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Evaluation of a ^{137}Cs radioactive source activity utilized in oil-welling in Albania

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Abstract: The Institute of Applied Nuclear Physics (IANP) is the national authority responsible for the management of radioactive waste and disused sealed radioactive sources (DSRS) in Albania. In carrying out this mandate, IANP works in coordination with both public and private institutions to ensure the safe handling, transport, and storage of radioactive materials.

This study describes the methodology used to assess the total activity of two ^{137}Cs sources with unknown activity. In 2018, IANP took possession of five DSRS from the Geophysical Service Center following the decommissioning of its temporary storage facility. According to the available source certificates and in situ radiation measurements, two ^{137}Cs sources with nominal activities of 52 mCi and 51 mCi, respectively, both manufactured in July 1978 were stored together within a single container.

To confirm whether the two ^{137}Cs sources were encapsulated within a single capsule, their combined activity was estimated using a point-source geometry approach. The measured total activity was 1.418 GBq, which is in good agreement with the decay-corrected certificate value of 1.528 GBq as of March 2018. This close correspondence confirmed that both ^{137}Cs sources were indeed present within the same encapsulation. Following verification, all sources were safely transferred to the National Radioactive Waste Storage Facility in Tirana for long-term management.

Keywords: radiation protection, ionizing radiation, storage facility, DSRS.

1. Introduction

Since 1999, a dedicated Radioactive Waste Storage Facility (RWSF) has been established in Albania. This facility was constructed for the processing and temporary storage of radioactive waste and disused sealed radioactive sources (DSRS), in full compliance with both National and International Waste Acceptance Criteria (WAC) [2], [3].

The RWSF consists of two main components, Operational Area dedicated to the handling, characterization, and short-term processing of incoming radioactive materials and the Interim Storage Area designed to house conditioned radioactive waste and disused sealed radioactive sources (DSRS) until a permanent solution becomes available. The interim facility is projected to reach full capacity by 2040, given the expected increase in the use and disposal of radioactive sources from industrial, medical, and research applications.

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The legal framework governing radiation protection in Albania is primarily defined by Law No. 8025, dated January 11, 1995, titled "On Protection Against Ionizing Radiation." This legislation has been subsequently amended by Law No. 9973 (July 28, 2008) and Law No. 26/2013 (March 2013) [1]. These laws establish essential safety standards aimed at protecting human health and the environment from the hazards of ionizing radiation. In accordance with these regulations, a safety assessment of the RWSF is conducted periodically, evaluating its potential impacts on workers, the public, and the surrounding environment [1], [4], [6].

The site, which has been operational since 1971, is designated to receive low-level and intermediate-level radioactive waste (LLW/ILW) originating from non-nuclear applications such as healthcare, industry, agriculture, education, and research.

All radioactive waste and DSRS must be fully characterized prior to their acceptance into the facility. Emphasis is placed on reducing the volume of waste, especially for materials that require long-term management solutions. In line with international best practices, the Radiation Protection Commission of Albania enforces the application of the IAEA Code of Conduct on the Safety and Security of Radioactive Sources and its supplementary guidance. This includes the obligation for importers of radioactive sources to ensure arrangements are in place for the eventual return of these sources to their manufacturers or to certified storage facilities abroad.

DSRS that cannot be re-exported or returned whether due to technical, regulatory, or logistical reasons are managed by IANP. This includes sources of unknown origin or those for which return arrangements were not initially made. Their acceptance into the RWSF is conducted under formal agreements between IANP and the relevant parties. IANP functions as the national centre for the collection, management, and conditioning of disused and orphan radioactive sources, ensuring the secure handling of such materials in the country.

In a recent case, an Albanian oil production company was required to transfer its inventory of radioactive sources to the national RWSF due to the expiration and non- renewal of its license for radioactive source storage. In response to the company's formal request, IANP undertook a full characterization of the stored DSRS and subsequently carried out the safe transport and transfer of all identified sources to its facility in Tirana.

