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SAFE MANAGEMENT OF MEDICAL RADIOLOGICAL WASTE

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Abstract: The International Atomic Energy Agency (IAEA) defines radioactive waste as material, of no useful value, that contains or is contaminated with nuclides in concentrations higher than levels specified by relevant bodies. Healthcare institutions and users whose business activities generate radioactive waste have the obligation to collect, label and store it in the prescribed manner until such time as it is taken over by a company which is authorized for its transportation, collection, keeping and storage. The goal of this paper is to point out the importance of improving the quality of health services through the process of regulating medical waste management, with a focus on measures and procedures for the disposal of waste generated in radiology. The system for the separation of radiological waste, and its adequate labeling with a number corresponding to its category, is a top priority for radiological waste management at all health institutions. The importance of controlling the generation of radioactive waste is primarily reflected in measures that contribute to its reduction, followed by reuse and recycling. Data on physical, mechanical, chemical, radiological, and biological characteristics is provided to characterize radioactive waste, thus ensuring its safe and secure management. The storage of radioactive waste is the procedure for the temporary placement of radioactive waste in a dedicated facility, i.e., in a warehouse for a specific period of time, in compliance with the prescribed measures for radiation and nuclear safety and the safety of stored waste. During the storage of radioactive waste, it is necessary to carry out a whole series of activities: radiation protection, monitoring radioactivity in the environment around the warehouse, inspection of the state of radioactive waste packaging and inspection of equipment, warehouse components and systems, maintenance of the warehouse, and the labeling and recording of radioactive waste packaging. The process for disposing of radioactive waste implies its isolation from people and the environment. While the location, designed barriers and operation of the facility for disposal of radioactive waste, should enable the application of all radiation safety and security measures and the prevention of reaching criticality. States should assume an unequivocal ethical obligation to eliminate the unnecessary burden, associated with the complex issue of radioactive waste disposal, from future generations.

Key words: medicine, radiological waste, storage, disposal.
Field: Medicine

1. INTRODUCTION

Healthcare institutions produce numerous and different types of waste, on a daily basis, which, if not disposed of in an appropriate and safe manner, can cause enormous damage to the environment and therefore represents a potential danger for its employees, users of healthcare services - patients, visitors, as well as those who handle waste without authorization. Hazardous medical waste, which also includes waste from radiology, requires special methods of treatment and final disposal. Standards must be established within all healthcare institutions that will ensure the separation of waste into basic categories at the point of generation, its proper packaging, labeling and disposal, separation of secondary raw materials from waste, recycling, as well as the use of clean technologies for the decontamination of infectious waste.

The goal of this paper is to point out the importance of improving the quality of health services through the regulation of medical waste management, especially through measures and procedures for the disposal of radiological waste.

The implementation of a unified radiological waste management system is one of the prerequisites for the introduction of an efficient medical waste management system as a whole. The first step is to use the European waste catalog, which provides a basic categorization of medical waste, where we also find a position for waste generated in radiology. In addition, in this manner, attitudes are clearly defined regarding the segregation (separation) of waste, as well as the labeling and treatment of different categories of medical waste. The legislative framework at the level of the European Union is Directive No. 70 Euratom from 2011 on the establishment of a Community framework for the responsible and safe disposal of spent fuel and radioactive waste, from its generation to its disposal. (EUROATOM, 2011) The

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management of radioactive waste within the healthcare system of the Republic of Serbia is regulated by the Law on Radiation and Nuclear Safety and Security, which was adopted in 2018 (Official Gazette of the Republic of Serbia, 95/2018), while in the Republic of Croatia it is the Law on Protection from of Ionizing Radiation and Safety of Sources of Ionizing Radiation. (Official Gazette of the Republic of Croatia, 2006) The Republic of Macedonia passed the Law on Radiation Protection and Radiation Safety (2002), which also established the Directorate for Radiation Safety. The Law on Radiation and Nuclear Safety in Bosnia and Herzegovina was adopted in 2007 and amended in 2013. That law established the State Regulatory Agency for Radiation and Nuclear Safety, and its task is to control the safety of radiation sources, the safety of radioactive waste, and the safety of transport. (Official Gazette of Bosnia and Herzegovina, 2007)

2. RADIOACTIVE WASTE

Radioactive waste, which includes fuel that is considered waste, must be kept on a long-term basis and isolated from people and the environment, inhabited by people. Precisely because of their specific nature, i.e., because they contain radionuclides, it is necessary to protect human health and the environment from the dangers of ionizing radiation, including disposal in appropriate facilities as final locations. It should also be noted that the storage of radioactive waste, even long-term storage, is a temporary solution, but not an alternative to disposal. (EUROATOM, 2011)

Radioactive waste includes solid, liquid and gaseous substances contaminated with radionuclides originating from in vitro and in vivo diagnostic and therapeutic procedures. It occurs as a result of procedures such as analysis of body tissues and fluids, in-vivo imaging of organs, localization of tumors and various tests and therapeutic procedures.

