Chapter 12 Waste management

In Chapter 10 we described the discharge of effluents from the nuclear fuel cycle, but there are also other radioactive wastes. These come not only from the various parts of the nuclear fuel cycle — from the mining and processing of uranium to the dismantling of old nuclear installations — but also from medical, industrial and research activities involving radioactive materials.

Different countries classify wastes in different ways, but a number of general categories can be identified

Exempt waste contains such a low concentration of activity that it does not need to be treated differently from ordinary non-radioactive waste;

Low/intermediate level waste consists of items such as paper, clothing and laboratory equipment that have been used in areas where radioactive substances are handled, as well as contaminated soil and building materials, along with more active materials used in the treatment of gaseous and liquid effluents before they are discharged to the environment, or the sludges that accumulate in the cooling ponds where spent fuel is stored;

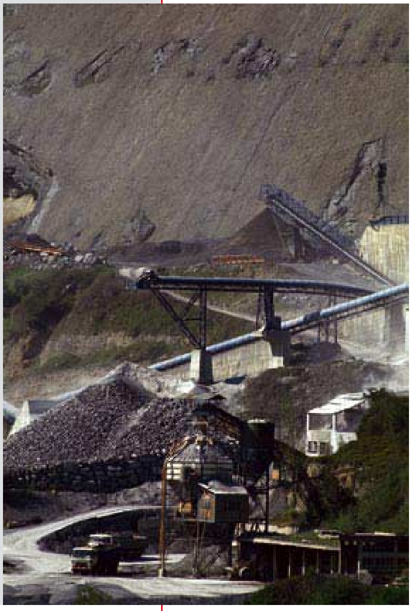
Short lived waste contains mainly radionuclides with relatively short half-lives (less than 30 years), with only very low concentrations of long lived radionuclides;

NORM (naturally occurring radioactive material) waste consists of often very large amounts of waste containing fairly low concentrations of naturally occurring radionuclides (though these concentrations are often higher than those found in nature). This type of waste is generated in the mining and processing of uranium and other minerals, such as phosphates used in fertilizers;

NORM waste is produced in mining and fertilizer processing

Alpha waste (or transuranic waste) — waste containing alpha emitting radionuclides such as isotopes of plutonium — is treated as a separate category in some countries; and

High level waste refers only to spent fuel from a reactor (in countries where this is regarded as a waste) or to the highly active liquid produced when spent fuel is reprocessed. The volume of this type of waste is very low, but its activity is so high that it generates considerable heat.



Type of waste	Typical sources	Characteristics	Disposal
Exempt waste	*Contains very limited amounts of radionuclides*	*Can be treated as normal refuse*	*Normal municipal refuse disposal facilities*
Mining waste	*Mine tailings*	*Huge volumes*	*Mine tailings dams — return high grade tailings underground*
NORM waste	*Waste from minerals processing scale from pipes or equipment*	*Enhanced levels of naturally occurring radionuclides*	*Mine tailings for low grades, on surface storage for higher grades*
Low/ intermediate level waste	*Contaminated paper, clothing, laboratory equipment, contaminated soil and building materials* *Ion exchange materials from treatment of effluents sludges from cooling ponds*	*Limited heat generation*	*Shorter lived in near surface disposal facilities or intermediate depth mined caverns (from around 60 to 100 m depth)* *Longer lived stored pending development of deeper disposal facilities*
Alpha waste	*As low/intermediate level waste, but with alpha (especially plutonium) contamination*	*Treated as a special category in some countries*	*Geological disposal, consideration being given to intermediate depth storage (tens of metres)*
High level waste	*Spent fuel (when treated as waste)* *Highly active liquor from reprocessing*	*Need heavy shielding and cooling*	*Geological disposal (a few hundred metres deep in stable geological formations)*

The aims of *waste management* are to process the wastes in such a way as to make them suitable for storage and disposal, and to store or dispose of them so that there are no unacceptable risks to present and future generations. Here *disposal* implies simply that there is no intention to retrieve them, rather than that it would be impossible to do so.

In many countries, short lived waste is disposed of in near surface repositories, which are normally either lined trenches several metres deep or concrete 'vaults' constructed on or just below the ground surface. The disposed waste is covered with a few metres of earth, and often a clay cap to keep water out. A similar disposal method is used in some countries for the disposal of large amounts of NORM waste, such as tailings from the mining and milling of uranium. For example, Sweden operates a repository under the bed of the Baltic Sea at Forsmark for its more active (but mostly short lived) low/intermediate level waste.

Underground repository in Sweden

Many low/intermediate level wastes do not occur in a form that is immediately suitable for disposal; they have to be mixed into an inert material such as concrete, bitumen or resin. In the past, some countries disposed of these wastes into the ocean, but since that has been prohibited by the London Convention, these wastes are normally stored awaiting decisions on the method of disposal. Among the most likely options is a repository deep underground in good geological conditions. Although many countries have plans for geological repositories of this type, only the USA is currently operating one, the Waste Isolation Pilot Plant (WIPP) in New Mexico, for wastes containing actinides.

