International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 10-No.2 (2024) pp. 228-235
http://www.ijcesen.com

ISSN: 2149-9144

Research Article

Handling, Conditioning of Low Level Radioactive Wastes (LLRW), Spent Radiation Sources (SRS), their transport to Temporary Storage Facility in Kosovo and Albania

Besire CENA[1]*, Luan QAFMOLLA[2], Nazmi HASI[3]

[1]University of Mitrovica "Isa Boletini", Faculty of Food Tehnology, Faculty of Geosciences, Kosovo
* **Corresponding Author Email:**bessirecena@gmail.com - **ORCID:** 0000-0002-5084-9542

[2] Institute of Nuclear Physics (INP), Tirana, Albani
Email:l_qafmolla@hotmail.com - **ORCID:** 0009-0008-0373-5105

[3]University of Mitrovica "Isa Boletini", Faculty of Food Tehnology, Faculty of Geosciences, Kosovo
Email:: nazmi.hasi@umib.net - ORCID: 0000-0002-8915-3788

Article Info:

DOI: 10.22399/ijcesen.323
Received : 18 May 2024
Accepted : 14 June 2024

Keywords

radioactive sources
management
conditioning
handling

Abstract:

The paper is intended to provide reference material, guidance and know-how on handling, conditioning and storage of spent sealed radioactive sources (SRS) to both users of sealed sources and operators of waste management facilities. Due to the limited availability of disposal practices for spent SRS, disposal is covered in a broad context only. Aspects of handling, conditioning, and storage of spent sealed radioactive sources resulting from the use of radioisotopes and radiation sources in research, medicine, industry, and agriculture are described. The paper presents the current situation in Kosovo and Albania regarding the management of low-level radioactive waste, temporary interim storage and their system until final disposal, taking into account the IAEA documents on this topic. The methods applied for the conditioning of LLRW and SRS are simple. The important point after the inventory of radioactive waste was their location and the ID (identifying number) of the radioactive sources, based on the type of radioisotopes and their activity. The paper contains in some detail technical procedures for the conditioning of spent SRS, describes the means required to assure the quality of the resulting package and discusses the measures to prepare waste packages with a certain flexibility to accommodate possible future disposal requirements.

1. Introduction

Spent Radiation Sources (SRS) are placed into 200 Litter drums, are cemented and conditioned from the Radiation Protection Divisions, which is the responsible Institution for treatment and management of radioactive wastes, and later transported to temporary interim storage buildings of respective countries.
More than 100 sealed radioactive sources have been in use in nuclear medicine departments of hospitals in Kosovo, industrial end users etc., including radioactive sources lightning. As result of the necessary information lack for most radioactive sources, were used different methods to identify the type of radionuclide and its activity. Diverse radioactive waste can be handled: spent fuel cladding, reprocessing sludge, contaminated technological waste (gloves, bags, bottles, etc.), ion exchange resin, etc [1].
Using the IAEA waste classification scheme was carried out the determination of the appropriate methods for safe management of the different group of waste, including its interim storage and final disposal [2].
Since May 1996, a new building was established, and it is under the operation for treatment and management of radioactive wastes and spent radiation sources within the territory of INP, in Tirana, Albania. Funds have been allocated accordingly: based on the Law No. 8025 of 25.11.1995, it is the Albanian Government's responsibility to finance activities, with about 120,000 Euro, concerned with construction of the

disposal facility, the management and treatment of radioactive wastes generating from the use of radioisotopes and radiation sources in different applications [3].

One of the main strategic priorities in Kosovo is still the construction of a warehouse for the management of hazardous waste resulting from the process of using radioactive resources [4].

The project "Design Development for the Disposal of Hazardous Materials" is included in the Kosovo Environmental Action Plan 2011-2020, in the Kosovo Strategy for Waste Management 2013-2022 and in the Medium-Term Expenditure Framework. This action has included the construction of hazardous waste disposal facilities based on the decision of the Government of Kosovo in 2009 and the services of supervision of the relevant works.

