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Research Article

Determination of the type of radioactive nuclei and gamma spectrometry analysis for radioactive sources

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Abstract:

Determining the type of radioactive nuclei is the second activity after the inventory of radioactive waste in Kosovo, their location and the number of radioactive sources. Before starting any type of radioactive waste action, it is necessary to determine the content of their activity, the type of radioisotope, physical and chemical form and the risks associated with their management. The realization of this is achieved as a combination of quality assurance processes, the inventory of the radioisotope and its activity that is present in the waste, the composition of the waste material and direct measurements. This serious activity was carried out entirely in the field and was undertaken due to the lack of source certification or any other indication of their classification and activity. The process of determining the type of radioactive nuclei helps to realize a more effective characterization of them as well as to determine the path of waste management. The probability that a gamma radiation detector interacts with it to produce a pulse represents the effectiveness of the detector.

1. Introduction

The second important activity after the inventory of radioactive waste in Kosovo, their location and the number of radioactive sources, is the determination of the type of radioactive nuclei and their activity. This difficult activity was carried out entirely in the field and was undertaken due to the lack in most cases of source certificates or any other document with the necessary data, which would make possible the identification of radioactive sources and their activity. To determine the activity of different radioactive sources that were located in different institutions, the relationship that exists between the activity of a radioactive source and the power of the equivalent dose created by this radioactive source at a certain distance was used. The relationship between these quantities is given by the following expression:

$$H' = \Gamma a / r^2 \qquad (1)$$

where **H'** is the equivalent dose power in mSv/hour (or μSv/hour), **Γ** is the specific gamma constant of radioactive sources in mSv.m^2/MBq.hour, ***a*** is the activity of the radioactive source and **r** is the distance of the measuring device from the source radioactive Starting from the above relationship, the activity of ***a*** radioactive source can be deduced as a function of the power of the equivalent dose **H'** and the distance **r** of the measuring device from the radioactive source under study.

$$a = H' r^2 / \Gamma \qquad (2)$$

For this purpose, in each case, we measured the power of the equivalent dose from a certain radioactive source at a fixed distance, which for ease of calculation was taken equal to 1 meter.

2. Material and Methods

As for the values of the specific gamma constant (Γ), they are taken from reference where, in addition to the specific gamma constant for the different radioactive sources, the half-life period of the corresponding radionucleus is given as well as the energy values of the gamma radiation emitted by this radio nucleus [1],[2].

These devices are: "Exploranium GR-130", "Inspector 100" and "Babyline 31", which are owned by the Radiation Protection Service of the Institute of Occupational Medicine, Obiliq.

2.1 Inspector device

The detector is an instrument to detect low levels of ionizing radiation (Fig.1).

Figure 1. *Inspector measuring device*

Inspector measures gamma radiation and X-rays. Its applications include:

• Detection and measurement of pollution on the surface
• Monitoring possible radiation exposure while working with radionuclides
• Examination for environmental pollution

The Inspector device uses a Geiger-Muller tube to detect radiation.

The data recorded by the Inspector varies from minute to minute due to the nature and type of radioactivity. A reading is more accurately expressed as an average over time, and the average is more accurate over a longer period of time.

Three equivalent dose power measuring devices were used as measuring devices, which, in addition to the value of the equivalent dose power, also identified the type of radionucleus subject to measurement (Fig. 2).
Based on these measurements, Table 1 was constructed, in which the main data for some radioactive sources are presented, including the type of radionucleus, the half-life period, the specific gamma constant, and the activity of the radioactive source [3,4].

Table 1. *Values of half-life, specific gamma constant, dose rate and activity for radioactive sources in the form of radioactive waste*