Radionuclides in health care are usually considered unsealed (or open) sources or sealed sources. Open sources are usually liquids that are applied directly or are not used in capsules, closed sources are radioactive substances that are part of equipment or apparatus or are contained in capsules, i.e., unbreakable or impermeable objects such as “germs” or needles.

Solid radioactive waste of low and medium activity is stored in plastic packages and packed in metal containers of standardized dimensions (200-liter metal barrels with lids). Solid biological waste containing radioactive waste is packed in plastic bags or immersed in formalin. The storage time for such material can be no longer than three days, after which such material is treated like any other solid radioactive waste. Places where liquid radioactive waste is generated must be equipped in a manner that reduces the possibility, to the smallest extent possible, of its spillage, as well as the possibility of exposure to radiation, during the collection of liquid radioactive waste.

In the event that radioactive waste is generated continuously during operation, and its daily amount exceeds 200 liters for RAW I and II categories, as well as 100 liters for RAW III categories, it is necessary to have a separate, closed drainage system for the removal of this material and its conveying to a collection tank. In other cases, when radioactive waste is not generated continuously during operation, sources of radioactive waste should be equipped with adequate containers for collecting liquid radioactive waste. (Ministry of Health of the Republic of Serbia, 2008)

It should be the ethical obligation of every state to avoid placing an unnecessary burden on future generations due to spent fuel and radioactive waste, including any radioactive waste resulting from the decommissioning of existing facilities. Through the implementation of the Directive of the Council of the European Union on the establishment of a community framework for responsible and safe disposal of spent fuel and radioactive waste, states should demonstrate that they have taken appropriate steps towards achieving that goal. (EUROATOM, 2011)

2.1. Classification of radioactive waste

Appropriate classification of radioactive waste ensures more efficient management and decision-making when choosing options for its disposal. The classification can be based on radiological, physical, chemical or biological properties, i.e., on the basis of criteria such as aggregate state, half-life period or concentration of activity of radionuclides that are present in radioactive waste. The significance of the classification of radioactive waste is in the management of such waste, considering that in this way it can be separated into several streams that are handled in different ways. Perhaps the most illustrative example can be found in the ability to separate very short-lived waste from other radioactive waste and temporarily store it until the levels for its release into the environment are reached. In case of long-lived radioactive waste, it must be further processed, which includes conditioning it so that it can be safely stored and disposed of over a long period of time. (Ciraj-Bjelac, Vujović, 2017)

Radioactive waste is classified according to:

1. Methods and place of origin (in the nuclear combustion cycle, industry, scientific research laboratories, medicine, etc.);
2. Physical properties (solid, liquid, gaseous, flammable, non-flammable, compressible and incompressible);
3. Chemical-biological properties (organic, inorganic, toxic, aggressive, explosive, volatile, etc.);
4. Amounts and properties of present radioactive isotopes.

3. IMPROVING WASTE MANAGEMENT IN RADIOLOGY

Waste management from radiology is regulated by legislation with the aim of prescribing measures to protect people and the environment from the harmful effects of ionizing radiation generated during the production, circulation and use of sources of ionizing radiation. Another objective is the adoption of safety measures during the use of nuclear energy, followed by the enactment of supervision over the implementation of those measures and the assignment of liability for damage caused by ionizing radiation.

The contamination of the environment by radioactive substances implies the presence of radionuclides in the environment in concentrations that exceed certain values. (Ministry of Health of the Republic of Serbia, 2008)

It is extremely important to define, within all state and private health institutions, a unified radiological waste management system through a system of separation of radiological waste and appropriate labeling, associated with a number according to the waste category. Taking into account available technological and human potential, the most suitable for now is the separation of radiological waste within the framework of the separation of total medical waste and it's labeling with different colors.