The main users of radioisotopes in Albania are the Institute of Nuclear Physics and the University Hospital Center "Mother Theresa" (Nuclear Medicine Laboratory and Oncology Institute) in Tirana and in Kosovo, Pristina Hospital(s) and some other private end-users for industrial, agriculture purposes have had in use several radioactive sources. The majority of these sources are used for calibration, scientific research, brachytherapy/teletherapy, and different organ functioning tests of patients. Radiation sources are also used in industry and agriculture for well logging, thickness meters, level gauges, food sterilization etc.

The main radioisotopes identified in radioactive wastes segregated and collected in both countries have been: ^{99m}Tc; ^{131}I ; ^{125}I; ^{32}P; ^{51}Cr; ^{65}Zn; ^{60}Co ; ^{137}Cs; ^{192}Ir; ^{242}Am; ^{238}Pu; etc., which make up more than 95% of all the volume of solid radioactive wastes generated by nuclear units, end users in Kosovo and Albania. The annual quantity of solid radioactive wastes generated by research institutions and nuclear research units in operation by both countries were more as tens Ci/m^3.

After the solid radioactive wastes have been immobilized, the waste packages are normally placed in an un-contaminated area, where the final control for outside contamination is carried out. The usual types of solid radioactive wastes collected in plastic bags are: plastic tubes, papers, gloves, clothes, PVC materials, laboratory glassware, emptied containers and some secondary wastes produced during treatment of liquids. Their origins are research laboratories, the radioisotope production departments of INP, Tirana, Albania and the radiobiological and radiopharmaceutical departments of Pristina hospitals etc.

Solid radioactive waste received in plastic or nylon bags (packages) and sometimes in 200 1 drums. Usually the solid radioactive waste with its package is fed directly into the drum and their compaction was performed. Compaction process is a mechanical volume reduction technique used by INP for low level combustible solid radioactive wastes. A volume reduction factor of 0.4 - 3 is obtained, depending on the type and compressibility of the wastes. The volume waste bags are grouped and evaluated together according to their specifications like: type of nuclides, their half-lives etc. If there is enough space on the drum to keep the bag until the activity decreases to exemption level within 1-3 years, it is better to keep it in the storage room for decay. Drums can be transported after at least 3 days stay at the temporary storage facility buildings. A layer of up to 5 cm of cement has to be added, whenever possible, before the drum(s) to be transported for interim in temporary storage buildings for a period of many years, providing an observation period of some years, before the drums disposal in repository areas at the same building. During that time, drums are periodically controlled for deformation, corrosion, etc., since necessary precautions must be taken before their final disposal. The temporary interim storage can take advantage of the activity decay with time to facilitate the safe transport to the final repository building. If the activity will decrease to exemption levels within 10 till 15 years, interim storage is used for that kind of conditioned wastes as a temporary host until they are sent to municipal waste collection area.

Based in the inventory of radioactive waste in Kosovo, as well in its classification, it is with interest by practical needs to organize its safe management in accordance with IAEA recommendations, which is implemented in accordance with its pertaining in the mentioned different groups of the classification scheme [5]. From safety point of view it is necessary to distinct the waste with radionuclides half-lives shorter than 100 days, the waste with half-lives less than 40 years and the waste with half-lives more than hundred years. This is related with radioactive danger represented by different group of radioactive waste, which is proportional with its half-lives [6].

Storage involves packages already manufactured or in production, but is also a prospective tool for developing new types of waste packages [7].

A high degree of safety can be provided through implementation of the institutional control measures, considering the safety and security of storage installation (e.g. landfills), as mentioned at the action where was included construction of the hazardous waste storage facilities based on the Kosovo Government's decision of 2009, and related works supervision services. The limitations of waste activity, which might be stored in a specific installation is related also with radiological, chemical and biological waste properties.

