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Handbook of advanced radioactive waste conditioning technologies

Edited by Michael I. Ojovan

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Radioactive waste characterization and selection of processing technologies

M. I. OJOVAN, University of Sheffield, UK

Abstract: The generic approach of radioactive waste management is to use more reliable natural and engineered barrier systems for more hazardous waste. The guidance for treatment and conditioning of radioactive waste is based on data obtained on waste material characterization. Characterization of radioactive waste gives important waste material parameters and enables its classification according to national regulations. Although classification schemes are country dependent, there is a generic consensus that end points (e.g. storage and disposal) and conditioning methods (e.g. immobilization and packaging) depend on the level of radioactivity and radionuclide lifetime. Radioactive waste processing routes are specified herein using the new International Atomic Energy Agency (IAEA) radioactive waste classification scheme which is based on long-term safety of waste.

Key words: radioactive waste, classification, processing, treatment, immobilization, conditioning, disposal.

1.1 Introduction

Although many of the radioactive substances currently used are of artificial origin, radioactivity is a natural phenomenon with natural sources of radiation in the environment. Radiation and radioactive materials have many beneficial applications, ranging from power generation to industrial and agricultural irradiators and radiolabelled compounds in medicine and scientific research. Radioactive waste associated with those applications is generated in a wide range of concentrations of radionuclides and in a variety of physical and chemical forms. There is a variety of alternatives for processing waste or storage prior to disposal as well as several alternatives for the safe disposal of waste, ranging from near-surface to geological disposal. Wide differences in waste compositions may result in an equally wide variety of options for the management of the waste; therefore a proper scheme of waste classification is required before any waste processing.

Many schemes have been developed to classify or categorize radioactive waste according to its physical, chemical and radiological properties, most of which are of relevance to particular facilities or given circumstances in which radioactive waste is managed. Nevertheless there is a generic consensus that the end points (e.g. storage and disposal) and conditioning methods (e.g. immobilization and packaging in containers) depend on the level of radioactivity and radionuclide lifetime. This approach has found reflection in the generic classification scheme developed by the International Atomic Energy Agency (IAEA) in the General Safety Guide GSG-1 [1], which has evolved via a long process of consultations and accounted for current worldwide practice on radioactive waste management. This publication is providing consistent and reliable guidance on the classification of the whole range of radioactive waste, beginning from waste having such low levels of activity concentration that it is not required to be managed or regulated as radioactive waste, and ending with highly radioactive waste resulting from nuclear fuel reprocessing and nuclear fuel in the case when it is considered radioactive waste. The IAEA classification scheme is focused on disposal where the multi-barrier principle holds [2]. The key issue with any disposal option is safety, which is achieved mainly by concentration and containment involving the isolation of suitably conditioned radioactive waste in a disposal facility. Containment uses many barriers around the radioactive waste to restrict the release of radionuclides into the environment. Such an approach is termed the multi-barrier concept and is often called matreshka after the popular Russian doll, which inside of each larger doll has a smaller one, so that the total number of dolls is large (Fig. 1.1).

The restricting barriers can be either natural or engineered, e.g. obtained via processing. The generic approach is to use more reliable barriers for more hazardous waste, including engineered barriers which result from the radioactive waste treatment and conditioning process. The IAEA waste classification [1] can be thus used to develop generic guidance for waste processing methods. This is particularly important as many countries use IAEA standards and approaches in developing national radiation and

1.1 Russian doll 'matreshka' as a symbol of the multi-barrier concept.

nuclear safety regulations. Therefore we will first analyse the new IAEA waste classification scheme and then use it as guidance for waste treatment and conditioning.

