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POTENTIAL EFFECTS ON HEALTH OF RADIOACTIVE WASTE DISPOSAL

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Radioactive waste is considered to represent a potential health risk for future generations by a section of the public which considers that its long-term management leaves room for improvement. This opinion is probably due to the conjunction of concepts relating to "waste", with concepts relating to "radioactivity" and also to the fact that industrial waste has not always been given the requisite attention.

1 - WASTE CATEGORIES AND PRODUCTION FORECASTS

It is important to search for the facts. Firstly, it shouldn't be forgotten that there are many varieties of radioactive wastes depending on origin and volume. They range from the fission products extracted during nuclear power plant fuel reprocessing to gloves or plastics used to protect personnel working in certain plants, from the components of nuclear reactors at the end of their working lifetime to the residues of uranium or plutonium purification operations, from used gamma radiography sources to certain accessories used in hospitals.

These wastes differ in the amount of radioactivity contained (which may vary from a fraction of millicuries per litre to thousands of curies per litre), in their radioactive period (from several months to thousands of years) and in the radiotoxicity of the radioactive elements contained. The processing and disposal of this waste is not identical in each case, hence the advantages of their categorisation. From the standpoints of disposal and long-term risk, it is convenient to divide them into three broad categories :

A. Low and medium activity wastes containing only small quantities of long-period radionuclides.

B. Low and medium activity wastes containing long-period radionuclides (α emitters hence the name "α wastes").

C. High activity wastes.

Table 1 gives forecasts for waste production in France up to the end of the century and table 2 gives forecasts for the entire European Community.

These tables show that :

- Low and medium activity wastes, large as they are in relation to those belonging to other categories, are very low in comparison to chemical and industrial waste volumes.

- High-activity wastes account for only very small volumes in the year 2000 and do not present serious problems for short-teem storage.

2- MANAGEMENT PROCEDURE

2.1. Guidelines

The main point is that waste management must follow very strict guidelines of which the two most important are as follows :

- Waste management must involve minimum risk to present and future generations.

- Management must involve minimum constraints for future generations.

Management should comply with health physics guidelines, i.e the public should under no circumstances be exposed to radiation beyond the values laid down in the relevant standards and,as recommended by the International Commission on Radiological Protection, doses received by the public should be kept as low as reasonably achievable, economic and social factors being taken into account. The quality of the environment should also be preserved and efforts should be made no to impede the present and future exploitation of natural resources.

2.2. Practical rules for management

These guidelines are the basis for practical waste management rules.

Efforts should be made to minimise production by using recycling waste inside plants and using decontamination techniques.

Once waste has been produced , two main options are possible ; to dilute and disperse, in other words to release waste to the environment, which is possible in certain cases and in certain conditions, or to concentrate and confine, which is done in most cases. There will then be four main management phases : waste processing to produce initial waste, waste packaging , temporary storage which may be made necessary by a certain number of factors and finally disposal.

This means that as long as it is impossible or undesirable to discharge wastes directly to the environment, they must be packaged in such a way that they can be stored along the requisite guidelines. This also means that the methods used may vary with each different waste category.

3- TREATMENT AND PACKAGING

A large number of treatments have been developed for decontaminating liquid waste with a view to the release to the environment of the largest possible fraction of the initial volume and with a view to the storage of only a small volume which will then be packaged in a suitable form for disposal.

The most widely used treatments for low medium activity wastes are : evaporation, coprecipitation, ion exchange.

Residues are conditioned :

- By blocking-up with a hydraulic binder (concrets, cement),
- Or by embedding in bitumen or in thermosetting resins.

The concrete is made according to a pre-determined formula and using components designed for the disposal conditions as well as in conjunction with special products for increasing the strength of the concrete and improving the adsorption of the radionuclides into the concrete.

For high-activity wastes, the most widely-used treatment and the only one now used on a commercial scale is vitrification. This process involves firstly evaporation of high-activity liquid wastes until they are completely dry followed by the incorporation of these oxides into a glass grid by high-temperature fusion with the glass particles. This produces a glass resistant to radiation, to the action of external agents and to the effects of water.

4 - RADIOACTIVE WASTE DISPOSAL

The basic problem presented by the long-term management of radioactive waste is the possibility of the dispersion of radionuclides which might reach the biosphere and could then reach man under conditions which would not meet basic protection requirements.