2. Material and Methods

The preferred option to reduce the safety risks for incidents or accidents with spent radiation sources is the immobilization and conditioning of spent sealed sources in a matrix, as soon as they are verified as spent and non-used radiation sources. The method has the advantage of using unsophisticated technology and materials with equipment which are easily available. The product package (200 l drum) is stable for a long time under temporary interim storage conditions. Using an additional shielding inside the drum it is always possible to reduce the surface dose rate outside of the drum(s) for transport purposes as well. By proper conditioning of a spent sealed source in concrete, the source is transformed into a form which cannot cause any large exposure even if the waste package is handled without special precautions. SRS may be classified according to their application. Such classification would give authorities and users an indication of the safety of radioactive sources in different applications. The International Standard ISO 2919 establishes a system of classification of sealed sources based on test performance and specifies general requirements, performance tests, production tests, marking and certification [8]. Prototypes of sources are tested for temperature, external pressure, impact, vibration and puncture in classes of increasing severity. Sources intended for an application have to meet minimum criteria outlined in the standard.
As soon as the source container or equipment is received, the surface dose rate is measured and an identification number is given. A registry form (Table 1) was opened for each received spent sealed source. Sometimes, the activity of an individual source may be very large, so that conditioning and additional drum shielding cannot decrease the surface dose rate enough for it to be transported.

Table 1. *Radioactive source registration form*

Received	Sealed Source
Identification Number: 040- 4 M	Surface dose rate: 1.1 mR/h
Received date: January 2023	Identified Nuclide: ^{137}Cs-137
Origin: Elbasan Steel Factory	Initial Activity: 0,9 Ci
Weight of Contenier: 60 Kg	Producer: Institute of Isotopes, Hungary
Responsible Person: Unknown	Dose rate: 28 u.R/h (1 meter distance)
Verification:	Leakage: No, sweep test by cotton
Date: 27.05.2023	Responsible Person: Dosimetry group
Nuclide & Activity: ^{137}Cs = 0.088 Ci	
Note: Surface dose rate has been verified	

In Albania, in accordance with IAEA recommendations, conditioning of spent radiation sources in Type A and Type B packages was used. The conditioning option is based on the immobilization, of the source within a Type A package. The source in its cask or container is placed in the center of a 200 1 drum filled with cement mortar (Fig. 1).

Figure 1. *The radioactive source in its cask or container*

This conditioning procedure is suitable for any type of source, assuming its size (including casket or container) allows it to be conveniently accommodated in the center of a 200 1 drum. Conditioning in this way prevents unauthorized removal of the source because of the weight, bulk and robust nature of the package.

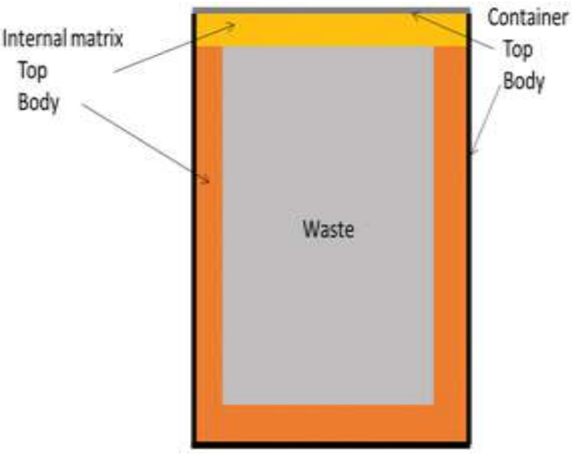

Figure 2. *Simplified description of a package used by STORAGE [1].*

It also provides a barrier against loss of containment of radioactive material (Fig. 2). The adoption of this method will depend upon a number of factors including:
- The number of spent sealed sources puted into drum(s);
- The half-life and activity of the sources;

- The toxicity of the radionuclides in the sources;
- The final disposal scheme for the sources.

Figure 3. *Final condition, container marked with symbols and inscriptions*

INP has used conditioning in Type A packages as an attractive option having a small number of spent sources and wishing to provide additional security and containment (Fig.3). INP has received some tens spent radiation sources from industrial plants in Elbasan, Fier and Shkodra, cities for conditioning (Table 2).