The safe and secure management of radioactive waste involves the following stages: generation and collection, characterization, preservation, processing, storage and disposal. Measures for controlling the generation of radioactive waste are implemented with the aim of reducing the generation of radioactive waste, the reuse of radioactive material and recycling. Radioactive waste characterization provides data on physical, mechanical, chemical, radiological and biological properties so as to ensure safe and secure management. The storage of radioactive waste implies the application of isolation measures and control, during all phases of management preceding disposal. Radioactive waste disposal facilities must, during design, construction, operation and closure, meet conditions that ensure passive measures of radiation safety and security. (Radiation and Nuclear Safety and Security Act, 2018)

3.1. Minimizing radioactive waste

Minimizing radioactive waste is the process of reducing the quantity and activity of radioactive waste to levels that can reasonably be achieved during all phases, from planning to decommissioning. This process can be realized by reducing the quantity of generated radioactive waste through recycling and reusing radioactive material, and by processing radioactive waste in a manner that reduces its activity, while also taking into account secondary waste as a consequence of its processing.

The drive to minimize radioactive waste is motivated by a reduction of radiation risk and the efficient use of space for storage and disposal.

In order to achieve the planned minimization of radioactive waste, one or more techniques are most often used such as:

1) Storage of radioactive material containing short-lived radioisotopes until the activity decreases below the level of release;

2) Revision of working procedures in terms of a reduction of generated radioactive waste, by implementing modern procedures, processes and technologies that ensure a reduction in radioactive waste generation;

3) Preventing the spread of contamination during any activity;

4) Planning and implementing appropriate methods for processing radioactive waste.

Minimization of radioactive waste is not synonymous and cannot be equated with volume reduction, which is one of the methods for processing radioactive waste. (Ciraj-Bjelac, Vujović, 2017)

3.2. Decommissioning facilities containing radioactive waste

Decommissioning is a set of administrative and technical measures taken to completely or partially release an object from regulatory control. The objective of assumed measures is to ensure the long-term protection of people and the environment and, as a rule, to implement measures aimed at reducing the presence of radionuclides in the materials resulting from decommissioning, as well as at the location of the facility. The assumed measures should ensure the reuse of decommissioned material, its safe disposal as radioactive waste or release from regulatory control. The decommissioning process is carried out at the end of a facility's life, with the goal of removing all work-related radiological and non-radiological hazards, as well as all systems from the immediate facility and its surroundings. In practice, this specifically means that the decommissioning process will include the decontamination and removal of the facility, or part of the facility, in order to reduce the risk of radiation. The decommissioning process may only include decontamination without removal, provided that all radiation risks are thereby removed. In that case, the facility can be freed from further regulatory control, and its purpose can be changed.

It should be pointed out that decommissioning cannot be applied to radioactive waste disposal sites where radioactive waste has already been placed, nor can it be applied to material disposal sites with a naturally elevated radioactivity content. At the end of their lifetime, such facilities are closed in a protective way, whereby all radioactive materials remain inside the facility and institutional control is established with the aim of isolating radioactive materials from the environment. (Ciraj-Bjelac, Vujović, 2017)

3.3. Storage of radioactive waste

Storage of radioactive waste is the procedure of temporary placement of radioactive waste in a dedicated facility, i.e., in storage for a certain period of time, while meeting all radiation and nuclear safety measures and the safety of stored waste. This specifically means keeping all radionuclides inside a warehouse, i.e., preventing them from escaping beyond the warehouse, isolating the stored radioactive waste from unwanted external influences and continuous monitoring of radioactivity in the environment around the warehouse.

Before storage, radioactive waste is segregated according to type, half-life, and physical and chemical properties. This creates the assumption that waste can be sent for further treatment, transferred to another warehouse, disposed of or released from regulatory control, without additional separation. All used sources of ionizing radiation, which have been declared radioactive waste, must be separated according to activity, half-life of radionuclides, physical and chemical properties of radionuclides before storage, and can only be stored if separated. (Ciraj-Bjelac, Vujović, 2017)

Before radioactive material is stored, it is necessary to compare its characteristics with the prescribed conditions for storage, carry out the necessary analyzes and categorize the radioactive waste in order to determine the exact location within storage. The criteria for receiving radioactive waste are defined as a set of qualitative and quantitative characteristics of that waste, and they are defined by the operator of the radioactive waste management facility, and confirmed by the regulatory body. Acceptance criteria determine the radiological, mechanical, physical, and biological properties of radioactive waste packaging, and there are also limitations in terms of the total or specific activity of radioactive waste packaging, or individual radionuclides or types of radionuclides, as well as limitations related to the dose strength on the surface of the packaging, or at a certain distance from the packaging, and restrictions on heat emission.