2. Materials and Methods

2.1 Method for DSRS Characterization

Proper characterization of DSRS is essential for ensuring safe handling, storage, and, where applicable, disposal. The following procedure outlines the systematic steps to assess the physical, radiological, and safety parameters of each source prior to its acceptance at the Radioactive Waste Storage Facility (RWSF).

1. Initial Radiation Survey

The first step involves assessing the external radiation dose rates in the vicinity of the radioactive source. This is a critical safety measure to ensure personnel protection and determine the necessary precautions.

- **Approach Protocol:**
  Do not approach the source directly if preliminary dose rate readings indicate high radiation levels. Maintain a safe distance and approach incrementally using remote handling tools or mobile detection equipment.
- **Measurement Strategy:**
  Use calibrated portable radiation survey meters suitable for gamma and/or beta radiation, depending on the expected radionuclide. Measure and record the dose rate at two key positions:
  - At the surface of the container or source housing
  - At a distance of 1 meter from the source
- **Safety Measures:**
  Follow institutional radiation protection protocols, including the use of personal dosimeters, lead shielding (if needed), time-distance-shielding principles, and remote monitoring techniques.

2. Contamination Assessment

To check whether the source is leaking or damaged, a contamination survey should be conducted as follows:

- **Wipe Test Procedure:**
  - Using a swab, filter paper, or absorbent material, wipe the external surface of the source or its containment unit.
  - For gamma-emitting sources, use long-handled tongs to prevent unnecessary exposure.
  - For alpha-emitting sources, the swab may be held manually using gloved hands due to the short range of alpha particles.

- **Measurement:**
  - Analyse the swab in a low background radiation area using a sensitive Geiger-Muller (GM) survey meter equipped with a pancake probe.
  - Record the background radiation level before testing the swab.
  - If the measured count rate exceeds the background level plus three times the standard deviation, the source is considered to exhibit removable contamination, indicating a potential leak.
- **Follow-up:**
  In the event of contamination, immediately isolate the source, notify radiation safety personnel, and initiate appropriate decontamination and reporting procedures.

3. Identification and Labelling

After verifying that it is safe to handle the DSRS, visually inspect the source housing or container for any identifying information. Document the following:

- **Device Information:**
  - Type of device (e.g., brachytherapy source, level gauge, soil moisture-density

gauge, lightning rod, transport/shipping container)
  - Manufacturer, model number, and serial number
  - Approximate dimensions (length, width, height)
  - Estimated weight and physical condition of the device
- **Source Information:**
  If available, record all relevant data about the radioactive source itself, including:
  - **Serial number of the source**
  - **Radionuclide** (e.g., Cs-137, Co-60, Am-241)
  - **Initial activity** (in Bq or Ci)
  - **Reference date** for the stated activity
- If labels are damaged, missing, or illegible, attempt to retrieve historical data from licensee records or supplier documentation. In such cases, further non- destructive analysis (e.g., gamma spectrometry) may be necessary to confirm the isotope and estimate the activity.

4. Documentation and Data Logging

All measurements, observations, and collected information must be thoroughly documented in the DSRS characterization form or tracking system. These data are critical for:

- Ensuring compliance with Waste Acceptance Criteria (WAC)
- Deciding on further treatment or conditioning options
- Informing long-term storage or repatriation decisions
- Supporting radiological safety audits and inspections

This protocol is aligned with international best practices for the safe handling of disused radioactive sources and supports the continued efforts of the Institute of Applied Nuclear Physics (IANP) to ensure a secure and efficient radioactive waste management program in Albania.

Fig. 1. Example of labels on the radioactive sources or devices

If activity and manufacture date are on the source label, we would calculate the activity at the present date using the radioactive decay equation.

$$A_t = A_0 e^{-\frac{Ln2}{T_{1/2}} t} \quad (1)$$

$$A_t = A_o e^{-\lambda t} \quad (2)$$

Where:

t = time (from the date of manufacturing to present date), A_t = activity at time t

A_o = initial activity, λ = decay constant, $T_{1/2}$ = half live of the radionuclide

In this particular case, the device lacked an identification label, making it impossible to obtain source information from external markings or accompanying documentation. Consequently, the characterization of the radioactive source had to be performed directly using appropriate radiation detection and measurement instruments [5], [7]. This approach is commonly adopted in situations involving orphan sources or legacy devices where provenance data are unavailable.

