DISPOSAL OF RADIOACTIVE WASTE

Perhaps the most important single problem arising from the increasing use of atomic energy for peaceful purposes is how to dispose of the growing amounts of radioactive waste. Many of its complex aspects were discussed at the scientific conference on the disposal of radioactive waste held by IAEA in Monaco from 16 to 21 November 1959. The conference was organized jointly with UNESCO, with the co-operation of FAO.

Addressing the inaugural session of the conference, the IAEA Director General, Mr. Sterling Cole, said that the term radioactive waste was rather a misnomer, because although there was no ready use for this material at the moment, it did not mean that a use would not be found in course of time. It would, therefore, seem more appropriate to think of the problem as one of storage rather than of disposal. The conference at Monaco, Mr. Cole said, had brought together specialists from many fields and from many countries and provided them with an opportunity to unite their skills in a common effort for the good of mankind.

The Director General of UNESCO, Dr. Vittorino Veronese, stressed the importance of the problem in terms of man's health and genetic future. The prodigious development of science created new problems for man, but, he felt, the scientists were aware of their new duties and responsibilities.

Origin and Nature of the Material

Radioactive waste originates in reactor operations, in the reprocessing of spent nuclear fuel and in the use of radioisotopes in industry, medicine, agriculture and research, by far the largest amounts being produced during the treatment of spent fuel. It is important to remember that the products of nuclear fission are radioactive. Some of these products may be extracted as useful radioisotopes; one can also recover fissile material like plutonium from that portion of the fuel elements which does not undergo fission. Ways are being devised for making the maximum use of these useful end products of reactor operations; nevertheless the major portion of the radioactive material has to be disposed of as waste.

This waste can be solid, liquid or gaseous and is usually classified according to its concentration and according to its radioactivity as low, intermediate or high level waste. Disposal can be carried out in the soil, in water or in the atmosphere.

Whatever the method of disposal, the possibility has to be taken into account that some of the radioactive material may re-enter man's immediate environment or even find its way into our biological system. Safe disposal may be described as a procedure that would ensure that the radioactivity of the waste does not reach man at higher levels than can be considered permissible. A valuable guide in the field of radiation safety is provided by the recommendations of the International Commission for Radiological Protection, but these recommendations cannot be applied directly to the disposal of waste, because the radioactivity released from this waste rarely reaches man in a direct manner. Safety in the disposal of radioactive waste depends not only on the nature and quantities of the materials involved, but also on the behavior of these materials in different types of environment and the nature of man's contact with that environment.

Broadly speaking, the problem of disposal can be tackled in two ways; the waste can be diluted and dispersed so that the radiation to which any single individual would be subjected would be negligible, or it can be concentrated and permanently isolated from man and his immediate environment.

Discharge into the Ground

A variety of methods for the discharge of radioactive waste into the ground were described at the Monaco conference. They range from letting liquid effluent run into pits or wells at appropriately chosen sites to the permanent storage of high activity material at great depth in geologically suitable strata. When the aim is to store the material, one of the first considerations is reduction in volume, so that the operation can be kept down to manageable proportions. If the waste is liquid, it has to be concentrated; if solid, it has to be compressed before being enclosed in containers. Medium level liquid may, for example, be

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mixed with cement in drums which are stacked and totally enclosed in concrete trenches. Medium level solids can also be buried in concrete-lined trenches, while high level solids can be placed in holes lined with steel or concrete piping.

Various methods have been evolved for keeping liquid waste in underground tanks. Studies are under way using natural or artificial cavities in natural salt formations as disposal sites. Several considerations favour this method. Among them are the impermeability of salt, the widespread distribution and availability of salt, its relatively high thermal conductivity that allows the heat generated by the radioactive material to disperse, and the relative ease in forming cavities in salt. In cases where the volume of low or intermediate level waste is too large for permanent storage or decontamination treatment, disposal in certain deep underlying geological formations such as sandstone might be both safe and economical. In such cases a system of injection wells might be necessary.

Many experts favour the transformation of liquid waste into solid forms. A number of reasons have been advanced in support of this practice; for example, solid materials have less mobility than liquids and hence are less likely to find their way back into man's immediate environment. Again, a reduction in volume makes disposal easier. Solids also cause less corrosion to vessels; besides, they facilitate the separation of useful fission products.

In operations where high level waste is stored underground, particular attention must be given during the first years to the removal of the heat generated by the radioactive material.

