radioactive waste management

An effective system for the management of radioactive wastes is essential wherever radioactive materials are used. The article which follows has been contributed by Dr. Emil Wallauschek, Head of the Division of Health, Safety and Waste Management of the European Nuclear Energy Agency of the OECD.

Most industrial and domestic processes give rise to waste production, and the nuclear energy industry is no exception. Radioactive wastes are produced wherever radioactive materials are processed or used. The wastes may be in the form of gases, liquids, sludges or solids, and their nature, physical and chemical form, volume and activity are all closely related to the original nuclear process.

Because of the inherent toxicity of many radioactive materials either these wastes must be treated to remove most of the contaminants before being released to the environment, or they must be so diluted that their concentrations of contaminants are below the permitted levels. When radioactive contaminants are removed from waste streams they will normally become concentrated, and will then require special treatment, handling and subsequent storage or disposal in isolation from the human biosphere.

The growing public interest in problems of environmental pollution from all sources is creating an increased awareness of the potential consequences of nuclear development, notably in relation to the management of radioactive wastes. Due to the complexity of the scientific and technical questions involved, most people outside the nuclear field consider radioactive wastes as a single homogeneous subject. In fact they represent a very heterogeneous collection of products of different physical and chemical forms, and, although the same basic considerations apply for their management, wastes from different sources such as nuclear reactors, research centres, fuel reprocessing plants or the widespread use of radioisotopes may be handled in different ways due, in particular, to local and regional factors. This is a complex subject and, in view of the growing interest in it, it is becoming urgent to make available improved information for the general public and to encourage public confidence by demonstrating that the environmental problems due to nuclear development and waste disposal operations are fully recognised, that the risks involved are well-known and controlled with a sense of responsibility, and that the management practices adopted have always included very wide safety margins to protect public health.

Radioactivity in the human environment

Radiation and radioactivity have always been present in man's environment: natural radioactivity has been with us since the beginning of time. Human life has thus never been free from exposure to ionizing radiation both from the earth itself (more than 60 radionuclides are known to occur naturally in the earth's environment) and from bombardment of the earth's gaseous envelope by cosmic rays originating outside our atmosphere. We should not forget that the energy needed to maintain life on earth, which is provided by the sun in the form of light and heat, is based on atomic fusion processes. Radioactivity and radiation in our human environment is therefore not a new problem.