radioactive source	Half-year period	Constant. specific gamma, $mSv.m^2/MBq.hour$	Distance, adsorbed dose	Activity
Object A				
First Source **^{60}Co**	5.3 years	3,697E-4	1.5m, 0.08 µSv/h	0.01x10 ^{3} MBq
The second source **^{60}Co**	5.3 years	3,697E-4	1.5m, 0.09 µSv/h	0.02x10 ^{3} MBq
The third source **^{60}Co**	5.3 years	3,697E-4	1.5m, 4.13 µSv/h	1.01x10 ^{3} MBq
Object B				
First Source **^{57}Co**	270.9 days	4,087E-4	1m, 4 µSv/h	0.9x10 ^{2} MBq
The second source **^{60}Co**	5.3 years	3,697E-4	2m, 0.78 µSv/h	0.3x10 ^{3} MBq
Object C				
First Source **^{60}Co**	5.3 years	3,697E-4	1m,- Sides of the container 0.17 µSv/h	0.018x10 ^{3} MBq
The second source **^{60}Co**	5.3 years	3,697E-4	1m,- The "holes" of the container without leaflets 5.14 µSv/h	0.55x10 ^{3} MBq
The third source **^{60}Co**	5.3 years	3,697E-4	1m, - The "holes" of the container with leaflets 1.53 µSv/h	0.16x10 ^{3} MBq
Object D				
First Source **^{137}Cs**	30.17 years	1,017E-4	1m, 1.06 µSv/h	0.4x10 ^{3} MBq
			2m, 0.13 µSv/h	0.2x10 ^{3} MBq
The second source **^{137}Cs**	30.17 years	1,017E-4	1m, 2.78 µSv/h	1.19x10 ^{3} MBq
			2m, 0.15 µSv/h	0.25x10 ^{3} MBq
The third source **^{137}Cs**	30.17 years	1,017E-4	1m, 0.10 µSv/h	0.04x10 ^{3} MBq
The fourth source **^{137}Cs**	30.17 years	1,017E-4	1m, 0.19 µSv/h	0.08x10 ^{3} MBq
The fifth source **^{137}Cs**	30.17 years	1,017E-4	1m, 0.23 µSv/h	0.09x10 ^{3} MBq

Object E				
First Source ^{137}Cs	30.17 years	1,017E-4	1m, 1.52 µSv/h	0.16x10 ^{3} MBq
The second source ^{137}Cs	30.17 years	1,017E-4	1m, 6.22 µSv/h	0.67x10 ^{3} MBq
The third source ^{137}Cs	30.17 years	1,017E-4	1m, 2.36 µSv/h	0.25x10 ^{3} MBq
The fourth source ^{137}Cs	30.17 years	1,017E-4	1m, 1.52 µSv/h	0.16x10 ^{3} MBq

Figure 2. *Radioactive sources identified by measurement [5]*

Using the "Exploranium GR-130" equipment, gamma spectrometry analysis was done for the sources, where we obtained the gamma spectra of these radioactive sources [4]. The Exploranium GR-130 represents a major advance in the field of radiation monitoring, offering the user not only the ability to search and find radioactive material, but also to automatically identify radioactive nuclei that are present (Fig.3).

Figure 3. *Measurement made with the Exploranium GR 130 device*

2.2. Gamma spectrometry

Gamma spectrometry is a useful non-destructive method that permits the simultaneous determination of many radionuclides in a bulk sample [6-19]. However, it is limited by the weak emission probabilities of many potentially useful emission lines [20,21]. The relatively poor efficiency of the High Purity Germanium (HPGe) 7 detectors over a wide range of energy, the difficult task of precisely calibrating the efficiency of the detector, and the need to evaluate self-absorption effects [22,23]. Selected ultra low background construction materials for the detector housing and preamplifier, and low background environments (e.g. under dam walls, underground) may also be used to further increase the sensitivity of the gamma spectrometry system [24]. Gilmore provides a detailed review of gamma spectrometry, covering theory and practical applications [25]. Gamma spectrometry relies on the generation of an electronic pulse, proportional in magnitude to the gamma ray emissions produced from the radioactive decay of a radioactive material being measured. Each radioactive material that emits gamma radiation has a characteristic 'finger print' that can be used to both qualitatively identify the radionuclide present, and quantitatively establish the activity concentration of the material (there are a number of decay processes where gamma radiation is not produced, these radionuclides cannot be measured directly by gamma spectrometry) [26]. The radioactivity levels of the samples were analyzed using gamma spectrometry, which is an equipped, high-purity germanium gamma-ray detector ORTEC, with a 55% relative efficiency and a resolution of full width at half maximum (FWHM) of 1.90 keV at 1.33 MeV of peaks for the gamma of $_{60}$Co. The detector was shielded by a cylindrical lead shield, with an average thickness of 10 cm, to achieve a background level as low as possible. Efficiency and energy calibration of the detector was carried out with a $_{152}$Eu calibration source (Amersham Company, Amersham, UK). As standard procedure the cylindrical geometry of samples with constant volume and distance were applied to all samples.

