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ATOMIC ENERGY COMMISSION

REPORTING OF THE HANDLING OF RADIOACTIVE WASTE MATERIALS IN THE UNITED STATES ATOMIC ENERGY PROGRAM

Note by the Secretary

The attached report, "The Handling of Radioactive Waste Materials in the U. S. Atomic Energy Program", is circulated for consideration by the Commission in connection with AEC 180/1.

Filed Oct 17, 1949

ROY B. SNAPP

Secretary

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THE HANDLING OF RADIOACTIVE WASTE MATERIALS IN THE U. S. ATOMIC ENERGY PROGRAM

U. S. ATOMIC ENERGY COMMISSION

WASHINGTON, D. C.

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INTRODUCTION

In the laboratory and production operations of the United States atomic energy program, a variety of potentially harmful waste materials are created which must be handled in special ways. This problem of wastes is not unique to the atomic energy industry. Many large industries are faced with the need for disposing 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 the improper handling of radioactive waste materials could endanger the public health, the U. S. Atomic Energy Commission believes that the facts which relate to this problem should be available to citizens generally, and particularly to those charged with responsibility for health and safety.

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, and 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

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agencies--notably the U. S. Public Health Service, the U. S. Weather Bureau, the Tennessee Valley Authority and the U. S. Geological Survey--are already co-operating 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 energy and particles released by radioactive materials is called "radiation." When it passes through other materials, such as air, metal or animal tissue, radiation 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 is related to 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. The fast-moving particles each bears a positive electric charge. The particles are the nuclei of ordinary helium atoms. Beta particles also travel at high velocities but in this case the particles--which are electrons--are very much lighter and have negative, rather than positive, charge. Gamma radiation, unlike alpha and beta rays, is pure radiant energy similar to light or X-rays. There is no associated particle, and the packets of energy, called photons, bear 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.

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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 that are associated with the problem of processing and handling radioactive waste. Some idea of the size of this problem may be gained by realizing that in an operating nuclear reactor, radiation equivalent to several hundred tons of the naturally radioactive element, radium, is generated. In contrast, only three pounds of radium have been made available in the whole world during the past 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." 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 disintegrate. 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, non-radioactive. The atomic nuclei of unstable materials continue to "decay" until all nuclei have 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 six half-lives have elapsed only 1.6 per cent of the original radioactivity remains.

Since radioactivity involves the nucleus 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-

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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 indicates the number of radioactive atoms that decay in a given period of time. The curie is a convenient unit for monitoring purposes, since it tells how much radioactive material is present. One curie is arbitrarily taken as 37 billion nuclear disintegrations per second. This is approximately the number of disintegrations that take place each second in one gram of radium. A millicurie is one-thousandth of this amount, or 37 million disintegrations per second; and a micro-curie is one millionth of this amount, or 37 thousand disintegrations per second.

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 being radiated. 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 ionizing any other material. These are termed roentgen equivalents. Conversion from one to another is rather complicated.

Effects of Radiation. Present knowledge of radiation effects is based largely on the observations of scientists 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 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 just what type of radiation caused the damage.

In discussing the amounts of radiation that the human body can stand, it should be remembered that everyone living on the earth is being bombarded continually by ionizing radiations in the form of cosmic rays. Persons living near sea level will probably receive about two roentgens of cosmic radiation during the course of their life-times. Persons living in the mountainous areas, on the other hand, may receive from ten to twenty times as much. At high 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 5000 roentgens (usually referred to as simply 5000 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 humans.

If less than a fatal dose of total body radiation is given to an individual, it will not have the same effect if it is spread over several applications that a single dose of the same amount would have. 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 r each day on three successive days. The same dose in a single application of 300 r would probably kill some out of a large group of people so irradiated. It is believed that a dose of about 400 r would kill half the people exposed to it. This is called a 50 per cent lethal dose (LD-50) or a dose sufficient to kill 50 per cent of the population receiving it.