To identify the radionuclide, a portable gamma radiation detection device was employed, as this technique is well suited for sources containing gamma-emitting radionuclides. The instrument was positioned at an appropriate distance from the source to ensure adequate count rates while avoiding detector saturation. Prior to measurement, the detector was energy-calibrated using reference sources to ensure accurate peak identification.

This non-destructive method enables radionuclide identification by comparing the measured gamma energy peaks with known characteristic energies from established radionuclide libraries. In addition to qualitative identification, the spectral data can provide preliminary information on source activity and shielding effects, although such estimates may be subject to uncertainty due to unknown source geometry and attenuation. Overall, portable gamma spectrometry offers a rapid and reliable means of radionuclide identification in field conditions without the need for physical manipulation or dismantling of the source.

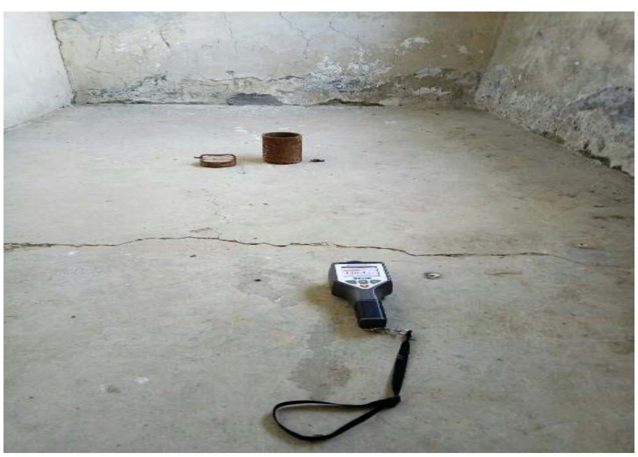

Fig. 2. Measurement of dose rate at 1 m distance.

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Due to the presence of shielding material surrounding the radioactive source, the measured ambient dose equivalent rates were significantly attenuated, resulting in relatively low external radiation levels in the surrounding area. Preliminary radiation surveys confirmed that dose rates remained within acceptable safety limits for handling under controlled conditions. Based on these measurements and after confirming the absence of abnormal radiation fields, it was deemed safe to open the shielding cover and carefully remove the source using appropriate radiological protection procedures. During source handling, standard radiation safety principles were applied, including minimizing exposure time, maximizing distance where practicable, and using suitable personal protective equipment and handling tools. Continuous dose rate monitoring was performed to ensure that radiation levels remained stable throughout the operation.

Following removal, the activity of the source was estimated by assuming a point-source geometry, an approximation commonly used when the physical dimensions of the source are small relative to the measurement distance. The dose rate (DR) was measured at a distance of 1 meter (r) from the source in free air to minimize the influence of scattering and shielding effects. Using this measured dose rate, the source activity was calculated by applying the inverse square law in combination with the appropriate gamma dose-rate constant for the identified radionuclide. This method provides a practical estimate of source activity.

Where:

$$DR = \Gamma \times A / r^2 \qquad (3)$$

DR – dose rate at a distance "r" from the source, expressed in mSv/h

Γ - Ambient dose equivalent rate, H*(10), produced at 1 meter by the radioactive source, expressed in $mSv.m^2/h.GBq$. These values are given in Table 1 for the radionuclides more commonly used in sealed sources

A – Activity of the source, in GBq

Table 1. Characteristics of Specific Isotopes

	Half-Life T1/2	Specific Activity (TBq/g)	Ambient dose equivalent rate, H*(10), at 1 meter, $mSv.m^2/h.GBq$
Cs-137	30.2 y	3.22E+00	0.092

