Classification of radioactive waste

Radioactive materials that cannot be used any longer – or whose users / owners do not plan to re-use them in the future – are considered as radioactive waste (or radwaste). In Hungary, according to the '**second atomic energy act'** (act No. CXVI. enacted in 1996), the state is obliged to arrange the final deposition of radioactive waste. The expenses have to be paid, as far as possible, by the institution which is responsible for the generation of the waste. It has to be emphasized that the above definition does not consider the spent fuels of nuclear power plants as radioactive waste because they can be re-used. However, reprocessing – the processing method of spent fuel – is the privilege of countries owning nuclear weapons.

Radioactive waste can be categorized in many ways. It is somewhat astonishing but there isn't a unified international method of categorization. In Hungary the regulation is based on Regulation no. 14344, which was first issued in 1989 and modified in 2004, and on Executive Decree no. 23/1997 of the Minister of Welfare, which was issued among the enforcement orders of the above-mentioned atomic energy act and modified by the decree of the Minister of Healthcare, Social and Family Affairs in 2003. The regulation and the executive decree mention the following aspects of **classification**:

by **state**: solid waste, waste of biological origin, liquid and non-inflammable, liquid and inflammable and airborne waste;

- by **heat generation**: low or intermediate level waste – its heat generation is negligible; and high - level waste – its heat generation must be taken into account in the course of storage or disposal;
- by **concentration**: low, intermediate and high - level radioactive waste;
- by **half-life** of the radionuclei contained in the waste: short-, medium- and long-lived (longer than 30 years) waste.

The classification on the basis of state reflects the viewpoints of waste processing and storage. It differentiates between the types of waste that need to be handled in completely different ways (organic and aqueous solutions). Moreover, it emphasizes waste of biological origin – the carcases of test animals, bacterial cultures and their media – because their decay produces chemically aggressive, corrosive compounds and (would) mean an increased risk to the materials of the waste containers.

The lower limit of **low level waste** is defined using the term 'exemption' (or 'clearance'). This term is not defined in the regulation but in the above-mentioned executive decree, which establishes exemption levels for both the artificial and naturally occurring radioactive isotopes appearing in practice. Those who have determined the concept and numeric values of **exemption levels** have taken up the nuclear safety measures accepted in international and also European practice, namely, the related sections of “International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (IBSS #115.)”, prepared by the International Atomic Energy Agency in 1994. According to this document, 'exemption level' is ambiguous because it might mean activity (kBq) or activity concentration (kBq/kg). If the activity of an object or a substance is lower than the exemption level, that object can get exemption from the atomic energy act and all corresponding regulations (it need not be managed as radioactive waste).

The exemption level is defined on the basis of the dose constraint system of radiation protection. The amount of radioactivity which is below the exemption level does not have any harmful effect on the health of those persons who get into contact with the substance, either through external or through internal exposure. Neither the regulation, nor the IBSS defines this dose rate explicitly, but the quantity of dose without a risk is supposed to be between 0.01 and 0.1 mSv annually. (It is well known that the Hungarian population receives a dose of about 2.4 mSv annually from natural radioactivity.)

Besides the table of activity concentrations the regulation contains a similar, definitely practical supplement which classifies waste on the basis of the gamma-radiation dose rate measured at 10 cm from the surface of the waste packages. In this case waste is considered as **low level** if the dose rate (dose per time unit) is **less than 0.3 mSv/h** and **high level** if it is **greater than 10 mSv/h**. This classification cannot characterize waste containing alpha-emitting nuclides, because alpha radiation has an extremely detrimental effect on health, but it is weakly penetrating and so it cannot be measured through the surface of the package.

The classification based on **half-life** is even more practical than the previous ones. **The half-life of long-lived waste is longer than 30 years**. Nuclides with half-lives longer than that (i.e. than that of 137Cs) are present above the exemption level only in some sources applied in certain laboratories and in the spent fuels of nuclear power plants.

As we have mentioned, there are many other systems of categorization in international use. Two of them need to be mentioned, although officially they are not used in Hungary. In many countries the concept of 'mixed waste' refers to waste that is, for example, chemically hazardous besides being radioactive. In the USA and Great Britain the main characteristic of high-level waste is not its activity concentration but the speciality that in highly radioactive substances the heat generated by the decays reaches 2 kW/m3.

The possibilities of radioactive waste management

Radoiactive waste management is a very broad term and processing is just one part of it. The steps of the whole process are the following:

- collection, preliminary characterization and temporary storage
- transportation
- processing – its substeps depend on the state and class of waste
- transportation and interim storage of the processed waste
- final deposition

The last three groups (processing, interim storage and final deposition) are collective terms all of which refer to several, rather different methods.

Processing solid waste can involve the following treatments: mechanical compaction (pressing), incineration, fixing (conditioning, see later). In the case of fluid, low and intermediate level waste, there are very many ways of volume reduction that are intended to reduce the expenses of storage. For example, the evaporization and incineration of solutions, as well as the pounce, filtration, extraction and ion exchange of radioactive components. The common characteristic of all these treatments is that the volume of the produced radioactive substance will be reduced and its activity concentration will be greater than that of the original solution, and the “inactive” particle fluence will have to meet the exemption principles.

Volume reduction is followed by solidification (conditioning). Aqueous solutions are usually solidified by cementing while organic ones are solidified by bituminization. Although solidification obviously means volume expansion and so further storage will be less economical, it is still necessary because the release of radioactive isotopes into the environment must be prevented.