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

Persons submitting to an ordinary chest X-ray will receive from 0.4 r to 1.0 r during 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 r. Remembering these facts helps keep perspective in discussing radiation problems.

Permissible Dose. Many years ago medical scientists agreed that a normal human could sustain a continuous day-in-and-day-out whole-body external exposure of 0.1 r 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 did 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, will probably recommend in the near future that the present "permissible limit" for continuous exposure be reduced to about 0.3 r 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 eight fields. The Subcommittees are:

1. External Permissible Dose
2. Internal Permissible Dose
3. X-rays up to Two Million Volts
4. Heavy Particles (Neutrons, Protons and Heavier)
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 the Subcommittees are given in Appendix A, p 30.)

<u>AEC Practice</u>. The radiation exposure of 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 two deaths and 13 injuries due to accidents involving external radiation in the Manhattan Project, the organization which produced the atomic weapons of World War II, in spite of the fact that the quantities of radiation were thousands of times greater than any heretofore encountered, and that tens of thousands of workers were employed in this operation. In contrast, more than 70 deaths of people working in the Manhattan Project were caused by construction accidents and other common industrial hazards. Even here the rate was far below the national average for similar work.

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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 plants and the reactors operating at the installations of the national atomic energy program--Oak Ridge, Hanford, Argonne National Laboratory, etc.; (2) the laboratories and hospitals where radioactive materials are used as research tools or for medical treatment.

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

The radioactive wastes causing disposal problems at hospitals and laboratories using radioisotopes in the main are liquids containing residues of the radioactive material which has served its purpose in experiments or treatment of patients. Scientists and physicians generally use only minute amounts of these materials. With a few exceptions, notably radiocarbon (carbon 14), the materials used for these purposes have short half-lives. The problems of handling wastes from these sources are not nearly so large as those of handling wastes from the atomic energy production installations and reactors.

Radioactive Waste Problem

From the beginning of the atomic energy program, it has been an operating principle that workers and the public should be protected at all times from <u>external</u> radiation--that is to say, from radiation that strikes only the

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outer surface of the body. In handling radioactive wastes, however, the principal problem to guard against is <u>internal</u> 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.

Among the materials discharged from some atomic energy installations which might be potentially harmful to humans if not well controlled are radioactive gases. These are usually discharged from tall stacks. Normally radioactive gases and particles carried by the gases will be quickly scattered and very few will be found in any given amount of 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 humans or fall to the surface of the ground in the form of leaf litter.

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

<u>Internal Radiation</u>. In animals and humans, 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.

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2. The point where the material goes in the body. If a small amount of radioactive sodium is swallowed, for example, it will be distributed widely throughout the body so that a gram of shoulder or upper arm muscle will contain about as much as a gram of lung or spleen. On the other hand, radioiodine is absorbed in highly selective fashion, and roughly seven-eighths of it normally goes to the thyroid gland. In a 150-pound man, the thyroid will probably weigh about half an ounce. There is not only a concentration by virtue of the seven-eighths localized there, but there is a further concentration by virtue of the great disparity in size between the thyroid gland and the body as a whole. 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, center of the body's blood cell-forming processes.

3. The rate at which the material is excreted from the body. The turnover 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 two-hour half-life, cannot be in any ordinary quantities a serious radiation hazard, since it loses its radioactivity so quickly. Radiocarbon, however, with a half-life of over 5,000 years, remains potent for as long as it stays in the body.

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Sources of Radioactive Wastes

Most of the operations in the atomic energy program of ore dressing and preparing feed materials for the plants that produce U 235 or plutonium are not associated with any great quantities of radiation. The largest and most difficult problems of handling radiation safely are those directly associated with or resulting from nuclear reactor operations, where the degree of radioactivity may be enormous.