4. TRANSPORT OF RADIOACTIVE WASTE

A large number and type of radioactive material is transported every day, from industrial medical radioactive sources to by-products of the nuclear fuel cycle. Transport of radioactive materials within the nuclear fuel cycle can be divided into two parts:

1) front - includes the mining of uranium ore and the production of fresh fuel elements and
2) last - includes transportation of spent fuel, its reprocessing and disposal.

Transport systems include a series of independent protective barriers that are tasked with keeping radioactive material safe, separated from nature. Safety is a key factor for the transport of radioactive material - each type of shipment is subject to strict regulations as recommended by the International Atomic Energy Agency in cooperation with the United Nations. Small amounts of radioactive material, either alone or as part of a device, can be transported in packages that are not subject to special safety regulations. Larger quantities, obtained from nuclear medicine and research centers, are transported in Class A packages, which must withstand the conditions of normal transport and potential rough handling. Assuming a serious accident, the integrity of such packages can be compromised - thereby upper safety limits are set up for the type of radionuclide that can be transported. Even larger quantities of radioactive material such as radioactive sources from medicine and industry, spent nuclear fuel, as well as various toxic materials, are transported in type B packages, which are required to withstand severe accidents that may occur during transport by land, water and air, and to significantly damage their integrity. (NEMIS, 2019)

Radioactive material can be in a gaseous, liquid or solid state. However, the most common transport of radioactive waste is in a solid aggregate state, and less often in a liquid aggregate state. Radioactive waste is most often transported by road or rail, followed by water and air to a lesser degree. International regulations define the conditions for all forms of transport.

Regulation in the field of transport provides general requirements regarding radiation protection, action during emergency events, quality assurance for transport containers and all operations during the transport process. Apart from these general requirements, there are alternatives to specific cases, when direct practical application of transport regulations is not possible.

The basic goal of standards that regulate the transport of radioactive materials is the appropriate control of the risks surrounding this type of transport by appreciating the specified determinants: maintenance of radioactive materials in a defined volume, control of the level of external exposure, prevention of thermal damage and prevention of criticality.

Radioactive material can, under strictly prescribed conditions, be transported by all means of transport, except public passenger transport. In addition, there is also special transport when the strength of the equivalent dose of radiation on contact with the package is up to 1 μSv/h. Each shipment of radioactive material is accompanied by appropriate documentation in a standard form. There is a corresponding 10x10 cm label on the packaging of the shipment which contains data on the source type, activity, category (in relation to the strength of the equivalent dose of radiation on contact) and transport index. The transport index (TI) is an unnamed number (1 - 3) that indicates the strength of the exposure (equivalent) dose of radiation, at a distance of 1 meter from the packaging lining. The international designation for the class of radioactive material is 7. (Stanković, 2014)

5. DISPOSAL OF RADIOACTIVE WASTE

The most important function of radioactive waste disposal is its isolation from people and the environment. The selected location, designed barriers and operation of the radioactive waste disposal facility should ensure the application of multiple radiation safety and security measures and prevent reaching criticality.

The designed barriers, structures, systems, and components, including the packaging of radioactive waste and the selected location, must:

1) ensure retention of radionuclides contained in radioactive waste for a period of time which, due to radioactive decay, achieves a significant reduction of risks associated with disposed radioactive waste;

2) prevent reaching criticality;

3) enable heat removal in case of disposal of radioactive waste that generates heat. (Radiation and Nuclear Safety and Security Act, 2018)

In practical application, there is a wide variety of technological options for the definitive disposal of radioactive waste, from above-ground concrete containers, through shallow submersion, to disposal in tunnels, abandoned mines or vertical shafts. Common to each solution is that the disposal site must be designed in compliance with a whole series of criteria that ensure maximum radiological protection, as well as independence in terms of long-term institutional control over the disposal site. In this sense, the radiological safety of facilities means a high degree of safety both under all operating conditions and in case of an emergency event. In doing so, the safety of protecting people and the environment, the protection of professional staff and the protection of, accidentally present, individuals is emphasized. (Kučar-Dragičević et al, 1992)