Table 2. *The main radionuclides of spent radioactive sources conditioned and stored in INP*

No	Users	Radionuclide
1	Hospital + Industry	^{137}Cs
2	Army +Industry	^{60}Co
3	Hospital, Geophysics / Chemical Enterprises	^{226}Ra
4	Research + Soil Institutions	^{241}Am
5	Soil + Industry + Agriculture	Am-Be
6	Industry	^{192}Ir
7	Army + Industry	^{90}Sr
8	Research	^{238}Pu

3. Results and Discussions

The Government of Kosovo has establish a public company in charge of operating and managing the Hazard Waste System. The company should be responsible for safe collection, shipment, and proper storage of the waste, including radioactive and spent radiation sources, ensuring that hazardous waste is dealt with in the safest way possible. Furthermore, the company should be in charge of classification and labelling, record keeping, monitoring and control obligations from the "cradle to the grave", i.e., from the waste producer to the final disposal or recovery (Fig. 4). Categorization should be done based on the properties which render waste hazardous, laid down in the EU relevant directives.

Figure 4. *Spent radioactive source in an industrial facility*

Kosovo has established the basic institutions and has formulated the main documents related to hazard waste management which are:

- Waste Management Strategy and action plan 2013-2022 of Kosovo which is to develop a sustainable management practices based on the relevant EU directives.
- Environmental Protection Strategy 2013-2022, which derives from the Law on Environmental Protection. The strategy objectives among other relates to measures for waste, chemical management and energy efficiency as well as the development of an environmental information system.
- Waste Management Master Plan (in draft version) for Kosovo for the upcoming 10 year period prepared, including investment programs and geographical distribution of infrastructure.

The Waste Management Master Plan should be updated and integrated according to the following outputs:

- Scenarios for reduction, categorization / separation, reuse and recycling of waste and other waste treatment practices alternative to landfilling [16];
- An investment hierarchy and investment program specifying the technological process for waste management in accordance with the National Waste Management Plan and EU standards.
- Lists of priority projects that are expected to be implemented in the upcoming 10 years period;
- Monitoring framework providing feedback on investment progress over time including mechanisms and protocols among key actors for regular review;
- Criteria for selection of sites and construction of storage facilities for industrial and toxic waste prepared and presented to the IPA II Energy Sector as a main beneficiary actor.

Conditioning in a Type A packages - considering the exempted levels, as well the situation of radioactive waste in Kosovo in relation with its activity and radionuclide, it is possible to define the following groups of radioactive waste (Fig. 5)**:**

- Exempted waste-EW;
- Very short half-lives waste-VSLW;
- Very low level waste-VLLW;
- Low level waste-LLW, and
- NORM waste [9]**.**

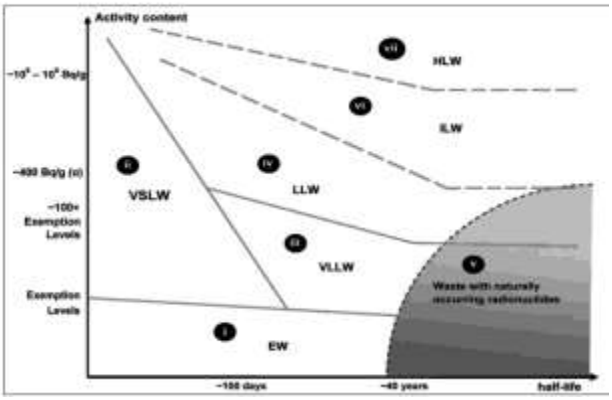

Figure 5. *Classification of radioactive waste in Kosovo [9].*

There are some radioactive sources like: **^{57}**Co or **^{60}**Co with low initial activity, which as result of their radioactive decay have the activity below 1 MBq or 0,1 MBq (exempted activity for both respective nuclides) and these spent radioactive sources belong to EW [15].

