Environmental Safety for Industrial Uses of Radionuclides

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IN THIS AGE of seemingly endless technological advances, alert public officials and prudent leaders in industry are coming to realize more and more that they have many common interests, and that in a large measure these interests rest on environmental considerations. Of particular importance to industrial uses of nuclear energy are weather conditions, local and regional topography, geology and hydrology, the influences of tides and currents in coastal waters and estuaries, the physical and chemical characteristics of soils, the surface cover whether in the natural state or cultivated, and the myriads of living organisms which serve to maintain a biological balance in our environment.

These environmental factors have profound influence on whether or not a specific area or region is a desirable place to live. They are also of prime importance in deciding whether or not an area is one where a new industry should be established, and, once established, whether capable of expansion without serious limitations. Such limitations may be those set by management as a result of operating experiences or those applied by public regulatory agencies in the interest of public health and safety or for the protection of natural resources.

The atomic energy industry, born as a wartime expedient and nurtured in strict secrecy is now in its 12th year. It is expanding rapidly. Farsighted leaders in industry and in Congress recognized that this industry would present special problems because of its rapid expansion and the hazardous nature of its products and byproducts. Wisely, they have insisted that precautions be taken to avoid errors made by other industries. What is more important, they have provided funds for research and development in order to appraise factors of public safety and economy.

It is doubtful whether any other major industry has evaluated its impact on people and their environment as has the atomic energy industry. Among the many reasons are the following:

- The products and wastes of the industry are both toxic and radioactive; they therefore present potential hazards to man and his environment.
- The kinds of radioactive materials used are many, and their levels of activity vary widely.
- The period of radioactivity of certain nuclides is so long that special consideration must be given to their storage and disposition and to the effect of these practices on the environment.
- The rapidly advancing technology of the industry on many fronts is presenting problems of expansion and obsolescence.
- The effects on man of exposure to low levels of radiation, especially the cumulative effects, are not precisely determined, although there is general agreement that any dose of radiation to the gonads increases the rate of genetic mutation.
- The staff of regulatory agencies responsible for public health and safety and for protection

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of natural resources are not as yet sufficiently trained in the technology of the industry or sufficiently expert in helping to prevent environmental contamination.

In these circumstances, it is essential that both management and public officials understand and evaluate the relative importance of the various phases of the industry and its products and byproducts. Because the demand for expansion of the industry is of deep significance to the economy and defense of nations all over the world, it is vital that no unnecessary blocks be placed in the way of progress. What is called for is a healthy balance between the requirements for public health and safety and the needs of the industry in its inevitable surge forward. Trained manpower is essential to achieve that balance.

Classification of Nuclear Operations

The hazards of the atomic energy industry are related primarily to the specific activity of the materials used and of the products and byproducts developed. It is therefore important that various operations be classified according to their environmental impact. For this discussion, the following classifications will be helpful:

Mining, handling, and storage of raw ores. Since radioactive radon gas is given off by raw ores, work areas must be well ventilated and free of dust. Application of well-established hygienic principles for the mining industry should be adequate. Tailings must be handled in such a way that losses to drainage areas will be within reason. This is not difficult since the weight of the ore favors recovery by sedimentation.

Production of nuclear fuel. Most of the materials used in the production of nuclear fuel from raw ores or from reclaimed fissionable material have low specific activity and a long half-life. Operations are similar to those in specialized chemical and metallurgical plants. Dusts and fumes must be kept under control. In addition, more than average attention should be given to inplant and offplant monitoring for radioactivity and to disposition of wastes.

Enrichment of fissionable materials for fuel. Here again the level of radioactivity is low, and usually the materials have a long half-life. Processing is in various stages, the more important resulting in gaseous fluorides of uranium. Under proper controls, release of fluorine gas and disposition of wastes, as in soluble fluorides, present no serious environmental hazards.

Research and development. Research in laboratories, hospitals, and manufacturing plants of various kinds usually uses small amounts of radioactive material, and, for the most part but not always, the levels of radioactivity are low. Research uses are expanding, and the places where radionuclides are used are becoming more numerous and geographically more widespread. Conditions under which radioactive materials are sold for research, however, are such that environmental hazards from this use are likely to be of low order.

Operation of nuclear reactors. It is in this area of the industry that materials with high specific activity are employed. The amounts and characteristics of the products and wastes are of importance with respect both to on-site protection of workers and to potential off-site environmental hazards.