The process of fission going on in operating reactors creates considerable quantities of heat which must be dissipated. Hanford reactors are cooled by water; those at Oak Ridge and Brookhaven are cooled by air in prodigious quantities. In both cases, the air or the water is discharged from the reactor building and not re-used. Both are open cycle operations. For use in power and test reactors of the future other coolants are now being developed which will involve closed cycles, and will therefore greatly cut down the amount of radioactive materials discharged to the air or the ground and simplify the problems.

Cooling Water. At Hanford, the cooling water is drawn from the Columbia River, purified in the normal manner, pumped through the reactors, held in a retention basin to permit the decay of much of the radiation as is picked up by soluble salts in the water and then discharged back into the river. The exit temperatures may be several degrees above river water but the temperature of the river as a whole is not noticeably changed.

Cooling Air. At Oak Ridge, and at Brookhaven (when the reactor goes into operation) air for cooling reactors is filtered to take out particles before and after use and then discharged into the atmosphere through stacks. Argon and other rare gases that occur in normal air in very small amounts become radioactive

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while in the reactor, but the half-life of radioargon is slightly less than two hours and the total quantity is small.

At Brookhaven the operation will be controlled according to conditions in the atmosphere. If the wind is right to dilute the stack gases and carry them away, operation will continue at full rate. If the wind is wrong, operation will shut down or will run at a reduced rate.

Chemical Separation Residues. At Hanford, metal containing uranium, plutonium and fission products ejected from the piles is allowed to cool to permit the decay of a large amount of the short-life activity, such as that of radioiodine. This material is then chemically processed to recover the valuable fissionable material, plutonium. It passes through rather conventional processing steps, such as dissolving, precipitating and washing--operations which are conducted by remote control behind many feet of concrete and using special ventilation. Ventilating air contaminated with radioactive particles from this process passes through scrub traps, filters and out a stack, again under controlled meteorological conditions--that is, discharge of the contaminated air is permitted only when the wind is right to permit discharge in the upper atmosphere. This results in high dilution and safe operation.

During chemical processing, the liquids increase in volume and hence the radioactivity per gallon is reduced from step to step. Ultimately the most radioactive wastes are stored in tanks underground. Wash wastes are also tanked but, after a sufficient period of decay, are discharged. This practice was adopted during the war, but it is being replaced by better methods as fast as they can be developed.

During the past few months improved processing techniques have reduced

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the volume of liquid wastes which must be stored by 20 per cent, and it is expected that the reduction will increase to 50 per cent in the near future. That will result in a saving on the order of a million dollars a year.

Solid Wastes. At all installations where radioactivity is encountered, considerable quantities of contaminated clothing are laundered and tested for re-use. Contaminated trash, biological specimens, etc., are disposed of by burial or, more recently, in some areas in closed cycle incinerators. Some contaminated scrap metal and discarded equipment such as motors, valves, piping is buried. Lead and aluminum shielding blocks used in pilot plant work are generally decontaminated and used again. Considerable quantities of other contaminated metals have been segregated and efforts are being made to see whether they can be decontaminated to place them back into normal commercial channels. To date, such accumulations have usually been kept on plant sites even though the level of activity is quite low.

Contaminated buildings also present a problem. In extreme cases the buildings may be painted to hold the radiation in, and to protect workers handling them. After painting they are taken apart board by board and the boards buried.

Handling "Hot" Laboratory Wastes. In "hot" laboratories where radioactive materials are used, ventilation 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

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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 Commission is currently sponsoring research and development of better waste-handling methods at many sites. (See Appendix B, p. 31.)

III. SAFE HANDLING OF RADIOACTIVE WASTES IN THE ATOMIC ENERGY INDUSTRY

Problems in the Control of Radioactive Wastes

In the manufacture of almost any product some wastes inevitably result. As a general rule, however, the less wasteful a process may be the more efficient is the production. This is no less true in the atomic energy industry, and at each 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. 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

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methods are worked out.

Two distinct basic methods for handling radioactive waste materials are <u>dilution</u> and <u>concentration</u>. Since living organisms do not pick up radioactive forms of a chemical element in preference to the non-radioactive 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 are observed as a result of present research, the present standards may be found unnecessarily severe.