The solid and liquid radioactive waste generated from nuclear medicine clinics (**^{99m}**Tc and **^{131}**I) with very short half-lives consist and belongs to VSLW. The majority of radioactive waste in Kosovo are with very low activity and belongs to VLLW.

In Kosovo have been in use some radioactive sources like: **^{241}**Am, **^{238}**Pu, **^{228}**Th, radioactive lightning devices with (**^{152}**Eu, **^{154}**Eu), which are with long half-lives or alpha emitters.

The mentioned sources needed to be treated with caution considering their confinement and isolation, which as general rule ought to resist for some hundred years and these sources belong to LLW. Also, there have been a big quantities of industrial waste near to chemical or mineral complexes in Kosovo, which content natural occurring radioactive material (NORM) of different activities concentration. This waste as general rule contents low concentration of natural radionuclides, but their long half-lives require special studies for considering its handling in different branches of economy or its management in accordance with its concentration. This group of radioactive waste belongs to NORM wastes [10].

Environmental considerations should be duly reflected in all financed activities for managing and treatment of Hazardous Waste Pollution at Power Plant of Kosovo, (concentrated phenols, phenol water, hydroxide sodium, acid chlorine, radioactive sources) and at other hotspots of Trepça, Zveçan, and other industrial sites (Fig. 6). Underline, that the main objective of this huge project is to improve the state of the environment in Kosovo and the results of all subprojects are expected to have an important environmental impact and consistent with environmental legislation and the directives for Environment Protection Strategy of Kosovo-EU [11].

Figure 6. *From working in a facility where spent radioactive sources are stored*

Radioactive waste in which the resources contained in them have total activity levels lower than the exception will be considered exempt wastes [12]. These remains as a rule after their collection and control for the amount of activity contained in them, are treated as common waste. To facilitate our work are presented in table 1 and table 3 values of total and specific activity for radioactive sources found in in the Republic of Kosovo.

Power measurements are performed with the device dose Exploranium GR 130. In Figure 7 and 8 is given the measurement of natural background radiation, measured with this device [13]. By computer processing of the results obtained it appears that the average natural background in space is measured 50 NSV / h, a value which characterizes the value of natural background radiation for many countries in the region. Conditioning in a Type B package - This procedure is used to the installation system of therapy machine, Alcyon-II**nd** with **^{60}**Co radioactive source, initial activity A_i = 240 TBq (May, 1995) in Oncological Department, "Mother Theresa" University Hospital Center, which has been in operation, since 1996. This system contains four important panels as follow:

Table 3. *Values of total and specific activity of radioactive sources found in Kosovo*

No.	**Tyoes of radionuclide**	**Activity specific Bq/g**	**Total activity Bq**
1	Cobalt ^{60}	1:10 ^{1}	1:10 ^{5}
2	Cobalt ^{57}	1:10 ^{1}	1:10 ^{6}
3	Cesium ^{137}	1:10 ^{1}	1:10 ^{4}
4	Europium ^{152}	1:10 ^{1}	1:10 ^{6}
5	Europium ^{154}	1:10 ^{1}	1:10 ^{6}
6	Thorium ^{228}	1:10 ^{0}	1:10 ^{4}
7	Teknecium ^{99m}	1:10 ^{2}	1:10 ^{7}
8	Iodine ^{131}	1:10 ^{2}	1:10 ^{6}
9	Americium ^{241}	1:10 ^{0}	1:10 ^{4}

