RAP CONFERENCE PROCEEDINGS, VOL. 10, PP. 147–151, 2025
ISSN 2737-9973 (ONLINE) | DOI: 10.37392/RAPPROC.2025.25
RAP-PROCEEDINGS.ORG

# ROOT CAUSE ASSESSMENT OF RADIATION PORTAL MONITOR FAILURE AT KAKAVIJA BORDER CROSSING POINT IN ALBANIA

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***Abstract.*** *The Republic of Albania is a non-nuclear country situated in the Balkan region. In Albania, radiation sources are mainly used in different applications including medicine, industry, agriculture, research and education. In Albania radiation portal monitors are installed since 2005 of type Yantar 1-U and Yantar 2 U from ASPECT company. In Kakavija border crossing point is installed a radiation portal monitor type Yantar-2U. The system is located at the entrance of the Albanian Border with Greece and covers one of the two incoming lanes. Its main aim is to serve the purpose of preventing and deterring the illicit trafficking of radioactive or nuclear materials through Albania. The main issue in relation to illicit trafficking and smuggling in nuclear materials is to detect any possible illegal transits through Albanian territory and borders and to respond to them properly. In the frame of the IAEA Coordinated Research Project J02014 "Advancing Maintenance, Repair and Calibration of Radiation Detection Equipment" under the research contract Nr. 23325 titled "Analysis of Radiation Detection Equipment Failures: Causes and Sustainable Maintenance Plans" Albania has made a root cause analysis of all the radiation portal monitors included in this Coordinated Research Project. In this paper, the root cause failure analysis of the Kakavija case is discussed. Analysis of radiation portal monitor failure or malfunction consisted of technical investigation, assessment of causes in case of failures or malfunctions and the recommendation of possible solutions. The importance of preventive maintenance, front line officers continuous training, cooperation between safety and security agencies/organizations, and tools to maintain, analyze and assess radiation portal monitors will be also covered.*

***Keywords:*** *radiation portal monitors, radiation sources, front line officers, border crossing point*

## 1. INTRODUCTION

In Albania, radiation portal monitors (RPMs) are installed and used for ensuring that border crossing points are equipped with effective radiation detection systems. These systems represent one element of the country's national infrastructure for combating the illicit trafficking of nuclear and other radioactive materials, a key component of both national security and public safety [1], [3].

The introduction of RPMs in Albania began in 2005, supported by international assistance programs, as part of global non-proliferation and nuclear security initiatives. Their primary role has been to strengthen border controls by detecting the unauthorized movement of radioactive materials. The RPMs have been installed in two phases.

- Early Installations (2005–2010): These included the deployment of Yantar-2U RPMs at certain land border points, such as Kakavija, which still operates an early-generation system dating back to 2005.
- Upgrades (2016–2020): More advanced systems were installed at high-traffic border crossing points (BCPs), such as maritime ports and the international airport, reflecting increased technical standards and evolving detection requirements.

A nationwide assessment of RPM functionality and effectiveness started in December 2019 and continued through 2024. The evaluation process was designed to identify the current operational status, maintenance requirements, and potential upgrade needs of each system.

At Kakavija BCP, the assessment included:

- On-site inspections of the Yantar-2U system.
- Operational tests and radiation background measurements.
- Consultations with Front Line Officers (FLOs) and Customs personnel to gather feedback on operational challenges, response protocols, and system reliability.

The RPMs ensures that Albania's land, sea, and air borders are monitored against radiological threats [2], [7].

## 2. MATERIALS AND METHODS

### *2.1. Description of Kakavija YANTAR 2U RPM*

Radiation Portal Monitor Yantar-2U is used at Vehicle (Passenger Car) entry control points. The detection thresholds, of this RPM are described in Table 1, [11].

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Table 1. Yantar 2U Detection Thresholds

| | |
|---|---|
| Cs - 137 | 390 kBq |
| Co - 60 | 190 kBq |
| Ba - 133 | 315 kBq |
| Pu | 5 g |
| U | 480 g |
| Pu shielded | 95 g |

Note: Pu means sample of highly-enriched Pu-239 and U sample of highly-enriched U-235.

- Cs-137 – 390 kBq: Relatively high detection threshold, indicating lower detection sensitivity compared with Co-60 under the specified conditions.
- Co-60 – 190 kBq: Lowest threshold among the gamma emitters listed, indicating the highest detection sensitivity.
- Ba-133 – 315 kBq: Intermediate detection threshold, with sensitivity lower than Co-60 but higher than Cs-137.
- Pu – 5 g: Very low mass detection threshold, indicating high sensitivity to the specified Pu source under the measurement conditions.
- U – 480 g: Highest mass threshold, indicating comparatively lower detection sensitivity for uranium.
- Shielded Pu – 95 g: Considerably higher threshold than unshielded Pu (5 g), demonstrating the significant effect of shielding on detection capability.

