Article

Management of radioactive waste: A review

Luís Paulo Sant'ana[1],**Taynara Cristina Cordeiro**[2]
[1]Universidade Federal dos Vales do Jequitinhonha e Mucuri,Diamantina, 39100-000, Minas Gerais, Brazil
[2]Universidade Santa Cecília, Santos, 11045-907, São Paulo, Brazil
Email: luispsant@gmail.com

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Abstract
The issue of disposal of radioactive waste around the world is not solved by now and the principal reason is the lack of an efficient technologic system. The fact that radioactive waste decays of radioactivity with time are the main reasons for setting nuclear or radioactive waste apart from the other common hazardous wastes management. Radioactive waste can be classified according to the state of matter and level of radioactivity and this classification can be differently interpreted from country to country. Furthermore, microbiological procedures, plasma vitrification process, chemical precipitation, ion exchange, evaporation and reverse osmosis are strategies used for the treatment of radioactive wastes. The major challenge is to manage these radioactive substances after being used and discharged. This report brings data from the literature published worldwide from 2009 to 2014 on radioactive waste management studies and it covers production, classification and management of radioactive solid, liquid and gas waste.

Keywords radioactive waste; waste management; waste generation; waste classification

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1 Introduction

Bobrakov et al. (2014) show that according to the Russian "Law on the Use of Atomic Energy" (November 21, 1995 N170-FZ) radioactive waste is described as nuclear materials and radioactive substances without any other further use. They claim that the issue of disposal of radioactive waste around the world is not solved by now and that the principal reason is the lack of an efficient technologic system, which proofs their utility and efficacy, and therefore the lack of the facilities for the application of the suggested technologies for radioactive waste management. Sartori (2013) reveals that nuclear waste management is a multi-disciplinary action that has been often discussed worldwide in the present century. The main concern is that nuclear waste needs to be disposed of in ways that guarantee safe isolation from the contact with the biosphere for long time enough to it decayed and reach insignificant effects on biological systems. Furthermore, the safe management of radioactive waste is a topic of much debate. In other words, discussing about it is essential for the use of nuclear energy in the future (Stanic, 2011). Another important aspect is that, while disposal alternatives for hazardous wastes are commonly well established, some sorts of hazardous waste face issues similar to other radioactive wastes, which also require long-term disposal techniques. Even though hazardous wastes are produced in much larger scale and come from a much higher number of sources than do radioactive wastes, preparations for their safe management and disposal have not drawn attention of public and political attraction (Radioactive Waste in Perspective, 2010).

2 Production of Radioactive Waste

According to Wattal (2013), all of the industrial activities produce some waste material, including nuclear industry that emits radioactive materials which might cause adverse effects on living beings and may impact on the next generations. Furthermore, these impacts and the fact that radioactive waste decays of radioactivity with time are the main reasons for setting nuclear or radioactive waste apart from the other common hazardous wastes management. He also points out that an efficient management of radioactive wastes implicates in separation, classification, conducting, treating, and supervising from the beginning to final disposal. In addition, in his study he claims that high level radioactive liquid waste (HLW) represents about 99 % of the radioactivity in the fuel cycle that is formed over reprocess of spent fuel.

In terms of volume, the overall production proportion of hazardous waste is up to three orders of magnitude greater than that of radioactive waste from the nuclear power industries, almost all industries and households produce hazardous waste. However, most radioactive wastes come from a very few sources, being electricity generation the principal generator. Statically, the current production rate of radioactive waste from nuclear electricity generation is around 0.4 million tonnes per year. Using the United States as an example, it produces 100 times more hazardous waste than radioactive waste generators (Radioactive Waste in Perspective, 2010). Stanic (2011) also finds that around 89,000 cubic meters of radioactive waste is generated every year in the EU. According to Bobrakov et al. (2014) over 30000 m^3 of solid waste of low and intermediate level are accumulated at Novovoronezh (Russia). Moreover, Laverov et al. (2013) reports 426.5 million m^3 liquid waste were accumulated by the beginning of 2011 in Russia, and Australia has concentrated around 4,000 m^3 of low level and short-lived intermediate level radioactive wastes (Management of Radioactive Waste in Australia, 2011).