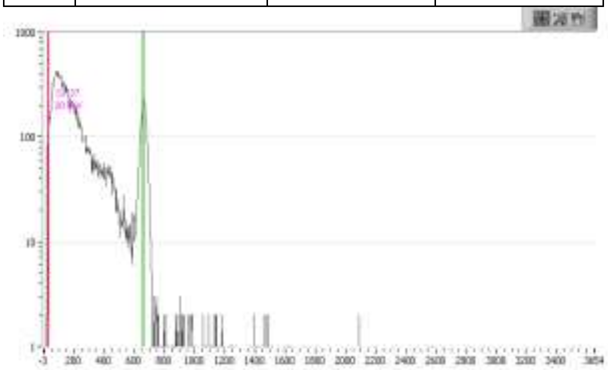

Figure 7. *The radioactive source spectrum of Cs^{137}*

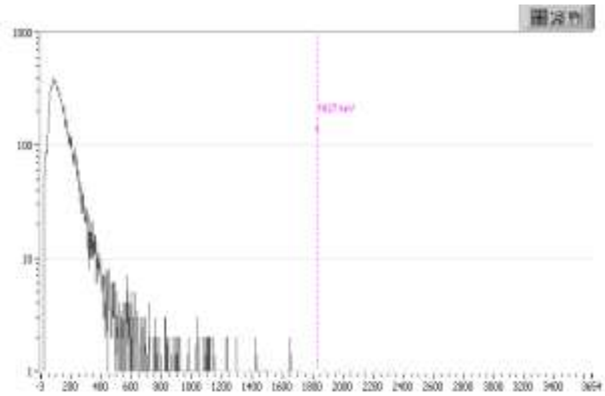

Figure 8. *The spectrum obtained from Lead ore samples, were not recorded the presence of any other element, is roughly similar to the natural*

- Revolving head with ^{60}Co source;
- Metallic support with its accessories;
- Electronic, electrical & surveillance instruments;
- The ventilation installation.

Some of them were degraded and are replaced with new panels during the assembling of the new therapy machine type. The ^{60}Co spent source was conditioned into the 1m^{3} cement and placed for temporary storage in the Centralized Facility in INP (Figure 9). The solid metallic frame was putted over the head of therapy machine and was jointed with a metallic dray with sizes: 800 x 800 mm x 45 mm (thickening). The source's window (collimator) was fixed by down head at the metallic plinth-sheet was conditioned and later was transported for temporary storage at the Centralized Facility in INP (Fig. 9).

Figure 9. *The ^{60}Co spent source was conditioned and placed for temporary storage in the Centralized Facility in INP.*

The removal process was performed including radiation dose measurement in contact and at 30 cm, far from the window's collimator. The leak test was performed for possible contamination using a swap test. The radiation dose also was carried out for individuals who ranged from 50-60 μSv/hr. The option, to reduce the risks for accidents / incident with spent radiation sources, is the conditioning of high risk sources including embedding in a matrix of cement mortar as in photo 1 shown. This method is applicable for radiation sources with activities up to a few TBq (terabecquerel), depending on the radionuclide and half-life. The method has the advantage of using a simple and cheap technology, materials and equipment that is available and it gives a waste package, the stability for a long time under interim storage for conditioning and transfer to the temporary storage facility area.

Funds for "Established the Radioactive Wastes Facility for the Management of Spent Sealed Sources and Hazard Materials" have been allocated accordingly: based on the Law No. 8025 of 25.11.1995, it is the Albanian Government's responsibility to finance activities, with about 120,000 Euro, concerned with construction of the disposal facility and management and treatment of radioactive wastes generating from the use of radioisotopes and radiation sources in science, medicine and industry etc. Since May 1996, a new building was established, and it is under the operation for treatment and management of radioactive wastes and spent radiation sources within the territory of INP, in Tirana, Albania [14]. It is planned to store more as 300 drums, to give enough space for movements of truck and fork-lift, and it is expected that the capacity of this building should be fully sufficient up to the year 2050.

4. Conclusions

The solution of the spent source management should be prepared in the international stand point and framework, because, at present, various materials including radiation sources migrate all over the world and the safety framework will be accomplished under a deep consideration of experiences of past accident and an activity of international information exchange [17]. Methods used by Kosovo and Albanian from responsible institutions up to now, to condition low-level radioactive wastes and spent radiation sources, are performed in compliance with the experience of other countries, IAEA recommendations and world-wide literature. Some State responsible Institutions of both countries such as: the Ministry of Health, the Radiation Protection Commission, Institute of Nuclear Physics, Ministry of Environment and Spatial Planning / Kosovo Environment Protection Agency etc., which are responsible in the field of management of Hazards Wastes including radioactive wastes, will continue on the investigation and establishment of a new National Policy and Strategy in above-mentioned fields and activities.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.