Another method discussed at Monaco consists in the incorporation of high level fission products in glass which is either buried or stored in vaults. The amount of radioactivity released depends on the composition of the glass, but in any case it decreases with time.

Whatever technique is employed for disposal underground, the choice of sites and methods is in the first place a geological problem. Among the questions to be examined in this connexion are those concerning the processes by which the wastes are fixed in soil or rock. It is also a hydrological problem, because it is the process of circulation of water in nature that enables the waste buried underground to return to man's environment.

Discharge of Waste into Water

There are considerable differences between waste disposal into rivers, harbours, outer continental shelves or the open sea. It was, for example, pointed out at Monaco that enclosed or intercontinental seas like the Baltic pose special problems of disposal.

So far as the rivers are concerned, the most significant quantities of waste likely to flow into them are those that escape from atomic energy establishments. These establishments, however, maintain strict control over all liquids discharged. Samples of water are continuously checked before the water is allowed to flow into local streams, and reservoirs are provided to hold the water lest its radioactivity should increase due to some accident. In the latter case, the contaminated water is treated and freed from radioactive material before discharge into streams.

Similarly, sewerage and other radioactive effluents are diverted to different treatment plants according to their levels of activity. Filtering, chemical treatment, ion exchange and other methods are applied to bring the radioactivity of the water down to a level where discharge into a river may create no hazards to the population at large. The radioactive effluent travelling down a river becomes diluted and dispersed and a good deal of the activity is reduced by the decay of short-lived radioisotopes. Again, part of the radioactive material is removed from the water by silt and biological organisms. Thus water used for the cooling of the reactors at Hanford (USA) and discharged in large volumes into the Columbia River is sufficiently decontaminated to be allowed to go into municipal water supplies about 55 kilometres from the reactor site.

The criteria for the safe disposal of radioactive material in the sea are basically the same as for other media: of limiting radiation doses to man to permissible levels. Except for high level contamination owing to some incident, the return of the material to man would be mainly through the biological cycle and the process of water circulation in nature. A large variety of physical, chemical and biological processes have a bearing on the distribution of radioactive material and on its return to man, such as the precipitation of water as rain and the uptake, concentration and transport by living organisms. They have to be evaluated in detail before a certain marine area can be used safely for waste disposal.

Great importance is attached to coastal waters, harbours and estuaries. These are the regions most convenient for the disposal of low level wastes from shoreside operations. Accidents to ships propelled by atomic energy may also occur at these places. At the same time, these are regions widely used as fishing and recreational grounds. An additional consideration in evaluating risks from waste disposal in these areas is the eating habits of the local human population.

In the open sea, plankton may act as an important carrier of radioactivity. In the Central Pacific Ocean, for instance, plankton were found to contain on the average nearly 500 times the general water concentration of fallout activity. Large areas of the open seas are, however, biological deserts where fishing is not profitable and in which larger amounts of radioactivity might be admitted. Research might therefore be needed to determine present and potential areas for commercial fishing. Since the faculty of marine organisms to accumulate radioisotopes is selective, safety in waste disposal would depend not only on the nature of the waste material but also on the kinds of organisms present. Certain molluscs, for instance, concentrate radioactive caesium but do not concentrate strontium except in their shells. The same applies to many crustacean shellfish and marine fish where one may find high concentrations of radiostrontium in shells, bones and scales but not in the edible flesh. On the other hand, radiocaesium is concentrated to the highest degree in the muscular tissues.

Deep sea areas have been used for the dumping of contained radioactive waste. According to some experts, this is a perfectly safe method, while some others maintain that research is still needed into the circulation, mixing and sedimentation in the deep sea, the rates of interchange between deep and upper layers, and the transfer of elements from the deep to surface layers as a result of the migration of marine organisms.

Disposal in the Air

Gaseous wastes, originating particularly from the reprocessing of irradiated reactor fuel, consist of gaseous fission products and radioactive particles suspended in air or other gases. The problem of airborne wastes has two distinct aspects: the pollution of the air in the immediate vicinity of an atomic plant and the possible long-term, widespread pollution which may constitute a hazard for the world as a whole. Much research has been carried out in the past on short-range air pollution from non-radioactive wastes, such as coal smoke and sulphur dioxide. It has produced useful data, some of which can be applied to radioactive waste as well. Again, study of radioactive fallout following nuclear tests has led to considerable knowledge of long range movements in the atmosphere.

All the data available, on short as well as long-term pollution, point to the desirability of keeping emission rates of gaseous radioactive waste to the lowest possible values. The continued advance in air cleaning techniques - filtering as well as chemical treatment - is making it possible to limit air pollution. In fact, it has been said that the problem of disposal of gas and airborne waste is much nearer solution than that of liquid waste.