3 Classification of Radioactive Waste

The description of radioactive waste appears in a variety of definitions. For instance, Radioactive Waste in Perspective (2010) mentions that according to the International Atomic Energy Agency (IAEA) radioactive waste is defined as any material that contains or is contaminated by radionuclides at concentrations or radioactivity rates higher than the exempted amount established by the competent authorities. In terms of states, Wattal (2013) indicates that radioactive wastes appear in different phases; solid, liquid and gas with a range of physical, chemical and radiochemical aspects. In relation to the level of radioactivity, IAEA describes radioactive wastes as Exempt waste, Low and Intermediate level waste and High Level Waste. Furthermore, solid waste can be classified as Primary Wastes including parts and machinery contaminated with radioactivity substances such as metallic hardware, used radiation sources, among others and Secondary Wastes produced from different operational actions. In addition, Sartori (2013) emphasizes that the radioactive source of the waste needs to be characterized with high precision, as its quantity will affect on how it will be treated. Table 1 lists the characteristics of waste classes according to Rahman et al (2011).

Table 1 Classification of Radioactive waste.

Waste classes	Typical characteristics
EW	Activity levels at or below clearance levels, which are based on an annual dose to members of the public of less than 0.01 mSv
LILW	Activity levels above clearance levels] and thermal power below about 2 kW/m3
LILW-SL	Restricted long lived radionuclide concentrations (limitation of long lived alpha emitting radionuclides to 4,000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package)
LILW-LL	Long lived radionuclide concentrations exceeding limitations for short lived waste
HLW	Thermal power above 2 kW/m3 and long lived radionuclide concentrations exceeding limitations for short lived waste

Another important point is that, radioactive wastes, especially those produced by nuclear power plants, also have well-known constant features, which is a significant advantage in terms of being capable of predicting their behavior when discharged to a repository. Furthermore, waste characteristics, and therefore management methods, are considerably different between hazardous waste, which can have a variety of hazardous characteristics, and radioactive wastes, which in general have only radioactivity as main criteria. In this case, different countries have different interpretations of this classification strategy, in some cases these methods are based on consent criteria for governmental radioactive waste disposal competences (Radioactive Waste in Perspective, 2010)

4 Management of Radioactive Waste

In relation to the management of radioactive waste, Sartori (2013) mentions that there are considerable strategies available in different countries depending mainly on policies. In this case, radioactive waste can go to direct disposal into deep geological repositories, or multiple recycling of spent fuel in closed fuel cycles and transmutation using accelerator driven systems (ADS). He also points out that final geological disposal will always be needed to manage radioactive waste and that different fuel cycle alternatives aim the reduction of the quantity to be stored apart from the biosphere. Demir et al. (2009) also carried out a study about the use of deep geological repositories as a method for converting minor actinides and long lived fission products. In addition, Radioactive Waste in Perspective (2010) highlighted that the existence of a worldwide accord amongst technical professionals in the field that accurately established profound geological disposal is an utterly adequate management approach for high-level waste and spent nuclear fuel. It also argued that the unit costs of managing hazardous waste are significantly lower than managing radioactive waste.

Stanic (2011) points out that achieving and maintaining a high level of safety worldwide in spent fuel and radioactive waste management, through the improvement of technical cooperation and by ensuring defenses against potential hazards radiation, are the aims of the Joint Convention (USA), now and in the future. However, Radioactive Waste Storage (2011) reports that the majority of countries are substantially ahead of the United States in establishing strategies for high level radioactive waste disposal. It also points out that countries such as Sweden and Finland are advanced in committing to a distinct disposal technology, while many other countries recover spent fuel or make contract with France or Great Britain to do this process, taking back the produced plutonium and high-level waste.

Pádua Ferreira et al. (2012) reveal that microbiological treatment has appeared as a new technologic strategy for the treatment of radioactive wastes. Rodrigues Silva et al. (2009) also used community bacteria as a method of absorption of radioactive wastes. Nonetheless, Bobrakov et al. (2014) indicate that one of the most common technologies that might significantly reduce the quantity of waste is the burning of radioactive waste in kilns, followed by final burial of ashes.