3. Results and Discussions

Using the "Exploranium GR-130" device, gamma spectrometry analysis was done for the sources, which resulted in the benefit of their gamma spectra. Figure 4 shows the spectrum of two sources of cobalt $_{60}$Co, which emits two groups of gamma radiation: the first with energy in the range 1119-1208 keV and the second with energy in the range 1285-1370 keV. The first peak corresponds to the gamma radiation energy of 1170 keV, while the second peak corresponds to the gamma radiation energy of 1330 keV (Fig. 4).

The energies corresponding to this cascading decay fit exactly to the $_{60}$Co source, which is part of the radionucleus library of the GR-130 device. It is theoretically known that the radioisotope of $_{60}$Co has a decay scheme where beta decay first occurs, and as a result the nucleus of $_{60}$Ni is created in an excited state, which passes to the stable state releasing two gamma rays with an energy of 1170 keV and 1330 keV and half-life 5.27 years. With the Exploranium GR-130 device, the spectra were realized, from which two spectra are presented for two $_{60}$Co sources with different activities (Fig.4) [6].

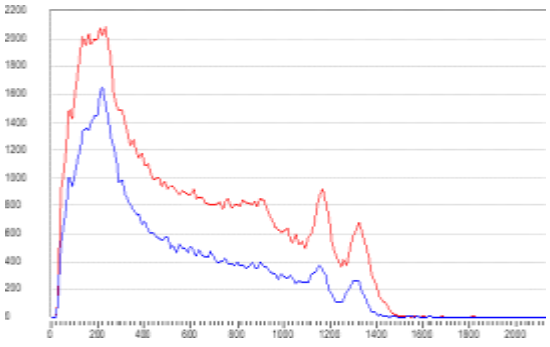

Figure 4. *Display gamma spectrometric two Co-60 sources*

All of the radioactive sources have been given a gamma spectrum and all of them have turned out to be isotopes of $_{60}$Co. The only difference that can be observed between the sources is a small difference in the activity of the resources in block 3 of the Kosova A Power Plant, which have a smaller activity than the activity of the resources measured in block 5 of the Kosova A Power Plant. The scheme of the decay of the radioactive isotope of $_{60}$Co is given in the figure below (Fig. 5) [7]. Several spectra were taken with the Exploranium GR-130 device (Fig.6, Fig.7, Fig.8, Fig.9).

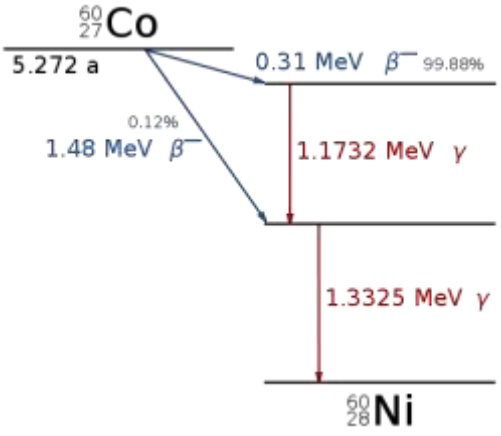

Figure 5. *Schematic of the radioactive decay of the isotope of Co-60*

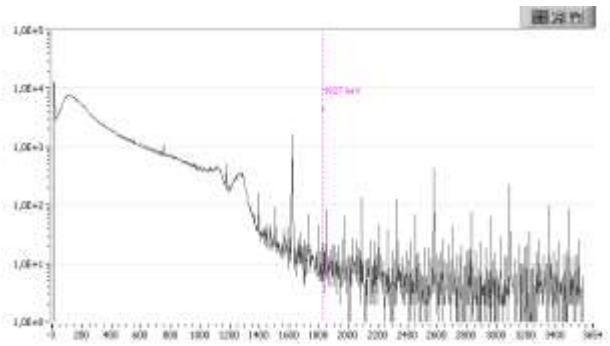

Figure 6. *Gamma spectrum of a barrel where two radioactive sources are cemented: $_{60}$Co and Eu 152/154*

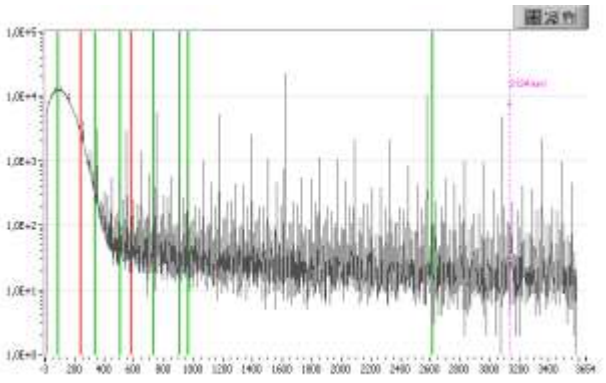

Figure 7. *This is where the gamma spectrum has gained a measure of the radioactive source which by physical shape, location, then, is proving Eu 152/154*

