thyroid, makes this a case of very specific absorption. Certain other materials, such as radiostrontium and plutonium may be deposited in the bone, where they do considerable damage to the radiation-sensitive bone marrow, where the body's blood cells are formed.
3. *The rate at which the material is excreted from the body.* The turn-over in sodium, for example, is very rapid. On the other hand radiostrontium, plutonium, and some other radioactive substances formed in the processes of the atomic energy program, if taken into the body, localize in the bones and may stay there for considerable periods of time.
4. *The half-life of the material.* A material such as radiofluorine with a 2-hour half-life cannot be a serious radiation hazard in any ordinary quantities since its radioactivity is so quickly lost. Radiocarbon, however, with a half-life of over 5,000 years, remains potent for as long as it stays in the body.

In "hot" laboratories where radioactive materials are used, gaseous and liquid wastes are handled in a number of different ways. No single method stands out for general use. Users of radioisotopes in tracer work do not as yet run into particularly severe waste problems, because of the small amounts of activity.

## DEVELOPMENT OF IMPROVED WASTE-HANDLING METHODS

In brief, gaseous, liquid, and solid wastes appear at each of the various "hot" steps in atomic energy processes. The methods of safe handling used to date have successfully protected workers and the public. The ultimate goal is to improve the basic design of equipment so as to cut down waste at the source, rather than to attempt to deal with the wastes by such means as filters and retention basins after they have been produced. The present steps will still be necessary, but they will no longer be the first line of defense. The storage of "hot" liquid wastes is expensive. It can be tolerated for a time at one or two locations, but if the industry is to expand, better means of isolating, concentrating, immobilizing, and controlling wastes will ultimately be required. To meet this need, the Atomic Energy Commission is currently sponsoring research and development of better waste-handling methods at many sites. (See Appendix B.)



# III. Safe Handling of Radioactive Wastes in the Atomic Energy Industry

At every atomic energy installation, technicians and engineers continually review production processes in order to reduce the volume of wastes. Much progress has been made; but improvement in control of wastes requires continued research and development work.

Many atomic energy wastes have an unusually large salvage or reclaim value. Some advance has been made in reclaiming certain radioactive waste materials; and substantial improvement may be expected from other methods now in the development or pilot stage. In the meantime, economic as well as safety considerations require that valuable wastes be stored until adequate reclamation methods are worked out.

Two distinct, basic methods for handling radioactive waste materials are *dilution* and *concentration*. Since living organisms do not pick up radioactive forms of a chemical element in preference to the nonradioactive forms, dilution of the radioactive material with the same material in a stable form is an excellent safeguard.

In cases where sufficient dilution is not feasible, it is desirable to concentrate the radioactivity in as small a volume of material as possible and then store it in a safe manner. Much research and development work now being carried on in the national atomic energy program is devoted to methods for concentrating gaseous, liquid, and solid radioactive materials.

In the urgency of maintaining high production, discharge standards have been set which on one hand do not seriously hamper production and on the other hand are at a rate so low that no damage to plants, animals, or humans has resulted. They are believed satisfactory from the public health standpoint. In fact, as the long-time effects of radioactive materials become better known through observation and research, the present standards may be found unnecessarily severe.

Successful use of atomic energy will develop on a wide scale only if production plants, laboratories, and hospitals carry on their operations so that the discharge of radioactive wastes does no harm to the surrounding community of plants, animals, and men. The complete achievement of this ideal situation will require much research and development work to find new and better waste disposal methods. For example, we must have more complete

861092°—49——3

understanding of the permissible doses (tolerance levels) which men, animals, and pla can absorb without affecting their health, growth, and length of life. The National Committee on Radiation Protection is now engaged in evaluating and establishing such permissible levels.

More information is also needed about the various biological systems, micro-organisms, higher plants and animals living in environments of low levels of radioactivity. These long-term studies take time. A number are already under way and additional research will be undertaken.

In addition, better methods of concentrating radioactive wastes in air and water are needed. These may be mechanical, electrical, chemical, or biological, or any combination of these.

## METHODS FOR HANDLING GASEOUS RADIOACTIVE WASTES

Several operations carried on in the plants and laboratories of the atomic energy program produce radioactive wastes that might create a hazard if considerable quantities of them were allowed to go into the air in and near the installations. Operations that produce these gaseous wastes include material processing, metallurgy and machining, air-cooled reactor operation, chemical separations, laboratory research, and incineration.