Vitrification is a relatively new method of conditioning which can be used economically in the case of intermediate and high level waste. During this process the solid(ified) waste is mixed into melted glass and when this mass solidifies it stabilizes radioactive waste much more efficiently than all other methods. It is very important that the special structure of glass can resist the significant heat generation of high activity waste.

The high activity by-products of reprocessing – the processing of spent fuels – that are unsuitable for being re-used must be treated as waste. Beyond the above-mentioned treatments, there have been experiments with transmutation which is another way of processing these by-products. A special nuclear reactor is necessary for this treatment, which transmutes long-lived radionuclides through their bombardment by neutrons.

In the field of **reprocessing of spent fuel** further development is expected in the future, as well as in the science of the behaviour and spread of released waste in the environment. Therefore, today most countries do not consider final deposition of spent fuel economical or justified. Those fuel cells that are not planned to be reprocessed are stored in safe interim storage containers, which are usually designed for some 50 years.

99% of the volume of radioactive waste produced on Earth is intermediate or low level waste, and its final deposition is a rather significant and expensive task. There are two types of repositories: surface (15-30 m depth at the max.) and underground repositories (deep, geological, 300 m depth at the min.). Europe's two largest repositories, L'Aube (France, 1 million m3) and Drigg (England, 800 thousand m3) are surface repositories.

In Hungary, there is one such facility at the moment in Püspökszilágy; a surface repository with a total capacity of 5000 m3. Another repository, which is designed to store the low and intermediate waste from the Paks NPP, will be built under the ground (deep repository). This National Radioactive Waste Repository Facility is located near Bátaapáti in county Tolna and received the first vessels of waste in December 2008 – in its surface facility. The underground part of final repository will be open soon.

The storage of low and intermediate level radioactive waste

In all nuclear power plants solid and liquid radioactive waste is produced necessarily during their operation and the same is true for Paks NPP. The minimization, management, processing and final disposal of this waste are among the most important tasks of the atomic energy industry of the world.

In Paks NPP the quantity of radioactive waste and its activity is far less than is defined in the technical specifications of the power plant. These facts characterize the high standards of operation and the tight control of radiation protection. The management of radioactive waste consists of its **selective collection**, measurement, **volume reduction**, packaging, **interim storage** and its **final disposal**. The aim of a final repository construction project is to guarantee the absolute isolation of radioactive substances from the biosphere for a long time. Unlike a nuclear power plant, it does not need energy, spinning machines, high pressure or temperature to fulfil its function. As to radiation protection, the risk in the case of such a repository is negligible and there are international references which show that its construction is a technical task that can be solved and has already been solved.

So far and for years, the storage outside the power plant has been solved in the Radioactive Waste Processing and Containing Facility between the fields of the villages Püspökszilágy and Kisnémedi (Pest County). This container was not built for the placement of waste from Paks and its capacity is restricted, so a long-term repository should be built, which will be specially proportioned to serve the needs of Paks NPP. As a result of a special project, a site has been chosen in the area of Bátaapáti which is suitable for this purpose. Under the direction of **Public Agency for Radioactive Waste Management (PURAM,** founded in 1997) the investigations, studies and investments started here. As a result, the final disposal of the waste packages containing the low and intermediate level waste of Paks NPP will soon be possible at this National Radioactive Waste Repository Facility.

Before the final disposal becomes possible the low and intermediate level waste produced in Paks is stored in interim storage containers within the territory of the power plant. These containers are designed to store solid and liquid radioactive waste. Solid waste is put in 200 l vessels that are stored in basins built for this purpose while liquid radioactive waste is stored in huge barrels made of stainless steel until processing or conditioning.

At Paks NPP both the interim storage and the final disposal – which will soon be possible near Bátaapáti – fulfil the task of storing low and intermediate level waste safely and in line with international practice.

Decommissioning a nuclear power plant

Out of all the industrial facilities of the world only nuclear power plants have got decommissioning plans for the period when their service life will have ended. Among those that have ever worked and been shut down several nuclear facilities have already been decommissioned. So there is sufficient experience in completing the decommissioning of nuclear power plants (which includes the final shutting down and dismantling of the power plant, the management of the radioactive and common waste that is produced in this process and preparation of the site for utilization for other purposes).

In line with the requirements of international organizations, Paks NPP has a decommissioning plan. The first plan, which was a study plan referring to Unit 1 and 2, was already prepared in 1993. Then by 1997 the initial decommissioning plan has been developed for the whole power plant. In line with national regulations, this initial plan is revised every five years and so it is getting refined. The final decommissioning plan has to be available a year before the final shutting down of the units.

The initial decommissioning plan includes three possible options:

- Immediate dismantling of the technological systems and of the buildings after shutting down the units.
- Safe storage of all contaminated facilities and the primary loop facilities that contain activated technological systems for 20-50-70-100 years and their deferred dismantling.
- Deferred dismantling of the so-called 'nuclear islands' (made up of the parts around the reactor) after safe storage.

Of the three options detailed in the initial decommissioning plan the second one is preferred at present, which means the deferred dismantling of the primary loop facilities after their safe storage for 50 years.

In each case decommissioning involves so-called 'greenfield status' dismantling work, i.e. all parts of the main technological buildings of the nuclear power plant above the ground will be demolished.

The decommissioning of a nuclear power plant is rather expensive. So as not to lay the burden of these sosts upon future generations, the Paks NPP pays a certain sum of money into the Central Nuclear Fund, which in the end will be sufficient for the fulfilment of the work. See more details about the purpose, amount and task of the fund on the website of PURAM Ltd.