The successful utilization of atomic energy on a wide scale will take place 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, it is necessary to have more complete understanding of the per-

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missible tolerance levels which can be withstood by men, animals, and plants without influencing 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 alone or in combination.

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

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filters. Better equipment is being installed in existing plants working on Commission 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 are not excessive in view of the low-level radioactivity of these products.

During the metallurgical and machining operations on uranium fumes and dusts of the metallic oxides may develop. These are removed by ventilation and filtering in order not to contaminate the work areas or the outside atmosphere.

Air-Cooled Reactor Operations. Air used for cooling a nuclear reactor or pile 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 fission 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 its operation is maintained safely at all times. Readings of radioactivity in air taken within a mile of the pile stack are about twice the normal cosmic ray background. It should be noted that making measurements of such low levels of radioactivity is very difficult. This does not represent a dangerous condition.

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A second air-cooled reactor is now under construction at Brookhaven National Laboratory, Long Island. The air will be filtered before and after delivery to the pile and will be dispersed to the atmosphere at high velocity through a stack over 300 feet high assuring ample dilution. Operation of the pile will be subject to an elaborate system of meteorological 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.

High-powered reactors of the future probably will employ closed-cycle cooling systems which will not discharge gaseous wastes to the atmosphere. Should additional air-cooled reactors be constructed, their design will provide for filtering of the cooling air and operations will be regulated in accord with local meteorological conditions to prevent any degree of hazard.

Meteorological Surveys. The combined effects of a high stack and strong average winds at the Brookhaven site will normally provide sufficient dispersal of the cooling air 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 made

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prior to the pile operation, including the observation of oil-fog smoke emitted from a 320-foot tower into the atmosphere, show that meteorological personnel will be able to determine when the radioactive argon in the cooling air may be insufficiently dispersed to permit continued operations at full power.

Area Monitoring Program. An extensive 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 provided radiation detection and recording equipment. Construction and installation of facilities at these sites will be completed well before the start of reactor operations.

Radiation background data on naturally occurring radiation levels is being gathered prior to the activation of the reactor. During the initial period of reactor operation data on radiation conditions will be gathered at each station. During this period health physics personnel will maintain close coordination with the meteorological and reactor operating groups.

Once the reactor is functioning and the general nature of the effects produced has been established, routine monitoring will begin. 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. This 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 check and to supplement coverage provided by the 16 stations.

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Chemical Separation Operations. The fission products obtained from uranium exposed to neutron bombardment in a reactor are highly radioactive. These fission products are separated from unused uranium and plutonium by a variety of chemical processes. 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 not carried on, and elaborate facilities are maintained at the production areas in order 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. However, at later dates, air, ground and vegetation tests indicated a possible need for decontaminating exhaust air prior to 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 separations 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 greater than the added radioactivity. The average 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.

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At Hanford health physicists have given careful consideration to the emission from chemical separation operations of short-lived gaseous wastes, primarily 8-day radioiodine (iodine 131), and 5.4-day radioxenon (xenon 133). The absolute 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 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 Argonne National Laboratory reactors 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 manipulation of radioactive materials and equipment is carried on 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 DuPage 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, the new buildings at the Radiation Laboratory, University of California, and the new Knolls Atomic Power Laboratory, Schenectady, New York.

Incineration. Burning of radioactive wastes and by-products 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 have been let for conducting research and development in these fields.

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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 giving maximum dilution. This has been very effective.

Liquid Processing Wastes. In the normal reactor operation, various radioactive elements such as strontium, yttrium, columbium, ruthenium, cesium, and cerium are formed. During the chemical processing these radioactive materials progress into the process solutions and subsequently into the wastes from the various operations. Material containing only short half-lived isotopes are monitored and stored for a relatively short time to permit decay of the radioactivity, after which such wastes are disposed freely to ground or streams. Longer-lived radioactive fission products are placed in semi-permanent retention 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.