1.2 Radioactive waste classification

Two main parameters of the IAEA classification scheme [1] are radionuclide half-life and radioactivity content. In terms of radioactive waste safety, a radionuclide with a half-life longer than that of ^{137}Cs (30.17 years) is considered to be long lived whereas those with half-life shorter than about 30 years are considered short lived. In terms of radioactive waste safety, radioactivity contents are analysed compared with exemption levels [3]. The activity content term is a generic name that covers activity concentration, specific activity and total activity and is used in classification schemes accounting for the generally heterogeneous nature of radioactive waste [1]. The activity content can range from negligible to very high, that is, a very high concentration of radionuclides or a very high specific activity. The higher the activity content, the greater the need to contain the waste and to isolate it from the biosphere, e.g. the more stringent are the requirements for safety barriers.

The IAEA classification scheme first defines exempt waste (EW). EW is that radioactive waste which contains such small concentrations of radionuclides that it does not require provisions for radiation protection, irrespective of whether the waste is disposed of in conventional landfills or recycled. The EW meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes which are given in IAEA publications [3, 4]. The criteria for exemption were established by the IAEA following recommendations and principles of the International Commission on Radiological Protection (ICRP). The criteria used to derive exemption levels for radioactive materials are an expected individual effective dose not higher than 10 μSv/y and a collective effective dose not higher than 1 person Sv/y. Exemption levels were established for both concentration and total amount of radionuclides based on the individual and collective dose. These were determined for each radionuclide taking account of all possible pathways to humans including assessment of individual and collective doses. Exemption levels are published in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [4]. Sources of radiation are exempt from control if at a distance of 0.1 metres the dose rate is below 1 μSv/h. Clearance levels are defined by the national regulatory authorities; however, since these take into account internationally approved recommendations, quantified clearance levels (with some exceptions) are similar in all countries. EW is thus in practice considered as a non-radioactive material and waste.

The IAEA classification scheme defines five classes of radioactive waste: very short lived waste (VSLdW), very low level waste (VLLW), low level waste (LLW), intermediate level waste (ILW) and high level waste (HLW).

VSLdW is that radioactive waste which can be stored for decay over a limited period of no longer than a few years with subsequent clearance from regulatory control. Clearance procedure is done according to existing national arrangements, after which VSLdW can be disposed of, discharged or used. VSLdW includes waste containing primarily radionuclides with very short half-lives which are most often used for research and medicine.

VLLW is that radioactive waste which does not necessarily meet the criteria of EW, but which does not need a high level of containment and isolation and is therefore suitable for disposal in near-surface landfill-type facilities with limited regulatory control. Typical VLLW includes soil and rubble with low levels of activity concentration.

LLW has higher activity contents than VLLW but with limited amounts of long-lived radionuclides in it. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near-surface facilities. LLW covers a very broad range of waste with long-lived radionuclides only at relatively low levels of activity concentration.

ILW is that radioactive waste which, because of its radionuclides content, particularly of long-lived radionuclides, requires a greater degree of containment and isolation than that provided by near-surface disposal. However, ILW needs no provision, or only limited provision, for heat dissipation during its storage and disposal. ILW may contain long-lived radionuclides, in particular alpha-emitting radionuclides that will not decay to a level of activity concentration acceptable for near-surface disposal during the time for which institutional controls can be relied upon. Therefore ILW requires disposal at greater depths, of the order of tens of metres to a few hundred metres. A precise boundary between LLW and ILW cannot be universally provided, as limits on the acceptable level of activity concentration will differ between individual radionuclides or groups of radionuclides. Waste acceptance criteria for a particular near-surface disposal facility depend on its actual design and operation plan for the facility (e.g. engineered barriers, duration of institutional control, site-specific factors). A limit of 400 Bq/g on average (and up to 4000 Bq/g for individual packages) for long-lived alpha-emitting radionuclides has been adopted in many countries. For long-lived beta- and/or gamma- emitting radionuclides, such as ^{14}C, ^{36}Cl, ^{63}Ni, ^{93}Zr, ^{94}Nb, ^{99}Tc and ^{129}I, the allowable average activity concentrations may be considerably higher (up to tens of kBq/g) and may be specific to the site and disposal facility [1]. A contact dose rate of 2 mSv/h has been generally used to distinguish between LLW and ILW [5], though contact radiation