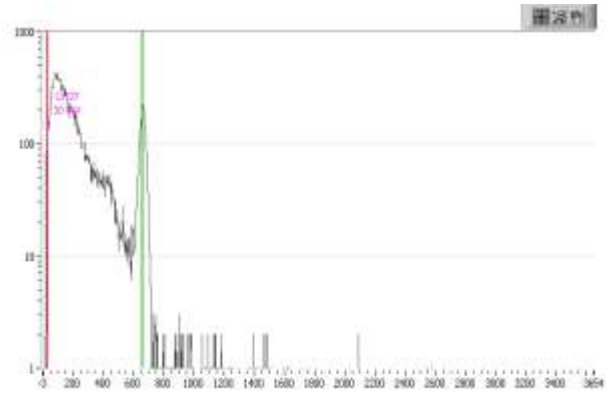

Figure 8. *The gamma spectrum of the identification of the radioactive residue* $_{137}Cs$

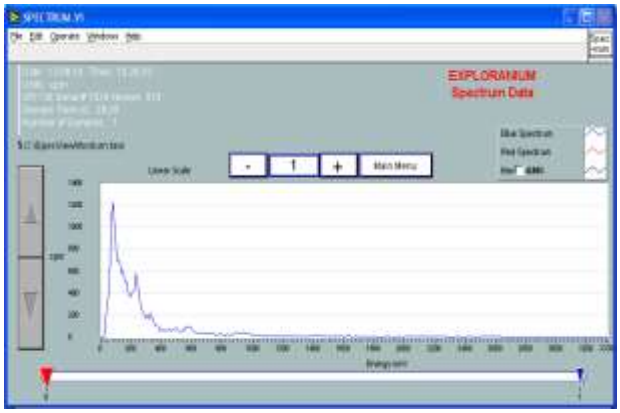

Figure 9. *Thorium 232 identified*

4. Conclusions

Determining the type of radioactive nuclei is essential in the case of the composition and origin of unknown waste. The study of radioactive waste has shown that more than 100 radioactive sources needs to collect and to manage in accordance with IAEA recommendations. This is a complex process that is the foundation of gamma ray spectrometry. All of the radioactive sources have been given a gamma spectrum. Vitally important to surround the calibration of analyzers, which makes these instruments effectively used for identifying high as the radioisotope through gamma radiation that they emit as well as quantitative determination of a radioisotope. This is possible because the number of channels is proportional to the energy of gamma radiation, and the radiation intensity in a channel is proportional to the amount of a given radioisotope. The results obtained by this study will serve as a reference for possible future changes.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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References

[1]Rihs, R., Condomines S, M., (2002). An improved method for Ra isotope (226Ra, 228Ra, 224Ra) measurements by gamma spectrometry in natural waters: application to CO2- rich thermal waters from the French Massif Central, *Chem. Geol.* 182;409-421.

[2]Semkow, T.M., et al., (2002) Low-background gamma spectrometry for environmental radioactivity, *Appl. Radiat. Isot.* 57;213-223.

[3]International Atomic Energy Agency, Policies and Strategies for Radioactive Waste Management, IAEA Nuclear Energy Series NW-G-1.1, IAEA, Vienna, Austria, 2009.

[4]Technical manual of the dosimetric device "Exploranium G-130", Canberra, 2009.

[5]Sehad Kadiri , Serdar Dizman,, Cafer M. Yes¸ilkanat, Hamdi Aliu and Gezim Hodolli, Radioactivity in Soils of Kosovo and Radiological Implications, https://doi.org/10.3390/app12199520

[6]Besire CENA, (2019). Characterization of radioactive waste in Kosovo through Gamma Spectrometry, *Ejmse*, 4(4);166-172.

[7]Besire CENA, (2020). An overview of the radioactive wasst in Kosovo, *Journal of Chemical Technology and Metallurgy*, 55(2);404-408.

[8]Herranz, M., et al., (2006) Radon fixation for determination of 224Ra, 226Ra and 228Ra via gamma-ray spectrometry, *Radiat. Measure*. 41;486-491.

[9]Parekh, P. et al., (2003). Non-destructive determination of 224Ra, 226Ra and 228Ra concentrations in drinking water by gamma spectrometry, *Health Phys.* 85;613- 620.