The Size of the Problem

The choice of disposal sites and methods depends not only on the nature of the waste and environment, but to a large extent also on the quantities involved, both for reasons of safety and economy. Considerable importance is attached, therefore, to estimates of the amounts of radioactive material that will have to be disposed of as waste.

Since the reprocessing of spent fuel is considered to be the largest source of radioactive waste, the amount of this material will mainly depend on the size of nuclear power industries. Firm estimates can, therefore, hardly go beyond the next decade. The order of magnitude of the problem may be gauged from a few figures given for a number of individual countries. In the United States, it is estimated that the nuclear power industry will have produced 3 thousand million curies of radioactivity in 27 million litres of solution by 1970, and 60 thousand million curies in 1.1 billion litres of solution by the year 2000. By then 88 per cent of the hazardous fission products generated will rest in waste disposal systems. A Canadian report states that more than 16 000 drums, each containing 55 gallons of low-level waste, were dumped off the coast of California from 1946 to 1957. At Harwell (UK) contaminated solid waste, consisting of building material, protective clothing, laboratory equipment, animal remains, etc., is first reduced in volume as much as possible, and subsequently either stored or discharged into the sea. The total volume of this waste amounts to approximately 3 200 cubic feet per week, weighing about 29 tons.

The handling and transportation of large quantities of radioactive waste also present a number of difficulties and hazards owing to the risk of irradiation and contamination. This fact has to be taken into account in the siting of atomic energy installations. It requires the drawing up of special regulations and the organization, equipping and training of special teams for waste removal and transportation.

Furthermore, the presence, transport, storage and discharge of radioactive material raises a number of administrative and legal problems - local, national and international. In the first place, it would seem essential that appropriate standards and criteria be developed and promulgated. Before authorization for waste disposal is given, estimates of permissible levels must be made by competent authorities. Subsequently, regular monitoring of the disposal areas has to be maintained.

Review of Discussions

Many of the experts at the Monaco conference were of the view that most of the proposed, or actually applied, methods of waste disposal were compatible with safety requirements. Some experts, however, felt that certain of these methods might not be harmless. This applied in particular to the possible hazards of disposal in the sea. There seemed to be general agreement, however, that much additional research was needed to devise more effective and economical methods of disposal and to gain a better knowledge of the effects of various types of disposal operations, particularly in view of the increasing amounts of waste material that will be produced as the nuclear energy industry expands.

Reviewing the discussions, Mr. G.W.C. Tait, Director of IAEA's Division of Health, Safety and Waste Disposal, told the concluding session of the conference that it was clear that whatever methods of disposal were chosen, they must have the overriding aim of not endangering man either immediately or in the long run. He said: "Irrespective of our different points of view, we are all agreed on one thing: we must make the atomic age a safe age". There also seemed to be general agreement that because of the wide diversity of wastes - both quantitatively and qualitatively - there did not exist any universally applicable method or set of methods for disposal. The conference, Mr. Tait said, had served a useful purpose in making scientists aware of the relevance of the various problems and of the findings of research workers in other fields. He pointed out that many of the differences of opinion were more apparent than real and were based less on differences of principles or philosophies than on difficulties of definition. In this regard also, a number of important clarifications had been reached and all participants were of the opinion that any method of disposal must at least be in conformity with the accepted maximum permissible levels of radiation. Mr. Tait added: "Radioactivity reaching man from peaceful applications is still negligible, but we are all aware of the destruction man brought upon himself and upon his environment when he embarked on the industrial revolution. We are on the threshold of a new revolution: the atomic age. The thoroughness and earnestness with which we have discussed the disposal of radioactive materials proves that we are aware of this lesson, that we are determined to prevent a repetition of what has happened in man's past."

The conference was attended by more than 300 experts from 32 countries and 11 international organizations.

Photographic exhibition in Vienna during the third session of the IAEA General Conference, showing progress in atomic energy in many of the Agency's Member States

Scientific documentation from the Central Technical Library of Czechoslovakia was handed over to IAEA on 2 November 1959; this was the second consignment of such documentation donated to the Agency by the Czechoslovak Government. From left to right: Jiri Švab, Alternate Governor for Czechoslovakia on the Agency's Board; Arkadij N. Rylov, IAEA's Deputy Director General in charge of Training and Technical Information, John Cummins, IAEA; and Reinhold Schlueter, IAEA