This problem has been solved (in the case of previous disposal operations) or will be solved by the creation of a system of barriers which will prevent this dispersion. The effect of some of these barriers will be vital during a given period of radioactive decay, but it is the barriers in their entirety which provide safety of disposal.

However the construction of the barriers and their number will vary according to the waste categories and therefore the time during which the radioactivity is to be contained.

4.1. Low and medium activity wastes

Two disposal processes are currently used around the world.

4.1.1. Shallow land disposal

Safety depends on two factors :

- Waste characteristics such as potential harmfulness, decay to a very low level within about 100 to 300 years,
- Creation of artificial barriers for containing radioactivity over this period.

Soil characteristics provide an additional guarantee.

After they have been made insoluble and packaged, wastes whose radioactivity exceeds a certain level are placed in concrete structures then covered with an impermeable layer of clay materials. Protection is then provided against freezing and atmospheric water. Surveillance of the effectiveness of the physical barriers and the protection against undesirable actions by man are monitored on the site until the radioactivity level is low enough to make the potential risk negligible.

Long-term safety is provided by limiting the activity of long-period radionuclides. It is impossible to rule out the possibility that after a few centuries the leaktightness of the clay cover may be reduced and that the aging of the coating will increase the rate of entrainment by leaching. Since administrative inspections will have lapsed and oblivion will have set in, unless the geographical location is carefully chosen, it is unavoidable that building works will damage all or part of the storage whose concrete structure may well have lost its mechanical strength.

However, the materials resulting from the degradation of concrete and clay materials preserve their capacity for retention and therefore only a small proportion of the elements entrained by leaching will reach the subsoil, whose characteristics have been selected for their capacity for adsorption in relation to any migrating activity. A quantitative relationship can be made between total storage α activity and α concentration which could eventually appear in surface water and an assessment can be made of the resulting maximum annual dose affecting individuals belonging to the group that is the most highly exposed to the various transfer paths already mentioned. The total α activity stored on site can be limited so that these individuals can only receive a negligible dose from the site disposal, i.e a few tens of millirems per year.

If allowance is made for the possibility of building works on the storage site after the monitoring period, the biggest potential risk is that of inhalation of aerosols by workers during earth works, assuming that the concrete and coatings are reduced to dust. The dose received in this case by a worker working over a given period of time on this site would be proportional to medium α activity per unit weight of stored wastes. By choosing probable hypotheses accompanied in each case by safety margins in their quantitative expression, a relationship can be established which would allow evaluation of the average specific activity which must not be exceeded so that the target maximum dose level is not reached.

4.1.2. Immersion

Another mode of disposal of low-activity waste is dumping in deep holes in the ocean. Such operations are currently being carried out by some European countries under the terms of the London Convention (1972) along the lines laid down by IAEA (1978) and under the surveillance of the Nuclear Agency of the OECD.

The selected site is in the North Atlantic more than 700 km from dry land (southermost capeof Ireland and north-western capeof Spain) average depth is 4400 meters. The total and specific activity of the immersed wastes is restricted ; they currently account for (in relatively short-lived radioelements) about a millionth of the natural radioactivity present in oceans.

The analyses which established the very wide margin of safety of such sea dumping allowed for the most pessimistic hypotheses and used the severest possible values in their calculations : rapid release of all radioactivity after deposit, model of relatively rapid exchanges between different oceanic layers, relatively high current values, maximum values for concentration factors in plankton and marine flora and fauna throughout alimentary chains. Any radioactivity which could reach man under these conditions would involve extremely low doses compared with those resulting from the presence of potassium 40, and natural thorium and uranium in everyday foodstuffs.

In practice experiments and tests have shown that containers are highly resistant and capable, in the case of concrete containers made to current standards, of guaranteeing containment over anything between fifty years and a century : this provides an extra safety factor.

4.2. Disposal of high-activity and α wastes

In these cases the barriers will be :

- The packaging material (glass, concrete etc),
- Container(s),
- An artificial barrier with adsorption properties preventing the migration of radionuclides,
- The geological barrier consisting of the geological formation containing the deposit, whose characteristics will be chosen accordingly.

Geological formations should meet a certain number of criteria (seismic and tectonic stability, absence of water or minimal water circulation, sorption characteristics of geological barrier). Many formations can meet these criteria (granite, shales, clay, basalt, salt formations) and are currently subject to a research programme in most of the countries.