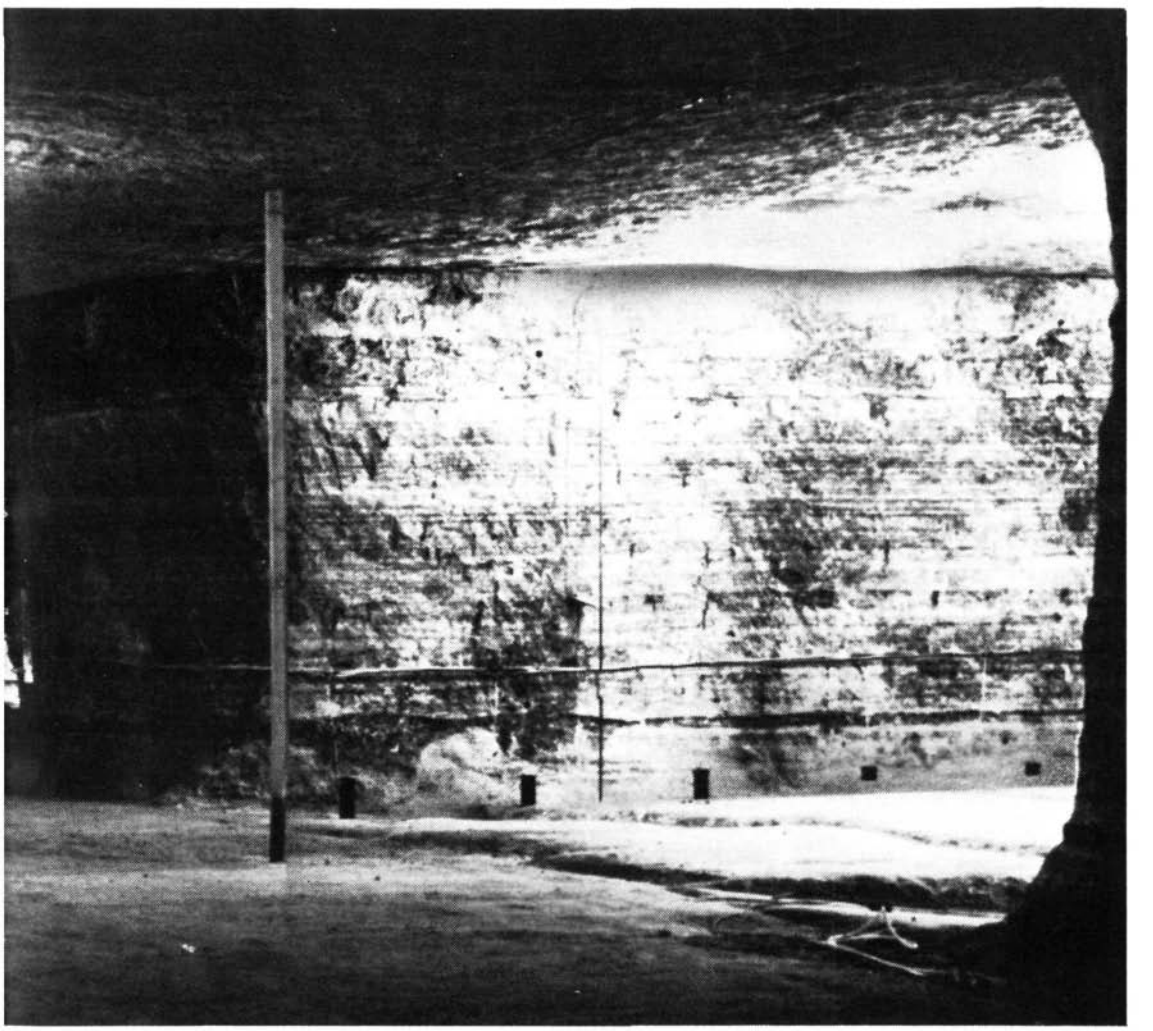
The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has established that the present doses to humans of naturally-occurring radiation are generally in the range of 100 to 300 millirems a year, but may in a few areas exceed 1000 millirems a year. Some 20 millirems a year of this originates from naturally-occurring radioactive materials within the human body itself.

An abandoned salt mine in Kansas, used by the United States Atomic Energy Commission in a study of the long-term storage of highly radioactive wastes. Photo: USAEC/Oak Ridge National Laboratory

Since the beginning of this century, and in particular during the last two decades, man has introduced many additional sources of radiation into his world, all of which can contribute to the total irradiation which he receives. These include radiations from medical treatment, from fallout (from nuclear weapons testing), from radiation sources used in research and in industrial processes, and from a variety of substances used or produced in the production of nuclear power. It is this last category which is principally responsible for the waste problem.

Most of these activities have resulted in the release of some radioactivity to the environment. For example, it has been estimated that the quantity of radioactivity released to the world marine environment as a result of nuclear explosions amounts to some hundreds of megacuries, and to a few hundred kilocuries a year as a result of other nuclear operations. If we compare these figures with the estimated total natural activity in the marine environment, of 500 000 megacuries, we have a first and simplified indication of the relative magnitude of contributions to environmental radioactivity. The contribution of nuclear power, even The contribution of nuclear power, even through waste disposal operations, is in fact an insignificant part of the world's total.

However, the implications for the public health are much more complex: they must be examined at local or regional levels (and, in particular cases such as that of Krypton-85, in



future also worldwide) and must also take into account the relative biological importance of the different radioactive materials released.

Basic considerations in waste management

The overriding requirement in all waste management operations is to ensure adequate protection against the potential dengers of radioactivity. Safety criteria are based on well-established and internationally-recognised radiation protection standards (discussed elsewhere in this issue of the Bulletin), and all operations must include control of the radiation hazards not only during handling and treatment of wastes but also after they have been either stored or released to the environment. Unacceptable risks either for the workers handling the wastes or for others including the general public must be excluded. All other considerations affecting waste management, such as the availability of various treatment, storage or disposal methods, or other environmental and economic factors, must be secondary in importance compared with the safety of human beings.