Where the intention is to dispose of spent nuclear fuel directly rather than reprocess it, the spent fuel is stored, either at reactor sites or in special central facilities. This is partly to allow the fuel to cool, but clearly it must continue until a disposal facility is available. High level liquid waste from reprocessing operations is normally kept in special cooled tanks, but facilities to solidify it by incorporation in vitreous material are being built. The glass blocks will be stored for several decades to allow them to cool before eventual disposal, probably deep underground.

Vitrified high level radioactive waste

Decommissioning

Decommissioning is the process that takes place at the end of the working life of a nuclear facility (or part of a facility), or any other place where radioactive materials were used, to bring about a safe long term solution. This might include decontaminating equipment or buildings, dismantling facilities or structures, and removing or immobilizing remaining radioactive materials. In many cases, the ultimate objective is to clear the site of all significant radioactive residues, but this is not always possible or necessary.

The Greifswald and Rheinsberg decommissioning project in Germany J. Ford/IAEA

After removal of nuclear fuel, reactor vessel is shielded for decommissioning work

To date, relatively few full scale commercial nuclear facilities have been completely decommissioned. However a great deal of experience has been gained from the decommissioning of a wide variety of facilities, including a few nuclear power plants, several prototype and research reactors, and many laboratories, workshops, etc. The fact that many nuclear reactors around the world are approaching the end of useful life has focused attention on the issues associated with decommissioning.

Decommissioning requires strict control of operations to optimize the protection of workers and the public. For dealing with the most radioactive parts of a facilities, particularly reactor cores, remote handling techniques have been developed. Dismantling of large facilities also generates large volumes of 'waste'. Some of this will be low/intermediate level radioactive waste and needs to be managed accordingly. However, there may also be large amounts of structural materials — such as steel and concrete — that are not significantly radioactive. Special procedures may be needed to 'clear' such materials as exempt, meaning that they do not have to be treated as radioactive waste.

Disposal criteria

Negatively pressurized compaction room, where dismantled pieces are compacted and placed in specialized containers

There has been considerable discussion of the criteria to be used in judging the acceptability of waste disposal methods both from a radiological protection point of view and from the wider social perspective. The consensus would seem to be that people in future generations should be protected to the same degree as they would be at present. However, it is difficult to translate this requirement into practical standards of radiological protection. For example, activity may only emerge from a deep repository many thousands of years later, and we have no idea what the habits or ways of life of our descendants will be so far into the future.

A second requirement is to apply the principle that all exposures should be as low as reasonably achievable once economic and social factors have been taken into account. This means that the various options for managing a particular type of waste — including treatment, immobilization, packaging and disposal — should be compared on the basis of the associated risks, costs and other less quantifiable, but no less important factors. Some of this comparison will be within the scope of radiological protection, but other influences could determine the eventual decision.

The difficult question for society about waste disposal is what weight to give now to a mathematical probability of harmful effects in the distant future. This problem is not unique to waste disposal nor to radiological protection, although it is particularly pointed here. The most ethical answer may be to assume that present conditions persist and that harm to future generations is of equal importance as harm to this generation. This response must of course be tempered by the uncertainties of making predictions of potential effects centuries and millennia from now.

Other waste management practices

Some other waste management practices in the past were, for various reasons, not as good as they should have been, and this has resulted in some cases of actual or potential long-term contamination of the environment.

Again, one example comes from military operations. Nuclear powered submarines from the northern fleet of the Soviet Union (and later the Russian Federation) have been taken out of service over the years. Many of these submarines are currently in dock awaiting proper management, but in some earlier cases the Soviet Union put waste from submarine reactors, and even reactor fuel, into the sea, notably the Kara and Barents Seas in the Arctic. Between 1993 and 1997, The International Arctic Seas Assessment Project, co-ordinated by the IAEA, reviewed the situation and concluded that, because of the slow release of radioactivity from the solid wastes and the dilution provided by the sea, the doses to members of the public would be very low (less than 0.001 mSv per year). Military personnel stationed in the area could get significantly higher doses, similar to the doses already received from natural sources (up to a few mSv per year).

Unrehabilitated uranium tailings in Tajikistan
F. Harris/IAEA

Several areas around the world are affected by large deposits of waste from the mining and processing of radioactive ores. This is most commonly from uranium mining, but in some areas the abundance of naturally occurring radionuclides is such that spoil from other types of mining (some of it as early as the Middle Ages) is also a significant radiological hazard. A number of industries, such as the manufacture of fertilizers and the oil and gas industries, also produce wastes of a similar nature. The radionuclides involved are all of natural origin, and hence it is only comparatively recently that these wastes have been recognized as a radiological problem. The levels of radionuclides in the ores were typically higher than average and have often been increased by chemical or physical processes, so they are significantly higher than usually found in nature (though their activity concentrations are not very high compared with those of nuclear waste). Furthermore, the radionuclides have extremely long half-lives, and there are often extremely large amounts of waste.

These wastes can be managed safely, for example in engineered, clay-capped impoundments, and countries such as Canada, the USA, Germany, and Australia have adopted such methods. However, some developing countries, e.g. central African countries and some of the central Asian republics that were formerly part of the Soviet Union, do not have the resources to handle such huge amounts of material in this way. The IAEA, among others, is helping these countries to find safe solutions.