Test and research reactors operated at low levels of energy and with small amounts of radioactive fuel are in demand by educational institutions and industry. Designs are conservative and operations are subject to strict regulation. Usually such reactors are a low-order risk from the standpoint of environmental hazards.

Research reactors for testing new designs, new fuels, or new fuel assemblies are a special group and are subject to strict supervision by the Atomic Energy Commission under the terms of their permit from that agency. They are built at areas under AEC control. Examples are the National Reactor Testing Station in Idaho, the Knolls Atomic Power Laboratory, and the Argonne, Brookhaven, and Oak Ridge National Laboratories.

Reactors for testing materials and facilities, for producing fissionable material or for developing power experimentally, or for commercial use constitute the major environmental hazards. Their design and construction are subject to thoroughly critical review and their operations are rigidly controlled. These reactors use substantial amounts of fissionable materials. Usually they are operated at high power levels, and the amount of heat generated may be prodigious. Examples of such reactors are the materials-testing reactor (MTS) at the National Reactor Testing Station, the production reactors at the Hanford Works in Washington and at the Savannah River Works in South Carolina, and the pressurized water reactor for power production now nearing completion at Shippingport, Pa.

Processing irradiated fuels. Chemical processing plants are necessary to separate unspent reactor fuel from fission products created as a result of neutron bombardment of fissionable material in the reactors. Large plants of this kind are operated, under AEC control, at the Savannah River and Hanford Works and at the National Reactor Testing Station.

Site Selection

Selection of a site for an atomic energy plant is one of the most important decisions management has to make. The site profoundly affects factors important in company policy, finance, and public relations. Among these are layout and design of structures and facilities, pattern of future expansion, day-to-day operations, and safety of employees or persons and property in the vicinity of the plant.

In the atomic energy industry, perhaps more than in any other, decisions as to a plant site focus largely on anticipations of the character and quantities of wastes to be released. This is particularly true for nuclear reactors and associated chemical processing plants where levels of radioactivity in product and wastes are high. With modifications, it also holds for feed material processing and nuclear fuel fabricating plants, research laboratories, and other places, where materials used have lower levels of radioactivity.

During World War II, the Government-owned atomic energy plants were located in areas of relatively low average population density. Sites were selected partly for reasons of security, but also because of availability of power and water. Since then, there has been opportunity to evaluate performance and practice. New plants have been built and old ones have been refitted. Much has been learned which now can be put to peaceful service.

With relaxation of security regulations concerning technical information and authorization for wider uses of nuclear materials given in the 1954 Atomic Energy Act, the interests of private industry in exploring the opportunity to use atomic energy have been pronounced. It seems likely that since these ventures will be organized and financed in an open competitive field, corporations will prefer to locate plants at strategic places in relation to the market and reasonably near populated areas. When it seeks a site for this new enterprise, a company wishing to build a plant to use atomic energy or to manufacture a product using radioactive materials must face up to its responsibilities.

One of the first considerations will be the possible concern of citizens of nearby communities as to hazards, real or imaginary, an atomic energy plant may bring to the area. Sometimes public officials may not accord an atomic energy plant the welcome they normally extend to a new industry, for they may be concerned over the future effects of this industry on the health of the people and the safety of the environment of their communities. This attitude is entirely understandable.

Experience has shown that the greatest concern of public officials over the location of atomic energy plants in their jurisdiction pertains to storage, release, or disposition of radioactive wastes. The interest that the public now shows in clean streams, preservation of recreational areas, protection of surface and underground sources of water supply, and clean air is a sign of progress in environmental sanitation. It may also be a portent of trouble for any industry so shortsighted as not to plan to meet reasonable requirements to reduce hazards related to disposition of its wastes. On the other hand, unreasonable demands on industry in the degree of waste restriction could seriously affect the interest of the industry and the community or region under consideration.

Radioactive wastes may be in the form of solids, liquids, or gases, and at times they may be in intermediate states as colloids. Problems associated with disposition of radioactive wastes are unique. The effects of radiation can be immediate or delayed. Radiation is an insidious contaminant with cumulative damaging effects on living cells. Certain highly active radionuclides continue to give off energy over long periods of time, to persist through many generations. These are facts of deep importance in evaluating risks and in establishing protection against them. They must never be forgotten in selecting a plant site, and in planning or practicing disposition of radioactive wastes.