### Material Processing, Metallurgy, and Machining

Preliminary preparation of uranium ores requires drying, crushing, grinding, sieving, and similar operations. Dusts from these operations are not highly radioactive so that ordinary precautionary measures are adequate. At this stage the hazards from chemical toxicity are perhaps greater than those from radioactivity. Dusts are removed from the working space and the atmosphere in the plants by ordinary industrial types of mechanical separators, electrostatic precipitators, and filters. Better equipment is being installed in existing plants working on AEC contracts, and in new plants the Commission insists on installation of equipment capable of removing practically all contamination.

In the chemical processing of ores, the fumes, mists, and gases are scrubbed and filtered before release to the atmosphere. The radiation hazard associated with uranium ores and the refined metal is not excessive because of the low-level radioactivity of these products.

During the metallurgical and machining operation on uranium, fumes, and dusts of the metallic oxides may develop. These are removed by ventilation and filtering to avoid contaminating the work areas or the outside atmosphere.



### Air-Cooled Reactor Operations

Air used for cooling a nuclear reactor becomes slightly radioactive. The most abundant component is radioargon (argon 41) having a half-life of 110 minutes. Radiocarbon (carbon 14) is discharged but in such small amounts that it creates no public health problem. Under abnormal conditions, uranium oxide and radioactive fisson products may contaminate the cooling air, but these materials are removed by proper facilities including filters.

The only air-cooled reactor now in actual operation is at Oak Ridge; this reactor is equipped with filters which treat the cooling air before it leaves the stack. Continuous air samples and other measurements are taken in the vicinity of the reactor building to insure that the stack discharge is safe at all times. Readings of radioactivity in air taken within a mile of the stack are about twice the normal cosmic ray background. This does not represent a dangerous condition. It should be noted that making measurements of such low levels of radioactivity is very difficult.

A second air-cooled reactor is now under construction at Brookhaven National Laboratory, Long Island. The air will be filtered both before and after delivery to the reactor and will be dispersed to the atmosphere at high velocity through a stack over 300 feet high to assure ample dilution. Operation of the reactor will be subject to an elaborate system of meterological forecasts. The level of operations will be adjusted to the conditions forecast so that there will be no danger.

According to design considerations, atmospheric contamination in the neighborhood of the Brookhaven reactor at full operation will be considerably less than the permissible limit, and careful monitoring of the area will assure that a low level is maintained.

### Meteorological Surveys

The combined effects of a high stack and strong average winds at the Brookhaven site will normally disperse the cooling air enough to permit safe and continuous operation of the reactor at full power. However, under certain adverse weather conditions, the reactor will probably operate at less than full power. The probable onset and duration of such adverse conditions can be predicted, and the level of reactor operations will be governed by the predictions made by the meteorology group of the laboratory.

Meteorological towers are equipped with measuring and recording instruments which operate continuously. Studies of atmospheric behavior, including observation of oil-fog smoke emitted from a 320-foot tower, show that the meteorology staff will be able to determine when the radioactive argon in the cooling air may not be well enough dispersed to permit continued operations at full power.

## Area Monitoring Program

An extensi program of area monitoring has also been undertaken at 16 selected sites in the vicinity of Brookhaven. Each of the monitoring stations consists of a frame building with radiation detection and recording equipment. These stations will be built and equipped well before reactor operations start. Data on naturally occurring (background) radiation levels are also being gathered. When reactor operation first begins, data on radiation conditions will be gathered at each station. During this period, the health physics staff will maintain close coordination with the meteorology and reactor-operating groups.

Once the reactor is functioning and the general radiation effects have been learned, routine monitoring will begin. Radiation-counting and laboratory facilities are being set up for routine analysis of laboratory sewage and of vegetation, soil, and water samples collected at selected points in the area served by the monitoring stations. These activities will provide continuing routine control data and will supplement more-detailed surveys made by biological survey groups. The equipment will be largely automatic and self-recording.

A trailer with battery power supply and a limited complement of monitoring equipment will be available for spot checking and to supplement coverage provided by the 16 stations.

## Chemical Separation Operations

The fission products obtained from uranium exposed to neutron bombardment in a reactor are highly radioactive. A variety of chemical processes is used to separate these fission products from unused uranium and plutonium. The equipment is largely automatic and operated by remote control. Ventilating exhaust air and dissolver off-gases are discharged through stacks 200 to 300 feet high. Radioactive particles in the dissolver off-gases which might contaminate the atmosphere are removed by scrubbing and filtering the dissolver off-gases before they enter the stacks.

When meteorological conditions are unfavorable, dissolving operations are stopped. Elaborate facilities are maintained at the production areas to supply the necessary meteorological information.