Management of high-level radioactive waste (VRAO/HLW) requires a different approach having in mind the fact that it occupies only 3% of the volume of total radioactive waste, but as much as 95% of total radioactivity. Without reprocessing, spent fuel is treated as highly radioactive waste. It consists of highly radioactive fission products and some heavy elements with a long half-life. During the process of extracting uranium and plutonium, highly radioactive waste is created in a liquid state and it is necessary to turn it into a solid state, which is achieved by the vitrification process which reduces its volume by 70%. (NEMIS, 2019)

Radioactive waste is subjected to controlled supervision, at the institution where it is located, and after the decay of radioactivity, procedures corresponding to sanitary waste are applied. Controlled monitoring is achieved by keeping radioactive materials in a suitable reservoir, until the activity decays to a negligible level. During controlled monitoring, there must be no excess radiation, and when disposing of radioactive waste, protection of personnel and prevention of contamination of space and equipment is an absolute priority. (Žuvić, Grošev, 2015)

When disposing of radioactive waste, it is necessary to fulfill several basic conditions. First of all, waste must be disposed of in such a way so as to ensure the long-term stability of the storage, which prevents the contact of radioactive isotopes with the biosphere. The stability of the radioactive material in the packaging depends on the characteristics of the steel barrel and the geological characteristics of the location for waste disposal. Choosing a location for a radioactive waste disposal site is a complex and long-term process, which also requires significant resources: during the initial phase, certain areas that do not meet the geological and hydrological criteria, based on predetermined criteria, are excluded using the elimination method. After that, if there are several suitable locations, a comparison and side-by-side ranking is carried out, taking into account the natural conditions of the terrain for the landfill and waste isolation. (Nađ, Kavur, 2016)

The safety of a deep geological repository depends mostly on the natural characteristics of the soil, especially considering that the soil at the location of the radioactive waste repository must provide stable hydraulic, mechanical, and geochemical conditions. In order to meet these conditions, the geological formation should have sufficient thickness, depth, and extension, as well as tectonic stability and low seismic activity, simple structure and lithological homogeneity, low water permeability and low hydraulic gradients, as well as appropriate radionuclide retention properties. Geological formations that most often meet the indicated conditions are eruptive rocks, clayey rocks, and rock salt deposits. (Gens, Thomas, 2006) Eruptive rocks (e.g., granites) are poorly permeable and hard, having high chemical stability and low economic value. Clay rocks are suitable for deep geological disposal, and their behavior in relation to the transfer of radionuclides is quite different from eruptive rocks, because they have the ability to self-heal cracks that may appear during construction, or during other phases of landfill exploitation. (Barnichon, Volckaert, 2002) It is generally known that clayey rocks are characterized by low water permeability, but it should also be stressed that because their strength is not great it is necessary to lay a lot of substructure, during the excavation and construction of underground rooms. In addition, clay rocks are sensitive to chemical changes. The most important characteristic of rock salt is its very low permeability. However, a landfill built in rock salt deposits is extremely sensitive to potential water intrusion. (Gens, Thomas, 2006)

6. CONCLUSION

If we look at overall environmental pollution, medical waste does not occupy a large share but is potentially among the most dangerous types of waste. Pollution from healthcare institutions can be dangerous to the health of those who work at those institutions, the patients, and the environment. Precisely because of the potential danger, there is a strict obligation to properly handle medical, in particular, radiological waste. The method of disposal and storage of radiological waste represents one of the biggest challenges as it must ensure that the entire process is safe, efficient and does not endanger the environment. Concern for the safe management of radiological waste, which also applies to all medical waste, should be the most important guide when collecting, storing, disposing, and transporting waste. All the countries from our region, as well as European Union countries, should harmonize their legislation with Directive No. 70 Euratom from 2011 on the establishment of a Community framework for the responsible and safe disposal of spent fuel and radioactive waste. The aforementioned Directive requires countries to present national programs in which they will state when, where and how they will dispose of spent fuel and radioactive waste, applying the highest safety standards. Of crucial importance is the obligation to create rehabilitation programs that offer technologically safe and environmentally acceptable solutions for all future locations. It is necessary to affirm, even more strongly, the approach according to which rehabilitation is carried out at the location itself, where it is expected that the rehabilitation program will be harmonized with the spatial and urban plans of the local community, within whose territory it is located. In addition, it is necessary to generate as many opportunities as possible for the reuse of materials, as well as to establish the concept of continued radiological monitoring of the site, with regular reporting. The work on the safe management of medical radiological waste should encourage further theoretical and practical research, respecting technological, economic and reliability criteria, while also showing reverence for the specifics of the environment.

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