High-Level Wastes

High-level wastes may contain as much as 10^2 curies of radioactivity per liter. In normal operations, their principal source is in the processing of irradiated fuel elements. The cost of treatment and disposition of these wastes is high. If nuclear power is to compete with other fuels, cheaper methods of waste disposition must be found. Cutting of costs must be done intelligently; unsound economies may introduce risks of environmental contamination.

Disposition policies are especially important with regard to high-level radioactive wastes that contain long-lived and biologically significant fission products, such as strontium-90 and cesium-137, and others with shorter half-lives, such as cerium-144 and ruthenium-103, and certain isotopes of rare earths, that may be difficult to control when released to soils.

Fixation on Soils

Nature provides some important potentialities for resolving environmental problems. These are being studied in order that they may be taken advantage of in reducing the cost of disposition of wastes from reactors and plants for chemical processing of spent fuels from other sources. Fortunately certain soils and the suspended and bed loading of most waterways have properties of absorption or adsorption of radioactivity. The exchange capacities of soils for radionuclides can be affected seriously by nonradioactive ions in wastes. This complex should be fully evaluated in deciding on the degree of pretreatment required before wastes are disposed to the ground. The heat in high-level wastes resulting from gamma radiation introduces an important problem in the disposition of these wastes. Research in ground disposition of wastes is under intensive investigation by the Oak Ridge National Laboratory, with the cooperation of the Earth Sciences Division of the National Research Council, and at several other AEC installations, notably at the Hanford Works.

The requirements of environmental protection could be met by fixing radioactivity in columns of selected and pretreated clays or other suitable material and then raising the temperature sufficiently to form a solid ceramic mass from which the wastes could not be elutriated or leached. Such a mass could then be stored in a selected area or be buried in a tight soil designated by a geologist as suitable for waste storage. Research to determine feasibility and cost of such a method is under way at the Brookhaven and Oak Ridge National Laboratories and the Los Alamos Scientific Laboratory.

Ground Storage

Two methods of ground storage may be feasible for highly radioactive liquid wastes. One is by pumping these wastes into cavities dissolved in deep salt deposits or salt domes. The other is by pretreating the wastes at the surface and then pumping them to the connate brines in closed basins at great depth and in areas where natural resources would not be unfavorably affected. The potentialities of each method are attractive, but much research must be carried out before it can be established that either is economically feasible and safe or even acceptable to responsible regulatory agencies.

Should either or both of these methods prove satisfactory, the presence of suitable deep strata would be an important factor in selecting a site for a chemical processing plant. It is conceivable that in the future the production of fission products will outrun the demand for selected radionuclides in wastes for use as radiation sources. In that event, disposition of high-level wastes from chemical processing plants directly to deep strata would have considerable advantage over the present practice of storing radioactive wastes in tanks near the surface.

Another possibility for lessening the environmental hazards associated with storage of high-level radioactive wastes is to remove the long-lived and biologically significant nuclides from the wastes prior to disposition. If this were done, wastes could be disposed to the ground in selected areas with greatly reduced environmental hazards. Almost complete removal of the high-level radionuclides, more than 99 percent, would be necessary.

Land Burial and Tank Storage

Land burial is an economically attractive method of disposing of solid radioactive wastes, but it presents serious environmental problems. An experienced geologist must assist in selecting burial grounds. Burial grounds should be fenced and well identified. They should be kept to a minimum in number since they may become so contaminated as to be unfit for any other use.

Underground storage in tanks without fixation of the high-level, long-lived radionuclides could affect the health of future generations. Tanks containing radioactive wastes, as well as waste burial grounds, should be located so that if leakage occurs pollution of ground water will be minimized. Preferably tanks should be set well above the water table and in tight soils from which movement of any leakage would be slow. Storage areas should be monitored periodically to detect any leaks.

Tank storage is not a final solution of the waste problem. The wastes may be radioactive for a century or more whereas the tanks in which they are stored may be expected to corrode and leak within decades. Therefore, this method of disposition obviously permits a potential environmental hazard to persist, even though transfer from old to new tanks is possible.

Storage of high-level radioactive wastes in underground tanks as currently practiced has the advantage of confining the wastes and of allowing time for decay of radioactivity. But provisions to remove heat from tanks often are required, and the method is costly.