When chemical separation operations began, it was believed that a combination of high stacks and large volumes of diluting air would remove any hazard from exhaust ventilating air. Later, however, air, ground, and vegetation tests indicated a possible need for decontaminating exhaust air before discharge to the stacks. This is now being done.

The radioactivity added to the atmosphere in the neighborhood of Oak Ridge National Laboratory by chemical separation operations and the cooling air from the reactor is of the order of 1/100,000,000 microcurie per cubic foot.



This should be compared with the natural radioactivity in the atmosphere in this part of Tennessee which ranges from 10 to 100 times ater. The average of natural radioactivity in the nearby Knoxville area is about 300 times greater. In many districts, notably in the Colorado Mountains, the radiation may be still higher by 10 to 20 times. But even there it is insignificant and not considered at all harmful.

At Hanford, Washington, health physicists have given careful consideration to certain short-lived gaseous wastes from chemical separation operations, primarily 8-day radioiodine (iodine 131) and 5.4-day radioxenon (xenon 133). The amount of such wastes can be regulated by increasing the cooling period between the time the slugs are taken from the reactor and the time that metal processing begins. For example, by increasing the cooling period 60 days (7 half-lives), the amount of radioiodine may be decreased by more than 100 times.

At present the radioiodine concentration in the atmosphere over Richland, Pasco, and Kennewick (Hanford area) is about 1/100,000,000 microcuries per cubic foot. As at Oak Ridge this level is not a public health problem.

At the present time radioactive metal from the reactors at Argonne National Laboratory near Chicago is not processed locally, nor is such processing contemplated in connection with the new reactor at Brookhaven National Laboratory.

## Laboratory Research

Gases produced in Commission research laboratories have varying levels of radioactivity but for the most part the activity is low level. In new laboratories, high-level working areas are usually designed so that they do not connect with low-level and uncontaminated areas. The areas are served by separate ventilating facilities usually arranged so that even in emergency the high-level activity can never contaminate an area of lower level.

As a further precaution in some laboratories, work involving radioactivity is done in special sealed boxes set in ventilated hoods and the radioactive materials and equipment are manipulated with protective gloves or by remote control.

At some of the older laboratories, especially those where existing facilities were adapted for research on radioactive materials, the nature of the facilities has not always permitted complete radioactive decontamination. Although these laboratories did not endanger personnel, they are being remodelled or replaced. The contrast between the original state of the older laboratories and the newer ones is striking and marks a step forward in the progress of the industry.

The new laboratory buildings at the Argonne National Laboratory in Du Page County, Illinois, are being built on a unit principle, each unit having about 100 square feet of space. Each unit will be provided with individual

supply and exhaust ducts. Similar separation of areas will be provided in the biological and medical laboratories under construction for the Rochester Atomic Energy Project, University of Rochester, Rochester, New York; the new buildings at the Radiation Laboratory, University of California, Berkeley, California; and the new Knolls Atomic Power Laboratory, Schenectady, New York.

### Incineration

Burning of radioactive wastes and byproducts cannot be done unless provision is made to decontaminate the products of combustion. This requirement is not a simple one to meet, but studies for improving incineration methods are in progress.

### Stack Gas Problem Working Group

In June 1948, the AEC Division of Engineering appointed an Advisory Stack Gas Problem Working Group, the membership of which included experts in industrial health and ventilating problems. The working group has recommended that special research be carried on in a number of fields having to do with improvement of existing filters and development of other types of equipment for removing radioactivity from air and gases. A number of contracts has been let for conducting research and development in these fields.

## SAFE HANDLING OF LIQUID RADIOACTIVE WASTES

### Reactor Cooling Water

Exposure of reactor cooling water to neutron bombardment creates a slight degree of radioactivity in the dissolved solids that the water carries. Before being returned to the river, however, the cooling water is held in a retention basin for several hours and monitored to make sure that the level of radioactivity is low enough for safety. Also, in returning the water to the river, care is taken to provide a high degree of mixing with the main stream to give maximum dilution. This has been very effective.

### Liquid Processing Wastes

In the normal reactor operation, radioactive isotopes of such elements as strontium, yttrium, columbium, ruthenium, cesium, and cerium are formed. During the chemical processing these radioactive materials get into the process solutions and subsequently into the wastes from the various operations. Waste materials containing only isotopes with short half-lives are monitored and stored for a relatively short time to permit decay of the radioactivity, after which such wastes are disposed of freely in the ground or in streams. Longer-lived radioactive fission products are placed in semi-permanent retention basins until adequate systems are developed for their isolation or recovery.