In Table 2, the characteristics of this type of RPM are described.

Table 2. Characteristics of Yantar 2 U RPM

| | | |
|---|---|---|
| Detection channels | | gamma, neutron |
| Gamma detector | | 2 plastics, 4.6 L each |
| Neutron detector | | 6 counters 0.6 L each |
| Parameters of the search area | Width | 6 m |
| | Height | 3 m |
| Speed of the controlled object | | 15 km/h |
| Power consumption | | 60 W |
| Operating temperature | | From -50°C to +50°C |
| Overall dimensions of a pillar | | 651x2073x300 mm |
| Weight | | 390 kg |

Note: Detection probability of the given masses of nuclear materials is 0.5 at level of confidence 95%, maximum background intensity 20 μR/h and maximum false alarm rate 1/1000.

- Detection channels: Combined gamma and neutron detection enables identification of a broad range of radioactive materials, including special nuclear material.
- Gamma detector: Two plastic scintillation detectors (4.6 L each) provide a relatively large detection volume for gamma radiation.
- Neutron detector: Six neutron counters (0.6 L each) improve the system's capability to detect neutron-emitting materials.
- Search area: A 6 m wide and 3 m high portal allows monitoring of vehicles and other controlled objects.
- Object speed: Detection is possible at speeds up to 15 km/h, supporting practical radiation monitoring at checkpoints.
- Power consumption: The relatively low 60 W consumption is suitable for continuous operation.
- Operating temperature: The –50°C to +50°C range allows deployment under severe environmental conditions.
- Dimensions and weight: The 390 kg weight and compact pillar dimensions provide a robust, stable structure suitable for fixed radiation-monitoring installations.

The Kakavija RPM system is shown in the following Figures 1 and 2.



Figure 1. Kakavija Yantar 2-U RPM




Figure 2. Control panel PVC-01

The RPM at the Kakavija BCP, located at the Albanian–Greek border, is operated by the Customs FLOs, who simultaneously perform other routine

customs procedures. The control and operation room of the RPM is shared with the Local Border Police.

The installed system consists of a Yantar-2U RPM, equipped with master and slave detection pillars, a telecommunication wallbox, and a video-monitoring unit. No additional supporting equipment, such as a dedicated operator workstation, has been installed; the only available component is the PVC-01 control panel (Figure 2).

During the site inspection, the system was tested using naturally occurring radioactive material (NORM) transported through the BCP [9], [10]. No alarms neither audio nor visual were triggered, confirming that the system had been non-functional for an extended period and had been kept shut down.

At the time of inspection:

- The main switch connecting the system to the mains power supply was set to the *off* position.
- The MAINS and BATTERY switches located inside each detection pillar were in the *on* position.

After reactivating the system, a second test was performed using the Institute of Applied Nuclear Physics (IANP) testing van with radioactive sources [2], [7]. The RPM generated an alarm signal only through the visual indicators of the master pillar, with no accompanying audible alarm.

The Yantar-2U RPM integrates multiple subsystems and constitutes a complete detection unit. For reliable operation, it requires trained personnel capable of:

- Recognizing both visual and audible alarms.
- Correctly interpreting alert signals.
- Applying appropriate response and follow-up procedures in line with established protocols.

The subsequent assessment phase was focused on identifying the causes of the system's failure and malfunctioning subsystems. This process followed a structured approach involving:

1. System monitoring and staff interviews to collect operational feedback.
2. Collection of environmental and site-specific data to assess outdoor physical conditions affecting system performance.
3. Observation of operator practices, including adherence to or deviation from recommended operational procedures.
4. Observation of traffic behavior (vehicles and individuals) passing through the detection area.
5. In-situ measurements and data logging, tracking changes in the electrical and electronic parameters of malfunctioning components over time.

## 3. Results and discussions

### *3.1. Malfunctioning devices and subsystems*

During the inspection, multiple system deficiencies were observed. The master pillar's sound alarm was found to be inoperative, with its wiring damaged and requiring replacement. Additionally, the data cable within the operator's workstation room had been severed, showing visible external damage along its length.

Although the system retained limited operational capability, its overall effectiveness was compromised. The radiation detection units continued to function; however, the lack of an audible alarm and a reliable communication link significantly hindered timely operator responses. As a result, critical radiation events could go unnoticed, increasing the risk of delayed intervention.

The condition of the damaged data cable suggested prolonged exposure to mechanical damages or environmental wear, highlighting the need for better cable protection and routing. With the sound alarm nonfunctional, operators were left dependent on visual cues or manual verification, complicating monitoring procedures and reducing situational awareness.

These findings underscored the urgent need for repairs and preventive measures to restore full system functionality, improve operator safety, and ensure compliance with operational and safety standards [6], [7].

### *3.2. Identification of failure factors*

The failure of the sound alarm was due to damaged wire connections, which rendered the alarm system non-functional. Similarly, data transmission failures were caused by a damaged protective channel along the cabling path, leaving the data cable exposed to environmental factors and mechanical risks from human activity, thereby increasing its vulnerability.