3. **Results**

Based on the available documentation and source certificates in possession of IANP, along with the on-site measurements conducted for verification, the inventory of radioactive sources included the following:

- Two Americium-Beryllium (^{241}Am-Be) neutron sources, each with an activity of 5 Ci;
- One Cesium-137 (^{137}Cs) source with an initial activity of 300 mCi;
- Two additional ^{137}Cs sources with activities of 52 mCi and 51 mCi, Respectively;
- One ^{137}Cs source of unknown activity;

The two ^{137}Cs sources with activities of 52 mCi and 51 mCi were reported to be stored together within a single container. As such, these sources required joint characterization using the standard procedure described earlier for DSRS.

Following the contamination control protocol, the external surface of the source container was tested for radioactive leakage. The wipe test confirmed that there was no removable contamination, and the container was deemed safe for handling.

For dose rate measurements, the FLIR Identifinder-2 instrument was used. Measurements were taken at a distance of 1 meter from the source capsule. The recorded ambient dose equivalent rate was 130.5 μSv/h.

To estimate the combined activity of the two ^{137}Cs sources, the point-source geometry method was applied. Using the standard dose-to-activity conversion coefficient for Cesium-137, which is 0.092 $mSv \cdot m^2/h \cdot GBq$ the activity was calculated using the following formula nr 3 described above. The resulting combined activity of the two ^{137}Cs sources was determined to be 1.418 GBq. Following the characterization, all remaining radioactive sources were securely transferred into metal storage buckets, each appropriately labelled with source identification details. The sources were then safely transported to the National Radioactive Waste Storage Facility in Tirana, where they were placed into temporary storage, in accordance with regulatory procedures and safety standards [8].

4. **Conclusions**

A comparison was made between the activity calculated through direct measurement and the certified values indicated in the source documentation in order to verify the characterization results of the two co-located Cesium-137 (^{137}Cs) sources. The activity determined through field measurement was 1.418 GBq, while the combined activity listed in the certificates was 1.528 GBq (corresponding to 52 mCi and 51 mCi, respectively). The proximity between these values supports the conclusion that both ^{137}Cs sources were indeed encapsulated together within a single container.

Following this verification, the sources were securely transferred and are currently under temporary storage at the National Radioactive Waste Storage Facility in Tirana, Albania. The Institute of Applied Nuclear Physics (IANP) serves as the central authority for the management and processing of disused and orphan radioactive sources within the country. In particular, IANP is the designated first responder in cases where unidentified or unauthorized radioactive materials are detected, including those identified at border crossings and customs points.

Albania has established radiation detection portals at key customs locations, which are actively monitored by the competent national authorities. These systems serve a critical role in ensuring the safety of both the public and customs personnel. The authorities are committed to maintaining and continuously improving these detection capabilities to respond effectively to

potential radiological threats.
In the event of detection, IANP is responsible for source assessment, secure transportation, and integration of the material into the radioactive waste management system, as outlined in the national emergency response plan. All identified sources are transported to the storage facility under strict safety protocols. The management of radioactive waste and DSRS is a dynamic process, requiring regular reviews and updates to programs, infrastructure, and safety practices. With anticipated growth in the use of radioactive sources in Albania, proactive planning is essential.
In this context, our current study supports the forecasted saturation of temporary storage facilities by 2040, reinforcing the need to identify and develop a permanent radioactive waste disposal solution. Such a permanent facility must be designed in accordance with International Atomic Energy Agency (IAEA) safety standards and guidelines, particularly for low- and intermediate-level radioactive waste disposal near the surface.

The siting study should consider:

- Geological stability
- Hydrological and environmental conditions
- Long-term safety assessments
- Community and stakeholder engagement

Initiating this national infrastructure project will ensure the sustainable and safe management of radioactive waste well beyond the planned lifetime of the interim facility, securing public and environmental protection for future generations.

"Data Availability Statement:
All data generated or analyzed during this study are included in this published article.

5. References

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