At Hanford the slow seepage of low-activity wastes into the ground has been safe to date because of the nature of subsoils. These soils tend to have a chemical affinity for most of the radioactive materials, so that they do not spread through the soils for great distances. While this method of disposal has proved a useful and safe temporary measure, it is not a satisfactory disposal method for permanent use. Geologists estimate that present practices may continue for many years without creating a public hazard. In view of present research efforts, the practice will undoubtedly be abandoned long before this period has elapsed.

At Oak Ridge National Laboratory, most of the liquid wastes are stored in underground tanks to permit decay of the short-lived fission products which make the bulk of the radioactivity. When the safety point is reached, the liquid wastes pass into a drainage system consisting of a large holding pond, White Oak Lake, White Oak Creek, and ultimately the Clinch River. The entire system is in the Oak Ridge restricted area and careful measurements are made of the radioactivity of the waste before it leaves the controlled area.

Recent surveys indicate that the mud in White Oak Creek is becoming increasingly radioactive. The situation is not acute. However, in order to keep it from reaching an acute stage, a program is underway to develop methods for processing wastes before they enter the creek.

The total radiation level in White Oak Lake must be sufficiently low not to harm fish in the water. The concentration of radioactivity from any combination of radioisotopes must remain so low that it would not harm a human being who for his lifetime used this as his only source of water. In addition, this low degree of radioactivity is further diluted by a factor of 20 to 1000 on entering the Clinch River. Health physicists have observed that the maximum added radioactivity in the water of the Clinch River is about 1/1000 microcurie per gallon. This is considerably lower than the natural radioactive content of many of the most popular mineral waters drunk in the United States.

### Laboratory Wastes

Most Commission installations have laboratories which use radioactive materials. The degree of activity varies over a wide range, from low-level tracer work to levels many thousands times higher which require special safeguards and "hot" laboratory facilities. In such laboratories research studies

are conducted in fundamental chemistry, physics, metallurgy, biology, and medicine, engineering development, and in some cases component and pilot plant testing.

At the Radiation Laboratory, Berkeley, California, concentrated liquid wastes are mixed with cement and stored in oil drums. Later these materials are dumped some 30 miles out at sea. No radioactive materials are dumped in the San Francisco Bay region.

### Research and Development

The principal aim of research and development of new methods for handling liquid wastes is to concentrate these wastes in small, more easily handled volumes. (See Appendix B.) At Oak Ridge, engineers have designed and installed an evaporator which is expected to reduce the original volume by 95 percent. A pilot plant evaporator is about to go into operation at Knolls Atomic Power Laboratory, Schenectady.

Many potentially valuable radioactive materials are now lost in wastes. The Commission is interested in developing suitable methods for salvaging as much as possible of this material. Research work on this problem is going on at several Commission laboratories.

Sanitary engineers are keenly interested in the effects of radioactive materials upon biological organisms and slimes found in drainage systems and sewage disposal plants. At New York University, a Commission-sponsored research project has been established to investigate these effects, using the unique experimental sewage disposal plant and facilities made available by the City of New York.

Research workers at Los Alamos have started an unusual series of studies to determine whether or not radioactivity can be concentrated from liquid wastes by bacterial action. Early experiments indicate that certain bacteria normally used in activated sludge processes for treatment of sewage do concentrate radioactivity to an unusual degree. As soon as more data are available, pilot plant operations will be established for use of biological methods on a routine basis. If successful, the method will be far simpler and less costly than chemical or mechanical methods.



# IV. Safe Handling of Wastes Resulting From Radioisotopes Distribution Program

Radioisotopes produced in the nuclear reactor for research and medical therapy have been called the most important research tool developed since the invention of the microscope. Because of their radioactivity these materials may be followed through complicated physical and biological reactions, such as digestion, photosynthesis, blood formation, processes for making gasoline from coal, and the like. Previously, scientists knew what went into a reaction and what came out. From this evidence they would try to piece together what had occurred. With radioisotopes they have a tool to follow these intricate processes step-by-step. By July 1949, more than 7,000 shipments of radioisotopes had been sent from Oak Ridge to more than 1,000 laboratories and hospitals in the United States.

While radioisotopes are distributed widely, the amounts distributed, in terms of millicuries of radioactivity, are very small compared to the amounts produced in the atomic energy production processes. Even so, certain precautions must be taken to safeguard people using the radioactive materials and to prevent contamination of equipment and local drains and sewage systems.

It should be noted that no large-scale shipments of radioisotopes have been made for routine industrial processing. If and when such industrial uses are developed, the problems of waste disposal will require considerable study in each case. No such shipments will be made until satisfactory techniques for disposing of wastes have been worked out.