The internationally-recognised radiation protection standards on which waste management safety criteria (and indeed safety criteria for all operations involving 'artificial' radioactivity) are based are those of the International Commission on Radiological Protection (ICRP). This Commission (in its Report No. 9) enunciates two main objectives for radiation protection policies: *the absolute prevention of acute and immediate effects, and the limitation of risks* of delayed and genetic effects to an acceptable level. These objective derive from detailed scientific understanding of the immediate effects of radiation exposure, coupled with the knowledge that man can receive certain small doses of radiation without significant risk of somatic or genetic injury. However, since the understanding of possible long-term effects of radiation is at present less complete, a further principle of the ICRP recommendations is that all exposure should be kept "as low as is readily achievable, economic and social considerations being taken into account".

This last principle introduces the risk-benefit concept. Nuclear energy constitutes an indisputable benefit. In accepting this benefit we have also to accept certain risks, and detailed analyses of all factors are necessary to arrive at a proper balance in the interest of human society.

In radioactive waste management all workers directly involved in the handling and treatment of wastes are submitted to well-established radiological control measures based on the ICRP principles. Basic radiation protection principles are also applied for the protection of the general public, though the problems here are more complex. For workers, received doses can be measured directly, but for the public indirect methods of dose evaluation must be used.

The choice of waste management methods

It is frequently maintained that radioactive waste management involves a choice between two basic approaches: the first being "dilute and disperse to the environment" and the second "concentrate, contain and isolate". The first approach, however, may be used only for wastes with low hazard potentials, when the radioactivity can be reduced to acceptable levels by dilution in the environment (mainly in air or water). As this method involves some increase in the possible public exposure to radiation, it can only be applied after a careful risk assessment has been made, taking into account such factors as dispersion mechanism, possible reconcentration by chemical or biological processes, and possible pathways whereby the radioactivity might return to man.

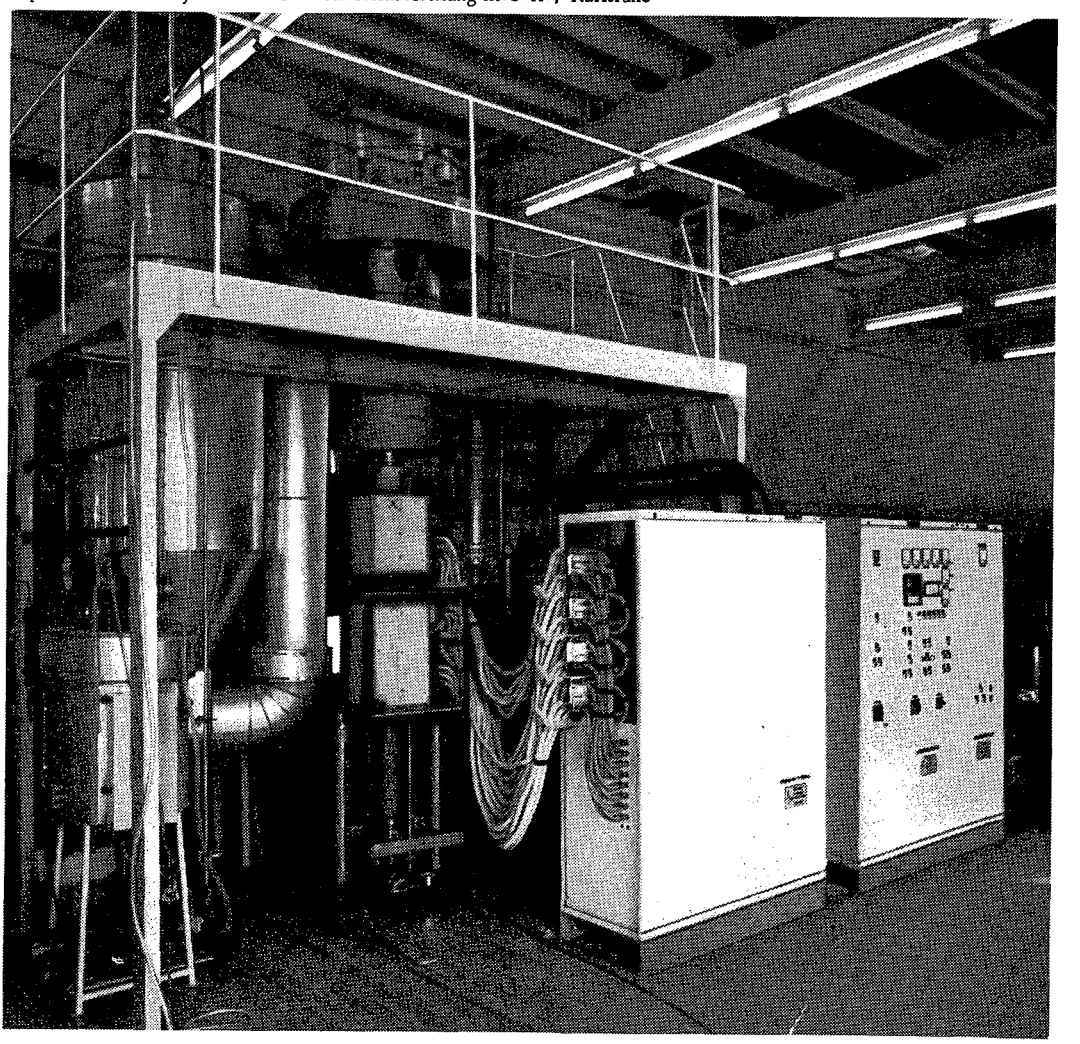
With the "concentrate, contain and isolate" approach to waste management there is virtually no exposure of the general public to radiation. This method is used mainly for solid wastes of all kinds, but also for high activity liquid wastes from the chemical