[10] Iskender Akkurt (2009). Effective atomic and electron numbers of some steels at different energies *Ann. Nucl. En.* 36(11,12);1702-1705 DOI: 10.1016/j.anucene.2009.09.005

[11] Parlar, Z., Abdlhamed, A. & Akkurt, İ. (2019). Gamma-ray-shielding properties of composite materials made of recycled sport footwear. *Int. J.*

Environ. Sci. Technol. 16; 5113–5116. https://doi.org/10.1007/s13762-018-1876-7

[12] Aycan Şengül, İskender Akkurt, Kadir Gunoglu, Kadir Akgüngör, R. Banu Ermis, (2023).Experimental evaluation of gamma-rays shielding properties of ceramic materials used in dentistry, *Radiation Physics and Chemistry*, 204;110701. https://doi.org/10.1016/j.radphyschem.2022.110701

[13] Aycan Şengül (2023). Gamma-ray attenuation properties of polymer biomaterials: Experiment, XCOM and GAMOS results. *Journal of Radiation Research and Applied Sciences*. 16(4):100702 . https://doi.org/10.1016/j.jrras.2023.100702

[14] Coşkun, A. , Çetin, B. , Yiğitoğlu, İ. & Topaklı, H. (2023). Comparison of the Radiation Absorption Properties of PbO doped ZrB2 Glasses by using GATE-GEANT4 Monte Carlo Code and XCOM Program . *International Journal of Computational and Experimental Science and Engineering* , 9 (3) , 274-279 .

[15] Aygun, Z. & Aygün, M. (2023). An Analysis on Radiation Protection Abilities of Different Colored Obsidians . *International Journal of Computational and Experimental Science and Engineering* , 9 (2) , 170-176 . DOI: 10.22399/ijcesen.1076556

[16] Zarkooshi, A. , Latıf, K. H. & Hawı, F. (2021). Estimating the Concentrations of Natural Isotopes of 238 U and 232Th and Radiation Dose Rates for Wasit Province-Iraq by Gr-460 system . *International Journal of Computational and Experimental Science and Engineering* , 7 (3) , 128-132 . DOI: 10.22399/ijcesen.891935

[17] Rwashdı, Q. A. A. D. , Waheed, F. , Gunoglu, K. & Akkurt, İ. (2022). Experimental Testing of the Radiation Shielding Properties for Steel . *International Journal of Computational and Experimental Science and Engineering* , 8 (3) , 74-76 . DOI: 10.22399/ijcesen.1067028

[18] Albıdhanı, H. , Gunoglu, K. & Akkurt, İ. (2019). Natural Radiation Measurement in Some Soil Samples from Basra oil field, IRAQ State . *International Journal of Computational and Experimental Science and Engineering* , 5 (1) , 48-51 . DOI: 10.22399/ijcesen.498695

[19] İskender AKKURT, N. Ayten UYANIK, Kadir GÜNOĞLU (2015). Radiation dose Estimation: An in vitro Measurement for Isparta-Turkey" *International Journal of Computational and Experimental Science and Engineering* 1(1);1-4 DOI: 10.22399/ijcesen.194376

[20]Kahn, B., et al., (1990). Analysis of 228Ra and 226Ra in public water supplies by a γ-ray spectrometry, *Health Phys.* 59; 125-131.

[21]Dulahova, H., Burnett, W.C., (2004) An efficient method for γ-spectrometric determination of radium-226, 228 via manganese fibers, *Limno. Oceanogr. Methods*, 2;256-261.

[22]KÖHLER, M., et al., (2000) Simultaneous determination of Ra and Th nuclides, 238U and 227Ac in uranium mining waters by γ-ray spectrometry, *Appl. Radiat. Isot***,** 52;717-723.

[23]Johnston, A., Martin, P., (1997) Rapid analysis of 226Ra in waters by γ-ray spectrometry, *Appl. Radiat. Isot.*, 48; 631-638.

[24]Jodlowski, P., (2006) Self-absorption correction in gamma-ray spectrometry of environmental samples – an overview of methods and correction values obtained for the selected geometries, *Nukleonika* 51;21-25.

[25]IAEA Analytical Quality in Nuclear Applications, Analytical Methodology for the Determination of Radium Isotopes in Environmental Samples, IAEA Series No. 19.

[26]Gilmore, G. Practical Gamma-ray Spectrometry, 2nd Ed. Wiley (2008).