### PRECAUTIONS TAKEN BY ISOTOPES DIVISION

Before an application for radioisotopes is approved and the shipment is made, the Isotopes Division at Oak Ridge determines that the physician or research worker who will receive the shipment is trained in techniques for using radioactive materials. Moreover, the laboratory or clinic in which he works must be provided with adequate measuring and protective devices. Safety, however, demands more than equipment and routine. Each operation and each experiment must be evaluated individually. Genuine understanding of the nature of radioactivity and its effects on living tissue is essential.

Radioisotopes distributed from Oak Ridge are shipped by common carrier—airline, railroad, and truck—in specially constructed containers, which range in weight from less than a pound to a ton, depending upon the energy of the radiation and the thickness of shielding required to stop radiation of that energy. Low energy radioisotopes, such as carbon 14, phosphorus 32, and sulfur 35, can be packed in light containers. Sodium 24, cobalt 60, and iodine 131, on the other hand, require heavier containers, the average weighing between 100 and 150 pounds. This type of radioisotope, in its glass or aluminum can, is placed in a steel container surrounded by a lead shield which is supported firmly inside a strong wooden box. After packing, the box is checked with a sensitive detection instrument, and if the radiation reaching the outside is still above completely safe limits, the consignment is repacked with a thicker shield.

During the 13 months from June 1, 1947 to July 1, 1948, a total of 166,494 millicuries of radioisotopes was shipped from Oak Ridge to research laboratories and clinics. Of this total less than 900 millicuries or about one-half of one percent consisted of radioisotopes considered very dangerous because of a combination of long half-life and slow rate of turn-over in the body. About 77,000 millicuries of phosphorus 32 and about 62,000 millicuries of iodine 131 were shipped during this period. These have half-lives of 14 days and 8 days respectively. Thus, the vast majority of distributed radioisotopes have fairly short half-lives or are elements which are not specifically concentrated in the human body at the dilutions encountered after the experiment.

## DISPOSAL OF LABORATORY AND CLINIC RADIOACTIVE WASTES

In almost all tracer experiments, the radioisotope is diluted by adding nonradioactive isotopes of the same element. Since both forms of the element behave chemically in the same way, the chance of selective absorption of radioactivity in wastes by living organisms is much reduced. In most medical experiments, the material is further diluted by fairly uniform distribution through a large organism such as the human body. There is also subsequent dilution with large amounts of organic matter and water, when the material is disposed of through the ordinary sewerage system.

In September 1948, a meeting sponsored by the Atomic Energy Commission was held in Washington to discuss the waste disposal of radioactive materials used by non-Commission laboratories. The men attending agreed on the following recommendations:

1. Any type of radioisotope can be buried in the earth, if the radioisotope is uniformly diluted with nonradioactive isotopes of the same element in the same chemical form provided that no more than 4.15 ergs* per gram of element were dissipated per day, that the burial is made only in suitably selected areas in possession of the user, and that the material is buried at a minimum depth of 5 feet.
2. Radioiodine (iodine 131) may be discharged from an institution into the main sewer, provided that to each millicurie of radioiodine discharged one gram of potassium iodide is added at the time of disposal, that radioiodine will be diluted to 10 microcuries per liter in the sewerage outlet from the institution into the main sewer, that regular surveys are made of plumbing fixtures, and that appropriate surveys are made before repairing the plumbing between the disposal outlet and the main sewer.
3. Radiophosphorus (phosphorus 32) may be discharged into the sewer, provided that it is diluted to 0.1 microcurie per liter in the sewerage system, that each millicurie is diluted with 10 grams of stable phosphorus as phosphate at the time of discharge, that the maximum activity disposed of in any one institution does not exceed 200 millicuries per week, that appropriate radiation surveys are made before repairs are made to the plumbing and disposal outlets to the main sewer, and that the sewage does not enter directly into fresh water systems.
4. Radiocarbon (carbon 14) may be exhausted in the air, provided that no person shall be exposed to the inhalation of air containing greater than 0.01 microcurie per liter and that particulate matter is filtered from the exhaust air.

*An erg is a measurement of energy and, in this case, would measure not only the rate of radioactive decay, but the energy of the particle or ray given off. The limit fixed—4.15 ergs—is inconsiderable.

## APPENDIX A

# AEC Advisory Committees

### Advisory Committee for Biology and Medicine

This committee, appointed in September 1947, conducts continuing studies and makes recommendations to the Commission about basic policies relating to the medical, biological, and health physics aspects of the atomic energy program. Among the problems considered by the Advisory Committee are those relating to the evaluation of present and proposed methods of handling radioactive wastes. The committee also reviews proposed research projects pertaining to the biological and medical aspects of handling waste. The members of the Advisory Committee are:

Dr. ALAN GREGG, chairman, director for medical sciences, Rockefeller Foundation, New York City.