Given production forecasts and contrary to low and medium activity wastes, there has up until now been no need to have such deposits and the need will only arise in about ten years for α waste and in several decades for high-activity wastes.

The barriers will provide long-term safety. Their long-term behaviour must therefore be determined and studies are currently under way to determine their laws of development on a scientific basis.

The choice of solid and of a container resistant to heat, radiation and corrosion as well as that of a suitable filler material capable of providing a buffer between the containers and the geological formation should ensure isolation of the waste over the 5 to 10 centuries corresponding to the decay and cooldown phase. Beyond the period, long-lived α emitters are the biggest problem ; assuming that the design barriers have lost their efficiency, dispersion must be controlled by nature and geological and hydrogeological qualities of the deep formations chosen for disposal.

Current studies are already showing that there exist formations with all the qualities required of natural geological barriers for the efficient prevention of the migration of radioactive substances to the biosphere. And models based both on deterministic and probabilistic methods are making it possible to calculate the maximum dose that the most exposed individuals are liable to receive in the future. A geological formation will of course only be recognised as acceptable if very small doses are involved, approximately equal to the variations between the different values for natural irradiation.

5-HEALTH PHYSICS ASPECTS

As a practical point of view, for all the categories of wastes, the operating procedures from the production to the disposal involve radiation exposure for workers and population. During the different phases, the exposure is intercorrelated : for example, reduction of risk at one stage may induce higher exposure at a later stage. In these conditions, the choice of the different procedures will strongly depend on the choice of the group of population or workers chosen.

Disposal of radioactive waste involves isolation of the radioactive material from the human environment over a sufficient period of time to permit decay. Any exposure that could still occur is due to :

- Leakage release mechanisms, leading to a previsional exposure pattern in space and time,
- Random disruptive events, with a probability of occurence and an exposure pattern.

The major difficulties for the prediction of exposure are mainly due to the very long time periods involved.

If one assumes that all individuals are to be protected alike, irrespective of time and location, the study of the radiological consequences has to be carried out such an upper limit for the annual dose has to be applied to each depository.

5.1. Methodology for normal leakage

The methodology is the same for every categories of repository, but should be adapted, taking into account the parameters for each case.

The "source-term" being defined, including all the man-made barriers through which leakage is likely to be expected, module of computation may be defined.

5.1.1. Transfer through physical medium

A big amount of mathematical models are available in the world, some of them being in one dimension, the others in 2 or 3 dimensions. Most of the mathematical approaches are based on the three fundamental hydrodynamics equations :

- Mass conservation,
- Momentum conservation,
- Energy conservation.

For the cases of sea repository two other equations have to be added : temperature and saltness states equations.

The major problems when using such models are not in the mathematical field. They essentially consist in the choice of the parameters to be used. For example, in the cases of terrestrian repository, two parameters play an essential role :

k_D, which is defined as the coefficient of radionuclides distribution in the rocks, and which takes into account the adsorption and desorption of radionuclides in the medium,

V, which is the water transfer speed through the medium...

These two parameters are fundamentally dependent on the repository site and can be determined only after extended hydrogeological studies, using experimental data and in situ observed values.

Furthermore, one major hypothesis has to be made : these parameters are constant throughout the centuries. This assumption is not unrealistic when considering 300 years but is difficult to hold over more than 1000 years. Studies of prospective behaviour over such a long period can probably be carried out, but will be very difficult, time consuming and will only give a rough estimation.

5.1.2. Transfer through food chain

In this module, the mathematical expression is very simple, but the transfer coefficients play an important role ; they are strongly dependent on the agricultural habits and once more the question arises : will they be the same in some hundred years or thousand years ? In this field, it is not quite sure that the historical data may allow a prospective and previsional survey, at least in France.

5.1.3. Transfer through food production distribution

The alimentary habits are usually known through national statistics on consumption or regional inquiries. Using such results in order to estimate the radiological consequences for a period of centuries is probably hazardous, but projected evaluations of alimentary habits is highly speculative.