Another significant contributor to system malfunction was improper cable connectivity. The cabling did not align with the vendor's original schematics, likely due to previous maintenance performed by the Customs team that may not have strictly followed the manufacturer's technical guidelines. Despite these issues, the subsystems that were tested remained operational.

During system testing, both the Master and Slave pillars were powered, and communication cables between them were properly installed. However, it was observed that detector signals were being transmitted without processing, indicating additional gaps in system functionality.

Further root causes of the RPM's operational failure were identified:

- The physical protection around the pillars was inadequately installed, and no traffic control measures were in place at the RPM entrance, leaving the pillars exposed to potential collisions or damage.
- The central control panel (PVC-01M) was missing, preventing centralized alarm monitoring and management.
- Although the telecommunication wall box was installed and powered, it could not function due to the absence of an operator workstation or control panel to process or transmit alarms.
- The operator computer was absent, eliminating the ability to manage or monitor system alarms and data effectively.

- The camera system, while physically present and powered, could not be tested due to the lack of the operator computer required for control.
- Field tests revealed a malfunction in the gamma detector installed in the master pillar, further reducing the system's detection capability.

In summary, the system's failures resulted from a combination of hardware degradation caused by environmental exposure and wiring issues and operational deficiencies, including missing essential control and monitoring components [8]. Improper installation and maintenance practices further increased the system's unreliability. Comprehensive corrective measures are required to restore full functionality, including replacing damaged components, properly installing protective systems, restoring the control panel, and providing complete operator equipment, ensuring the RPM can operate reliably and safely [5],[6].

### *3.3. Repair of the RPM and testing*

Since 2021, an extensive program of maintenance, testing, and restoration has been implemented to ensure the system operates at full capacity and meets all operational standards. A key milestone was the successful re-establishment of the data connection between the slave and master terminal boxes, as well as the restoration of the communication link between the operator cabin's communication box and the master pillar. These actions restored reliable information flow across the system, which is critical for timely detection and response.

The slave pillar was thoroughly inspected, tested, and fully restored to operational condition. Its radiation detection functionality was confirmed, and information transmission to the PVC-01M control panel was verified. To enhance RPM performance, both the sound and visual alarm systems of the slave pillar were carefully adjusted, ensuring proper functionality under operational conditions.

Laboratory testing of the master pillar's gamma detector confirmed that the sensor remained undamaged. A minor electronic circuit defect was identified and corrected, restoring the detector to its full functional capacity. In parallel, both the master and slave pillars' audio and visual alarm systems were repaired, and preventive maintenance measures including the replacement of aging batteries were carried out. These actions were designed to guarantee long-term reliability and minimize the risk of future malfunctions. After repair the RPM background values were stable and it was tested using NORM materials passing through the BCP [4],[9]. The presence of NORM materials was confirmed also by using the Radioisotope Identification Device and Personal Radiation Detectors [10].

Overall, these restoration and preventive measures have significantly improved system performance, ensuring reliable radiation detection, proper alarm signaling, and uninterrupted communication between system components. The interventions also reinforced system flexibility, operator safety, and compliance with operational standards.

## 4. Conclusion

Based on the current technical status described above, the RPM is fully operational. To ensure greater system durability, the data cables were rerouted through protective channels connecting the master pillar, the slave pillar, and the operator workstation. This preventive measure aims to protect the cables from future physical damage.

Furthermore, a sound and alarm unit were fixed to enhance the system's detection and notification capabilities. A control panel (PVC-01M) was also installed to centralize the registration of all alarms and to fully restore system operability.

Following the restoration, it was recommended to operate the system using only the PVC-01M control panel. This configuration simplifies system usage, making it more intuitive and user-friendly for the Front-Line Officers (FLOs). The simplified setup enables immediate secondary inspections whenever a sound or visual alarm is triggered, significantly improving the response time.

Additionally, this approach reduces the potential for operator errors, lowers maintenance complexity, and is more cost-effective by minimizing the need for frequent replacement of spare parts. Overall, the interventions not only restored the RPM to full functionality but also optimized its operation for long-term performance, reliability, and ease of maintenance.

In conclusion, the system's communication, detection, and alerting capabilities were fully recovered, ensuring the safety and operational readiness of the equipment. Preventive actions, such as battery replacement and alarm system adjustment, have strengthened the overall resilience and extended the service life of the RPM. These interventions have significantly minimized the risk of future malfunctions and reinforced the reliability of radiation monitoring operations.

***Acknowledgements:*** *The authors are grateful to the International Atomic Energy Agency for the financial support in the implementation and realization of this study and its continuous support. Thankful General Custom Directorate, Tirana University and the Institute of Applied Nuclear Physics for supporting, the infrastructure and equipment's made available for this study.*

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

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