Dr. ERNEST W. GOODPASTURE, vice-chairman, dean of the school of medicine and professor of pathology, Vanderbilt University, Nashville, Tennessee.

Dr. DETLEV W. BRONK, president, Johns Hopkins University, Baltimore, Maryland, and chairman of the National Research Council.

Dr. G. W. BEADLE, division of biology, California Institute of Technology, Pasadena, California.

Dr. A. BAIRD HASTINGS, professor of biochemistry, Harvard Medical School, Boston, Massachusetts.

Dr. E. C. STAKMAN, division of plant pathology and botany, University of Minnesota, St. Paul, Minnesota.

Dr. JOSEPH T. WEARN, dean of the school of medicine, and professor of medicine, Western Reserve University, Cleveland, Ohio.

### Stack Gas Problems Working Group

In June 1948, the AEC Division of Engineering appointed an advisory Stack Gas Problem Working Group. The members of this group are:

ABEL WOLMAN, Johns Hopkins University, chairman.

PHILIP DRINKER, Harvard School of Public Health.

LYLE GILBERTSON, Air Reduction Sales Company Laboratory.



GEORGE R. HILL, American Smelting and Refining Company.

H. F. JOHNSTONE, University of Illinois.

EARL P. STEVENSON, A. D. Little, Inc.

W. P. YANT, Mine Safety Appliances.

The group has held two meetings in Washington, one in Hanford, and one in Oak Ridge.

The Stack Gas Problem Working Group has recommended that special research be carried out on the following list of problems, and contracts are being made to implement this program:

1. Research and development of filters to meet the various needs of atomic energy production and research plants.
2. Development of equipment for recovering radioactive iodine and some of the rare gases by fractionation and low temperature cutting.
3. Development and design of an incinerator having minimal radiation characteristics.
4. Research in the theory of diffusion of gases and aerosols in the atmosphere, the deposition of aerosol particles from the atmosphere, the effect of the nature of the particles on their disposition, and the development of new methods for removing suspended particles from gas streams.
5. Study of commercially available dust collecting equipment, such as electrostatic precipitators, cyclones, rotoclones, etc., and of new methods of collection of dusts in supersonic chambers. Evaluation of the effect by which the sudden expansion and cooling of supersaturated water vapor will produce a heavy mist, and thus possibly entrain particles of submicron size.
6. Experimentation and research on absorption by vegetation of radioactive gaseous contaminants.
7. Development and standardization of better sampling techniques and methods for determining the concentration, size, and distribution of particles in stack and off-gases and in the ventilating air stream in buildings handling radioactive materials.

### Committee on Liquid Process Waste Disposal and Reclamation

In June 1948, the AEC Director of Engineering appointed an advisory committee to survey liquid waste disposal and reclamation problems at Commission sites and to make recommendations for a program to improve present practices. Members of this committee are:

S. LAWROSKI, Argonne National Laboratory, chairman.

J. J. GREBE, Dow Chemical Company.

L. A. MATHESON, Dow Chemical Company.

M. M. Harris, Monsanto Chemical Company.

P. C. Meade, Jr., Monsanto Chemical Company.

W. A. Rodger, Argonne National Laboratory.

Following its initial survey the committee prepared a list of general principles applying to handling of liquid radioactive waste. It also made a number of specific recommendations in regard to a long-term research and development program. The general principles are:

1. Insofar as possible, methods of disposal should depend primarily on the physical and chemical properties of the waste itself and not on special site conditions such as soil types, community environment, and climate.
2. Tolerances must be realistic and based on experimental evidence. However, in operation the goal should be to reduce contamination to natural background levels.
3. Potential waste disposal difficulties should be considered at every stage in the research and design of operations processes.
4. High priority should be given to research on and development of new methods of decontaminating and recycling chemicals, solvents, and other operations-process liquids.
5. Wherever possible, standard industrial equipment and practices should be adopted in setting up waste disposal processes.
6. Extensive dilution in a disposal process is permissible only if it yields highly decontaminated effluent not otherwise obtainable.

The committee recommended specific research programs on evaporation carrier precipitation, sand filtration, ion exchangers, electro-dialysis, metallic displacement, differential volatility, electrolytic separation, solvent extraction, and biological processes. To implement this research program the committee made the following recommendations:

1. A long-range research and development program in liquid waste disposal should be established and given a higher priority since waste disposal is a limiting factor in the full development of the national atomic energy program.
2. This program should include fundamental studies of the chemistry of waste disposal, development of new methods through the pilot plant stage and assisting in the design and construction of full scale plants at various sites, and research into better methods for recovering, separating, and packaging radioisotopes and valuable reagents.
3. Every consideration should be given to encourage cooperation between the Commission and its contractors, and public health, geological, oceanographical, meteorological, and water supply agencies, both nationally and locally.
4. The Commission should encourage critical examination of present practices at every site with a view to reducing, even if only to a small extent, the volume of waste produced.