5.1.4. Health consequences

As it has been stated by ICRP, dose calculations have to be carried out with respect of the three basic principles :

- Justification : as it happens currently in industrial activities, advantages and possible damages do not involve the same individuals. Consequently, the balance has to be made for the society as a whole. It means that the societal risk has to be estimated using the collective dose,
- Respect of optimisation : as the doses to workers and population have to be as low as reasonably achievable, taking account of economical and sociological aspects, the collective dose is the parameter to be used. But it has to be corrected by factors which express among other considerations, individual doses distribution in the more exposed groups and the fact that these exposures are projected in a far future and are of stochastic nature,
- Respect of dose limitation : when optimisation studies have determined an optimal level of protection on the collective point of view, the individual risk has to be considered. In the case of waste disposal, usually optimisation is carried out so that the level of exposure for the future stay within the variation of natural irradiation. Consequently this third principle is "ipso-facto" respected. [1]

5.2. Methodology in case of disruptive events

The methodology is almost the same as for the other stages of nuclear energy production. As possibility of disruptive events cannot be neglected, probability values must then be assigned to the few disruptive events that are expected to cause significant exposure. Then, as proposed by D. Beninson and B. Lindell [2], event tree assessments using composite probability values for a number of exposure situations may be used. They also proposed, as the simplest approach, to assess for each exposure situation maximum doses as if they occured simultaneously in one and the same critical group. This reasoning is valid for doses which could cause either stochastic effets, either non-stochastic effects.

In view of computation for the radiological consequences of such disruptive events, one has to assume hypothesis on the scenarii involved, and then to treat separately the different kinds of waste repository. In France, at the moment, in the case of shallow land disposal and deep ground disposal, the following scenarii are considered :

- seisms which may lead to rupture of the different man-made barriers,
- dam destruction which leads to flood and diversion of watercourse,
- meteorite fall,
- man intervention (building, digging) after the 300 years periods.

Except for meteorite fall, the probabilities associated with these different scenarii are rather difficult to estimate.

In case of seabed disposal, the System Analysis Task Group of the International Seabed Working Group proposes different types of scenarii but their probabilities of occurence are not yet available [3]. They considered the following events : erosion of sediment cover due to turbidity currents, slumping, earthquakes or volcanic activity, by unexpected upward movement of a canister as a result of buoyancyforces, by unforeseen human exploitation of the seabed. These events may lead to different consequences : single undamaged canister on sediment surface, single undamaged canister 10 m deep in sediment, single damaged canister 10 m deep in sediment with for each cases different conditions of dispersions.

The radiological consequences of such scenarii are based also on models for the transport of radioactivity through the different modules.

5.3. Conclusion

An assessment of the total collective dose commitment from a disruptive event as well as from the normal release is therefore highly speculative [2]. Fortunately, however, this is not the quantity actually needed. In optimization of protection, we are only concerned with doses actually avoided by changes in the protection. The time period of interest is therefore the period in which the alternative protection levels (engineering solutions) have an influence on the exposure pattern. This time period cannot be longer than the assumed retention period. The retention period may be short enough (300 to 10 000 years) to make collective dose assessments reasonably realistic. No depository is expected to retain the deposited material over geological time periods but it is not necessary to garantee a total retention.

By using the models described before and taking into account very conservative assumptions, it has been possible to conclude that the future generations will only be exposed at a dose of the same order as the natural irradiation.

6 - GENERAL CONCLUSION

In a lecture given last year at Richland during a symposium on Treatment and Handling of Radioactive waste; Dr. DIXY RAY who was chairman of the AEC and former Governor of the State of Washington presented waste management as a non problem.

And certainly radioactive waste does not constitute a problem at the present time. The methods of conditioning and disposal used are safe, especially in view of the amounts now being produced and of the huge capacity of the potential recipient media.

If there is a problem, then it lies only in the long distant future because it is difficult to evaluate very carefully the behaviour of the conditional wastes, of the engineered barriers. But the margin of safety adopted, the number of barriers can give a garantee. Furthermore geologic disposal will not differ much from disposal made by nature itself for instance for the confinment of one billion of curie of radium in upper 200 m. of french soil.

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PRODUCTION OF WASTES IN E.E.C
FROM 1980 TO 2000

in m³

LLW and MLW	1 600 000
α W	80 000
HLM	4 700

Table 1

PRODUCTION OF WASTES
IN FRANCE

in m³ - cumulative figures

	1980	1990	2000
L and MLW	150 000	400 000	800 000
α W	8 000	15 000	45 000
HLW	100	800	3 000

Table 2