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At Oak Ridge National Laboratory most of the fission product liquid wastes are stored in underground tanks to permit decay of the short-lived products which form 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 not exceed an amount which 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 laboratory facilities in which radioactive materials are used. The degree of activity varies over a wide range from low level tracer work to levels many thousand times higher requiring special safeguards and "hot" laboratory facilities. In such laboratories research studies are conducted in fundamental chemistry,

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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 thirty 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, p. 32.) At Oak Ridge engineers have designed and installed an evaporator which is expected to reduce the original volume by 95 per cent. A pilot plant evaporator is about to go into operation at Knolls Atomic 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.

The effects of radioactive materials upon biological organisms and slimes found in drainage systems and sewage disposal plants is of interest to sanitary engineers. 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 bacteria normally used in activated sludge processes for treatment of sewage does con-

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centrate 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 pile 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 occurred. With radioisotopes they have a tool to follow these intricate processes step-by-step. By the end of 1948 a total of 4,542 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, in terms of millicuries of radioactivity the amounts distributed are very small compared to the amounts produced in the atomic energy production processes. Even so, certain precautions must be taken to prevent injury to personnel using the radioactive materials and 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

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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, June 1, 1947, to July 1, 1948, a total of 166,494 millicuries of radioisotopes were shipped from Oak Ridge to research laboratories and clinics. Of this total less than 900 millicuries or about one-half of one

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per cent consisted of radioisotopes considered very dangerous because of a combination of long half-life and slow rate of turnover 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 non-radioactive isotopes of the same element. Since both forms of the element behave chemically in the same way, the chance of selective absorption or radioactivity in wastes by living organisms is much reduced. In most medical experiments, the material is further diluted through 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 sewer 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 non-radioactive 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 five feet.

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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 sewage 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 sewage 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.

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APPENDIX A

AEC ADVISORY COMMITTEES ON DEALING WITH PROBLEMS OF HANDLING RADIOACTIVE WASTES

1. 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.

2. 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., and 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 super-saturated 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 from the ventilated air stream in buildings handling radioactive materials.

3. 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. Haring, Monsanto Chemical Company; P. C. Meade, Jr., Monsanto Chemical Company; and W. A. Rodger, Argonne National Laboratory. Meetings have been held at Argonne National Laboratory, Knolls Atomic Power Laboratory, Hanford Works, Oak Ridge National Laboratory, and Mounds 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. In so far 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.

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4. High priority should be given to research 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 radio-isotopes 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 every site to examine critically

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present practices 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 will be effected.

4. 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 the setting up of 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; 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

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of North America; R. R. Newell and J. L. Weatherwax, American Roentgen Ray Society; Edith Quimby and J. E. Wirth, American Radium Society.

The members of the subcommittee are: 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.

APPENDIX B

WASTE DISPOSAL RESEARCH AND DEVELOPMENT SUPPORTED BY THE ATOMIC ENERGY COMMISSION

1. 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 between AEC, the Chemical Corps, U. S. Army, and Carbide and Carbon Chemicals Corporation, Oak Ridge, is soon to be initiated for the development of more efficient filters and adsorbents 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 Fiberglas Co., American Air Filter Co., and others.

The Air Reduction Sales Company has completed research and development work 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

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supersonic chambers in the collection of dusts and on the use of sudden cooling of super-saturated air to produce a heavy mist to entrain particles of submicron size.

2. <u>Concentration of Liquid Wastes</u>

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 considerable 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 DuPage 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.

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3. 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.

4. Effects of Radioactivity on Sewage 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 sewage systems. Approximately 100,000 gallons of sewage per day can be treated in the sewage 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 Authority.

5. 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 Co. has a contract for the development of sampling techniques for stack gas particles.

6. Decontamination Methods

At Oak Ridge and other laboratories the development of better methods of decontaminating building, 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 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.

7. 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 & 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.

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Johns Hopkins University. Investigation of the absorption and assimilation of radioactive 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. Also studies are in progress of 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.