A survey of area facilities, personnel, and programs is completed which will serve as basis for establishing the coordinated programs. In particular this program will assist those areas where waste disposal problems are critical or where no facilities now exist for proper waste disposal. As improvements in operating techniques are made, the information will be sent to all interested facilities, so that maximum immediate use of these developments can be made.

## Subcommittee on Waste Disposal and Decontamination of the National Committee on Radiation Protection

The National Committee on Radiation Protection, established under the auspices of the National Bureau of Standards, is concerned with setting up radiation standards in the United States and determination of permissible limits and tolerances. The recently established Subcommittee on Waste Disposal and Contamination is interested primarily in establishing permissible limits for disposal of radioactive waste materials. To date the latter group has made no specific recommendations, but as soon as such recommendations are available they may supersede some of the permissible limits that have been adopted on a provisional basis at national atomic energy installations. The members of the main committee are:

L. S. Taylor, National Bureau of Standards, chairman.

R. C. Peavey, National Bureau of Standards, secretary.

H. L. Andrews and E. G. Williams, United States Public Health Service.

Shields Warren and K. Z. Morgan, Atomic Energy Commission.

L. F. Curtis, National Bureau of Standards.

E. E. Charlton and L. L. Call, National Electrical Manufacturers Association.

H. B. Williams, American Medical Association.

R. S. Stone and G. Failla, Radiological Society of North America.

R. R. Newell and J. L. Weatherwax, American Roentgen Ray Society.

Edith Quimby and J. E. Wirth, American Radium Society.

Lt. Col. W. S. Cowart, U. S. Air Force.

Maj. W. W. Stone, Jr., U. S. Army.

Dr. W. H. Sullivan, U. S. Naval Radiological Defense Laboratory, U. S. Naval Shipyard, San Francisco, California.

The members of the subcommittee are:

L. S. Taylor, National Bureau of Standards, Washington, D. C.

Marvin M. D. Williams, Mayo Clinic.

John C. Geyer, Johns Hopkins University.

Roy Overstreet, University of California (Berkeley).

Oliver Placak, Oak Ridge National Laboratory (U. S. P. H. S.).

Edith Quimby, Columbia University.

C. C. Ruchhoft, sanitary engineer, Cincinnati, Ohio.

Nathan H. Woodruff, Atomic Energy Commission, Oak Ridge.

Sergi Feitelberg, Mt. Sinai Hospital, New York, N. Y.

James H. Jensen, Atomic Energy Commission, Washington, D. C.

R. H. Fleming, U. S. Coast and Geodetic Survey, Washington, D. C.

R. C. Peavey, National Bureau of Standards, Washington, D. C.



# APPENDIX B

# Waste Disposal Research and Development Supported by AEC

## Filter and Dust Collection Methods

In April 1947, the Oak Ridge Operations Office requested the Chemical Corps Technical Command, Edgewood Arsenal, to determine the efficiency and operational characteristics of standard filter papers in removing radioactive airborne contamination. From this joint effort a filter unit was developed which subsequently has been installed in many of the Commission areas.

A second cooperative program among AEC, the Chemical Corps, U. S. Army, and Carbide and Carbon Chemicals Corporation, Oak Ridge, will soon start the development of more efficient filters and absorbents to remove radioactive particles. The development of longer-life filters and better methods of replacing units will be investigated.

A supplementary program for design and study of special types of filters is being conducted for the Commission by the A. D. Little Co., Cambridge, Massachusetts. Commercial manufacturers of potentially useful filter media are taking part in this work. These include the Owens Corning Fiberglass Co., American Air Filter Co., and others.

The Air Reduction Sales Company has completed a research and development program on methods and equipment for capturing radioactive iodine from process gases. Further studies on this subject are underway at Hanford on a full-plant scale. The Air Reduction Sales Company is also engaged in development work for the design and construction of an incinerator having minimal radiation characteristics.

The Harvard School of Public Health is working on the application of supersonic chambers in the collection of dusts and on the use of sudden cooling of supersaturated air to produce a heavy mist to entrain particles of submicron size.