reprocessing of irradiated nuclear fuels. A proper containment or storage site is of course needed to exclude any possibility of interaction of radioactive materials with the human biosphere, at least until radioactive decay has reduced the activity to insignificant levels.

In some cases, such as for the disposal of low activity solid wastes into the sea, a combination of the two methods may be chosen. In other cases, a third or compromise method of "delay and decay" may be used. The wastes in such cases are stored (which means their emplacement with the intent and in such a manner that they can be retrieved later) for a certain time to allow "cooling down" by decay, after which they are finally disposed of (which means emplacement in such a manner or location that, for all practical purposes, they become irretrievable).

An important consideration in determining waste disposal policies is that practices now used should not leave unsolved problems for future generations. Rather, it is acknowledged that provision for the ultimate safe disposal of wastes should be the responsibility of the generation producing those wastes. "Temporary storage" should not therefore be used merely to pass on the problems to future generations.

Equipment used in research on the solidification of highly-active wastes at the Karlsruhe Research Centre, Federal Republic of Germany. Photo: Ges. für Kernforschung m.b.H., Karlsruhe



Waste treatment practices

For certain categories of wastes, such as slightly contaminated solid materials or wastes in gaseous or liquid forms whose radioactive content is very small compared with the capacity of the receiving environment there is often no justification for treatment prior to disposal. Treatment methods, when adopted, may be used to:

- separate wastes of different levels in order to allow the release of the low activity component to the environment;
- convert the wastes into a physical form which permits their handling, storage or disposal more safely, conveniently or economically;
- reduce the volume of the wastes in order to reduce transportation or storage costs.

Such treatment methods involve, besides segregation, such processes as incineration, mechanical baling, and incorporation in concrete or bitumen for solids; chemical processes of precipitation, ion exchange, volume reduction by evaporation, and others for liquids; and various cleaning processes and filtering for gases.

The use of the environment

A principal problem in waste management is to decide which parts of the waste may be released to the environment without delay, and which parts must first be treated or stored either temporarily or indefinitely. It is therefore important that the various types of wastes should be segregated according to their suitability for further treatment, their level of activity, and other criteria relevant to their management. In this respect the ability of the environment to assimilate wastes in particular ways is an important factor.

In addition to the immediate problem of radiation protection, we have a particular responsibility towards future generations. Clean air, fresh water and suitable food are all essential for man's life and for maintenance of the health and growth of the human race. Although the environment can absorb wastes up to a certain limit without significant damaging effects, its capacity is not unlimited. Any waste disposal operation must therefore be undertaken only after careful assessment of possible harmful effects, not only for the present but for future generations.