5 Management of Solid Radioactive Waste

Recycling of solid radioactive waste produced from the different processes and at nuclear power plants, in huge amount, is a technical challenge related to the solution of the multiple obstacles of technological and environmental concerns currently (Bobrakov et al., 2014). Radioactive Waste in Perspective (2010) reported that in most of the countries, all solid waste from coal-fired generation is allowed to be discharged to landfills.

Plasma arc vitrification project for high-level radioactive waste has been studied as a solution of management of plasma in UK (Murray et al., 2009). Both (Laverov et al.,2013; Pflieger et al., 2009) also mentioned other studies related to the process of vitirification as a method of treating plasma. Experiences of handling radioactive waste (RAW) has convincingly shown that solid waste is isolated from the environment much more readily than liquid waste. Bobrakov et al.(2014) reminds that the establishment of plasma technology for the processing of solid radioactive waste plant increases economic effectiveness of handling combustible and noncombustible radioactive waste because of economies on waste storage machinery and conditioning activities. They also point out that compared with the traditional method of burning, plasma methods guarantee higher proportions of reducing waste amount and the quantity of secondary waste produced. In addition, experiences of handling radioactive waste (RAW) has shown that solid waste is confined from the environment much more easily than liquid waste (Laverov et al.,2013).

6 Management of Liquid Radioactive Waste

Strategies for management of liquid radioactive waste consider the need of adequate isolation from the biosphere and vigilance for long periods. In this context, depending on the features of the waste, radionuclides and rate of contamination, the treatment is chosen to concentrate bulk of the action in a small amount. The supernatant is discharged to large water bodies after polishing and controlling as suggested by national and international standards. Moreover, in some cases where stream of radioactive liquid waste has short-lived isotopes, it might be stored for enough time to guarantee that most of the radionuclides die down. However, in all other cases, the waste might requires for adequate treatment in order to achieve wastes more susceptible to discharge. For the treatment of liquid radioactive waste, many methods can be used such as chemical precipitation, ion exchange, evaporation, reverse osmosis are employed either singly or in combination for the treatment (Wattal, 2013)

Wang and Liang (2012) showed that reprocessing by using deep geological burial and using Purex process to recover U and Pu as MOX fuel are two appropriate strategies used for spent fuel disposal. In addition, Poskas et al. (2012) explain that In Lithuania, waste oils include oils from different sources such as turbines, compressors, diesel engines, transformers, refrigerators and equipment are currently managed in tanks separately from other types of waste.

In terms of management of gas radioactive waste, Radioactive Waste in Perspective (2010) noticed that most of the gas radioactive waste produced at nuclear power stations are treated by filtration methods. Smai (2009) also shows that a multiphase fluid and transport model were tested to management of gas radioactive waste in France.

7 Conclusions

In conclusion, as it has been shown to maintain society development several types of newresources have been used to supply its needs. In this case, the use of radioactive substances by various processes of production has become considerably common. Despite that fact that the use of these substances can provide advanced tools and better welfare to humans beings, the major challenge is to manage these radioactive substances after being used and discharged. In other words, the mains issue is that radioactive waste can take a long time to disappear from the environment and it can cause serious environmental problems and damage to human health. In this present context, it is clear that further special laboratory investigations and new regulations (local and international) are needed to treat radioactive waste properly. In addition, it is fundamental that all the countries cooperate to each other in order to stablish accurate standards of treating radioactive waste also sharing appropriate strategies and methodologies used to manage this type of waste. Stablishing this relationship, any waste to be discharged of would need to meet general and site-specific agreement.

The emergence of new technologies that can reduce the decay period might be one of the most adequate strategy to be considered. Otherwise, the replacement of radioactive waste by other less hazardous substances could be another alternative. Unfortunately the “cost & benefit” seems to be another principal issue, once the methods of treating radioactive waste are far more expensive than the ones used to treat other types of waste.

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