Low-Level Wastes

Release of low-level radioactive wastes, whose activity is 10^3 or 10^4 in excess of permissible long-term limits of exposure, may also produce an environmental hazard. Because the quantities of these wastes are large, release to the atmosphere, surface waterways, or the ground is economically attractive and has possibilities if conditions are favorable for dilution.

Extensive research in determining the significant parameters for appraisals of favorable dilution factors in nature is being carried out under Atomic Energy Commission contracts with the Weather Bureau, the Geological Survey, and several universities. Staff of AEC and its operating contractors at the Hanford Works, the Knolls Atomic Power Laboratory, the National Reactor Testing Station in Idaho, and the Brookhaven, Argonne, and Oak Ridge National Laboratories are conducting similar research.

Remote Locations

Within the next decade atomic energy plants may be built in remote places throughout the world where the need for power is so important that the factor of cost or the competitive price of solid fuels may not be significant. Here again the industry has a real obligation to maintain high standards of safety and environmental sanitation. Even though initially exposure of people and property in such areas may be slight, a reckless attitude toward disposition of long-lived wastes should not be permitted. With advancement in travel and transport to these areas and perhaps unpredictable uses of their natural resources, careless practices in this generation in the interest of low costs could preempt use of these resources by future generations. History is replete with examples of the penalties paid by subsequent generations for the reckless, uncontrolled actions of their forefathers.

Plant Expansion

In site selection, serious consideration should be given to the possibility or probability that a plant as originally built may be enlarged or its functional processes changed with relatively greater hazard. When a plant or site planned for one purpose is put to another use, it is important that such basic services as utilities, waste systems, and points of release of waste effluents be restudied to ascertain their adequacy for the new use. Modification should be discussed with public officials responsible for public health and safety. If the original plant is served by public utilities, such as water, power, and sewers, this obligation is all the more pressing.

Selection of a site for an atomic energy plant calls for the integrated judgment of competent people from a variety of professions. These might include nuclear and health physicists, biophysicists, physical and nuclear chemists, structural and ground water geologists, nuclear, chemical, sanitary, and safety engineers, industrial hygienists, ceramists, biologists, mineralogists and soil scientists, meteorologists, hydrologists, public planners, and others. Important among the assignments on which these specialists should assist are:

- Selection of sites for various units of a plant, making the best use of area topography and environmental conditions.
- Availability of water for processing and for domestic uses.
- Type, capacity, and location of waste storage and treatment facilities.
- Degree of waste treatment required initially and later in a progressive expansion program.
- Points and methods of discharge of waste effluents.
- Sites for burial grounds for radioactive and toxic wastes.
- Dilution factors in nature which could be used in disposition of wastes.
- Selection of monitoring points for establishing information on background radiation and subsequently the effect of day-to-day operations on background.
- Development of program for evaluating environmental hazards in the event of a serious accident or spill and for notifying public officials promptly so that proper warning may be given to off-site populations and industries.

Under normal operations, waste products from a reactor or chemical processing plant operating on a continuing basis can be predicted and a program for on-site decontamination planned so that the ultimate dilution of radioactive gaseous or liquid effluents released will be such as to protect against environmental exposures of significance. But in selecting a site for such plants, it would be unrealistic to assume that operations will always be normal. In evaluating environmental hazards, it would be prudent to accept certain pessimistic positions.

Management of most industries seeks insurance against accidents that may affect employees, plants and facilities, and lives and property in the environs of the plants. Insurance in connection with atomic energy plants is complex. Experience is too limited to establish the probability of occurrence of a major accident. The gross potentialities of an accident and its aftermath, especially for reactors and chemical processing plants, are reasons for concern. (The 85th Congress approved insurance up to $500 million a risk against reactor accidents above the $65 million which private insurance companies are prepared to underwrite. The damage from a reactor accident is estimated by AEC to be in the billion dollar range.)

The alternative to selecting a remote site to reduce the possibility of exposing off-site populations to radiation should an accident occur is to confine the reactor within a tight shell strong enough to withstand an explosion and prevent escape of fission products and other hazardous materials. An example is the steel sphere 225 feet in diameter and nearly an inch thick which encloses the submarine test reactor at West Milton, N. Y. The cost of providing such protection for a small research reactor or a large power reactor may be less than the cost of locating the facility a great distance from the area the reactor is to serve.

Careful planning is needed if plants for the use of atomic energy for peaceful purposes are to be built near populated areas. This new industry must avoid the mistakes of other great industrial enterprises in which early enthusiasm for expansion shaded judgment.