Well over 99.9 per cent of the total radioactivity contained in wastes now being produced, concentrated into small volumes, is stored in isolation from the living environment, and controls are therefore necessary to ensure continued isolation of such wastes. Unfortunately we have no method, at least with technologies available at present, of accelerating the natural rates of decay of radioactivity in either naturally- or artificially-occurring substances.

Depending on their physical and chemical characteristics, radioisotopes released to the environment behave in many different ways. Dilution and dispersion, sedimentation, ingestion or absorption, and reconcentration processes in living organisms are extremely complex and differ from element to element. Further, wide differences in behaviour are observed in the various media – air, sea water, fresh water, and the agricultural and ground environments. These are matters of fundamental importance in deciding on a waste management policy for any given situation, and since the overriding consideration must always be health protection, a detailed risk assessment has to be made and a substantial safety margin thus incorporated.

In the case of release to the environment the determination of release levels involves many different considerations. Among these are the form, quantities and activities of the wastes concerned, the characteristics of the different radioisotopes involved, their behaviour in the environment, the local and regional conditions of the receiving environment as well as its capacity to absorb wastes and, last but not least, a comprehensive study of the possible path-

ways back to man. In addition, social, economic and political factors may also influence the waste disposal policy finally adopted.

The scale of the waste management problem

The magnitude of the problem of radioactive wastes arising from research and development work involving radioactive materials can be considered to be stable. Although the use of radioisotopes for industrial and other purposes is increasing rapidly their contribution to the total production of wastes by society is very small and relatively easy to control. This leaves as the principal problem of waste management, now and in the future, that of wastes from the industrial phases of the nuclear fuel cycle.

It is not, of course, at the sites of the nuclear power plants themselves that waste management problems of significance to the environment arise. Only minor quantities are released to the environment at this stage, while the fission products produced during fuel burn-up remain contained in the reactor fuel elements. Important problems arise, however, when the fuel is reprocessed and the fission products separated. At this stage the large amounts of radioactive wastes produced must be treated and the high-activity components dealt with in such a way that isolation from the biosphere is ensured. This can be, and is, done today with a high degree of safety. Substantial quantities of high-activity wastes are at present stored, mainly in liquid form, but the accumulation of these wastes will certainly constitute a severe problem in waste management during future decades, and alternative methods (solidification and final storage under suitable geological conditions) are being developed. [The management of radioactive wastes from fuel reprocessing is to be discussed at a joint ENEA/IAEA Symposium in Paris in November this year.]

Past, present and future

During the first stages of the development of nuclear energy, waste management problems were limited to a laboratory scale and concerned only the comparatively few early establishments where the development was taking place. But even at this early time, more than two decades ago, the potential hazards in waste management were well understood, and many principles were established long before the need arose to apply them on a larger and industrial scale. Although there was some degree of collaboration between countries this was in general limited to exchanges of information and experience, while national authorities tended to set their own standards of regulation and control in order to meet their own particular conditions. Already, however, the recommendations of the ICRP were accepted as the proper basis for assessing the safety of discharges of radioactivity to the human environment.

A continuous growth in international collaboration which followed these early stages has contributed to increasing knowledge of the many and various aspects of waste management technology. This increasing knowledge is at least partly the reason why, although many new nuclear establishments have come into operation during the past decade and while there has also been a significant increase in the use of radioactive materials for many purposes, there is no evidence of any unacceptable increase in contamination of the environment by radioactivity. Our objectives should now be to see that this situation is maintained in the future.

Management methods for gaseous, liquid and solid wastes from different sources, as well as basic criteria to be applied for ground and sea disposal, have been discussed in detail on many occasions and a great many publications are available. In the present short paper it is not possible to develop these subjects, but some of the most recent publications are noted in the list of references.

Particular mention many be made, however, of a recent study, undertaken for the Western European area (last reference listed) which has shown that radioactive waste management practices have been established on sound basic principles and related to internationally recognised standards. Public health authorities in the countries concerned have been provided with effective, objective and generally-accepted means by which the practices of radioactive waste management can be regulated in the public interest, and it is clear that the optimum development of nuclear energy need not be impeded by the radioactive waste management problems which will result. It is no less clear, however, that regional environmental problems, sea disposal, the use of international rivers, and the probability of grouping together of neighbouring countries to solve their radioactive waste management problems, will together call for close co-operation at the international level.

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