- **Author contributions:** The authors declare that they have equal right on this paper.

- **Funding information:** The authors declare that there is no funding to be acknowledged.

- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1]S. Esnouf, A. Dannoux-Papin**,** C. Chapuzet**,** V. Roux-Serret**,** V. Piovesan **&** F. Cochin, (2022). STORAGE: A Source Term Model for Intermediate-Level Radioactive Waste.'' *Nuclear Technology* 208(12);1806-1821. https://doi.org/10.1080/00295450.2022.2081481.

[2]INTERNATIONAL ATOMIC ENERGY AGENCY, Strategy and Methodology for Radioactive Waste Characterization, IAEA-TECDOC-1537. IAEA, Vienna, Austria, 2007.

[3]INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Sealed Radioactive Sources - Classification, ISO 2919:1980, ISO, Geneva (1980).

[4]B. Cena, K. Dollani, Sh. Dumani, S. Kadiri, G. Hodolli, "An overview of the radioactive waste management in Kosovo*"*, *Albanian Journal of Natural and Technical Sciences, Academy of Sciences*, 24(2), 2013.

[5]INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for The Disposal of Radioactive Waste, Safety Guides Series, No. GS-G-3.4, Vienna, Austria, 2008.

[6]INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste, Safety Guide Series No. GSG-3, Vienna, Austria, 2013.

[7]C. LAMOUROUX and F. COCHIN, (2012). Study of Long Term Behavior of Intermediate Level Long Lived Waste Packages: An Overview of the R&D Approach and Results. *Procedia Chem.*, 7,559 https://doi.org/10.1016/j.proche.2012.10.085.

[8]Ionizing Radiation and Safely of Radiation Sources in Albania. Law No. 8025 of 9.11.1995.

[9]B. Cena, K. Dollani, (2013), Classification of the radioactive waste in Kosovo, *International Journal of Ecosystems and Ecology Science (IJEES)*. 3(4): 791-796.

[10]L. Qafmolla, K. Dollani. "Conditioning of Spent Solid Sources in INP". IAEA, (2000) ", Management of radioactive waste from the use of radioactive waste from the use of radioanuclides in medicine ", Vienna.

[11]EU Project. Instrument for pre-accession assistance (IPA II) 2014-2020 "Construction of Hazardous Waste Storage Facilities in Kosovo".

[12]Scientific Works of the Union of Scientists in Bulgaria-Plovdiv, series C. Technics and Technologies, Vol. XIII., Union of Scientists, ISSN 1311-9419, Session 5 - 6 (November 2015), B. Cena, "Radioactive Waste Management in Kosovo", Plovdiv.

[13]B. Cena, K. Dollani, (2013). Classification of the radioactive waste in Kosovo. *International Journal of Ecosystems and Ecology Science (IJEES)*, 3(4): 791-796.

[14]L. Qafmolla, K. Dollani. "Conditioning of Spent Solid Sources in INP". IAEA, (2000) ", Management of radioactive waste from the use of radioactive waste from the use of radioanuclides in medicine ", Vienna.

[15]B. Cena, K. Dollani " Clasification of the radioactive waste in Kosovo'' the 3rd International Conference of Ecosystems (ICE 2013), Tirana, Albania, May 31-June 05, 2013. ISBN: 978-9928-4068-7-3.

[16]INTERNATIONAL ATOMIC ENERGY AGENCY, Strategy and Methodology for Radioactive Waste

Characterization, IAEA-TECDOC-1537. IAEA, Vienna, Austria, 2007.
[17]Radioactive Waste Management Project Group, Forum for Nuclear Cooperation in Asia: The Consolidate Report on Radioactive Waste Management in FNCA Countries, March 2003.