## Concentration of Liquid Wastes

Several Commission laboratories are conducting evaporation studies leading to the design of equipment for reducing liquid waste volumes. Since the chemical composition of liquid wastes varies considerably from site to site, the equipment requirements vary accordingly. A pilot plant evaporator having a capacity of 450 to 600 gallons per hour is about to go into operation at the Knolls Atomic Power Laboratory, Schenectady. Preliminary results indicate that the volume reduction may reach 98 percent.

Similar studies will be started at Argonne National Laboratory as soon as facilities are available at the new Du Page County site. An experimental evaporation unit at Oak Ridge is well along in the design stage. Completion of this plant will provide additional waste storage capacity. Such plants are expected to find use at other atomic energy sites. Tests at Oak Ridge have indicated that commercially available types of spray driers and other evaporators do not require considerable modification in order to be useful for specific problems encountered in the atomic energy program.

Studies of ion exchange methods for removing fission products from liquid wastes are carried on at Knolls, Hanford, Argonne, Brookhaven, and Oak Ridge Laboratories. Adsorption characteristics of local soils are under study at Hanford, Los Alamos, and Brookhaven. Other chemical methods for concentrating low-activity materials from liquid wastes are also under investigation at various sites.

## Biological Concentration Processes

At Los Alamos the use of activated sludge for concentrating certain types of radioactivity from waste liquids appears promising. The U. S. Public Health Service and the University of California are cooperating in this study.

## Effects of Radioactivity on Sewerage Systems

The Department of Sanitary Engineering, New York University, has a research contract to study the effects of radiophosphorus, radioiodine, radiocarbon, and uranium on sewage-treatment processes. These studies are being conducted to determine the concentration of wastes which can be discharged safely into sewerage systems. Approximately 100,000 gallons of sewage per day can be treated in the sewerage plant associated with the laboratory.

During the course of this study an investigation will be made of biological and mechanical concentrations of radioactivity in soil pipes, traps, digestion tanks, etc. The Sanitary Engineering Department, Johns Hopkins University, is studying the effects of radioactivity on bacterial slimes encountered in sewer pipes and systems. Oak Ridge National Laboratory is working on



a similar project with the cooperation of the U. S. Public Health Service and the Sanitary Engineering Department, Tennessee Valley Auth y.

## Monitoring Techniques

Instrument shops at Oak Ridge, Hanford, and Brookhaven are developing new types of monitoring equipment for routine measurement of activity in liquid, gaseous, and solid samples. At the Rochester Atomic Energy Project, methods for making more accurate counts of airborne particles by size have been developed. The Mine Safety Appliance Company has a contract for the development of sampling techniques for stack gas particles.

## Decontamination Methods

At Oak Ridge and other laboratories, the development of better methods of decontaminating buildings, equipment, and general areas is under investigation. This work will be useful not only in the atomic energy program but also to the armed forces in developing means of decontaminating equipment in combat zones. Progress is reported on development of strippable films which can be used to cover contaminated apparatus, and, if necessary, be placed by remote control. At Argonne and the Radiation Laboratory at Berkeley, similar coatings have been developed for painting hot laboratories. From time to time the contaminated paints can be removed, and the laboratory walls do not become permanently contaminated.

## Biological and Medical Aspects of Radioactive Wastes

In the last analysis the evaluation of waste disposal methods and the establishment of permissible limits depends upon knowledge of the effects of radioactive substances upon living things—plants, animals, and human beings. For this reason many of the Commission's research contracts in the fields of biology and medicine have real application in the practical problems of disposal of radioactive wastes. A list of research contractors and the subjects of their investigation follows:

*American Smelting and Refining Company.* Research on absorption of stack gas contaminants by vegetation.

*California Institute of Technology.* Investigation of the genetic effects of radiation on biological systems using molds, fruit flies, and Indian corn as test material.

*University of California.* Investigation of the effects of irradiation on animal tissue.

*Johns Hopkins University.* Investigation of the absorption and assimilation of ra ctive materials by surface slimes.

*University of Kansas.* Studies on the biological effects of ionization, with emphasis upon localized cellular damage.

*Massachusetts Institute of Technology.* Studies on the removal of radioactive materials by standard water-purification systems.

*North Carolina State College.* Studies of the movement of ions through soils systems.

*Southern Research Institute.* Studies of body retention of radioactive carbon.

*University of Texas.* Research on the uptake of various radioactive materials by various species of algae.

*United States Department of Agriculture* (Plant Industry Station, Beltsville, Md.). Study of the movement, fixation and release of various radioactive substances in various soil types. Studies are also in progress on the uptake and deposition of radioactive materials by various crop plants.

*Washington State College.* Studies on the absorption, translocation, and disposition of various elements in plants.