

Security of Industrial Radioactive Sources in Mining Sector: A Field Assessment of Practices

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Publication Date: 2026/03/14

Abstract: Radioactive sources are widely used in the mining industry for industrial process control, particularly in density gauges and analytical instruments. While these technologies provide significant operational benefits, they also introduce safety and security risks if the gauges and instruments get missing, stolen, or are improperly managed. International concern over the malicious use of radioactive material has increased attention to the security of sealed sources throughout their lifecycle. This study evaluates the security practices associated with radioactive sources used in Ghana's mining industry. A field-based assessment was conducted across seventeen mining facilities using radiation detection equipment, facility inspections, structured questionnaires, and interviews with facility personnel. The findings indicate that although most facilities maintain source inventories and general physical protection arrangements, important gaps remain in nuclear security culture, emergency and contingency preparedness exercises, continuous personnel reliability measures, and documentation of source movement. These gaps could increase vulnerability to loss of regulatory control of radioactive material. The study highlights the need for strengthened regulatory oversight, improved security training, enhanced record management systems, and greater integration of nuclear security culture into mining operations. The findings provide practical insights for regulatory authorities and operators seeking to strengthen radioactive source security in industrial sectors.

Keywords: Radioactive Source Security; Nuclear Security; Mining Industry; Cs-137 Gauges; Regulatory Oversight; Ghana.

How to Cite: Etornam Ann Mensah; Nelson Agbemava; Cyril Cyrus Arwui; Henry Lawluvi; Ernest Beinpuo; Kwame Appiah (2026) Security of Industrial Radioactive Sources in Mining Sector: A Field Assessment of Practices. *International Journal of Innovative Science and Research Technology*, 11(3), 692-697. <https://doi.org/10.38124/ijisrt/26mar617>

I. INTRODUCTION

Radioactive sources are extensively used in industrial applications, including mining, where they support material density measurement, process control, and analytical monitoring. In Ghana's mining industry, sealed radioactive sources, particularly Caesium-137 density gauges, are commonly used for operational measurements in mineral processing plants.

Although these sources provide significant technological advantages, they also pose safety and security risks if they are not adequately controlled throughout their lifecycle. The loss, theft, or unauthorized access to radioactive sources may result in radiation exposure incidents or the potential misuse of sources in malicious acts, including radiological dispersal devices [1,2].

Globally, the security of radioactive sources has become a core element of nuclear security governance. The International Atomic Energy Agency (IAEA) has emphasized

the need to protect radioactive sources against theft, sabotage, unauthorized access, and loss of control through a graded and risk-informed approach. This is reflected in the Code of Conduct on the Safety and Security of Radioactive Sources, Nuclear Security Recommendations on Radioactive Material and Associated Facilities (IAEA Nuclear Security Series No. 14), and guidance on radioactive material in use, storage, and transport.

Historically, many industrial users of radioactive sources have focused primarily on radiation safety and regulatory compliance rather than on dedicated nuclear security practices. However, international developments have made clear that safety and security must be addressed together if radioactive sources are to remain under effective regulatory control throughout their operational life [2,3].

In Ghana, the project team embarked on a national assessment programme to ascertain and evaluate security measures of radioactive sources used in the mining industry. The project was designed to identify vulnerabilities in source

management and provide recommendations to improve nuclear security practices in the mining industry.

This paper presents the findings of that assessment. It examines current security practices, identifies operational and governance gaps, and proposes measures for strengthening radioactive source security in Ghana's mining sector.

II. LITERATURE REVIEW

➤ *Global Security Concerns Related to Radioactive Sources*

Radioactive sources used in industrial and medical applications are generally sealed sources that emit radiation for measurement, treatment, or analytical purposes. Although such sources are designed for safe industrial use, they can pose significant risks if removed from regulatory control or improperly managed [1,4].

International experience has shown that orphan sources, defined as radioactive sources that is no longer under regulatory control, can lead to serious radiological accidents. The Goiânia accident in Brazil remains one of the most frequently cited examples of the severe health, environmental, and social consequences that can result from loss of source control [4].

The IAEA has developed several guidance documents to strengthen source security. These include the Code of Conduct on the Safety and Security of Radioactive Sources, Nuclear Security Series No. 14 Nuclear Security Culture Nuclear Security Series No. 7), and guidance on radioactive material in use, storage, and transport. These documents emphasize the importance of source inventory control, physical protection, personnel reliability, security culture, and effective regulatory oversight.

➤ *Nuclear Security in Industrial Sectors*

Industrial sectors such as mining, oil and gas, and manufacturing rely heavily on radioactive sources for process monitoring and material analysis. Unlike nuclear power facilities, these industrial environments often operate with less specialized security infrastructure, which may increase the vulnerability of radioactive sources to unauthorized access or theft [2,6].

Previous studies have shown that industrial facilities often prioritize operational efficiency and radiation safety compliance, while nuclear security receives comparatively less attention. This can produce weaknesses in access control, source accountability, personnel reliability, and incident reporting [6,7].

The integration of nuclear security culture into industrial organizations has therefore been identified as a critical factor in improving radioactive source security performance [5].

➤ *Nuclear Security Governance in Developing Countries*

Emerging nuclear countries often face additional challenges in implementing effective nuclear security frameworks because of limited regulatory capacity, resource constraints, evolving institutional structures, and uneven

operator awareness [3,8]. Under such conditions, regulatory bodies must simultaneously strengthen legal frameworks, build technical expertise, maintain national source inventories, and implement meaningful inspection programmes.

Strengthening source security governance in such environments requires coordinated efforts involving regulatory inspections, operator training, emergency and incident response planning, and international cooperation [3,8].

III. METHODOLOGY

A. *Study Design*

This study adopted a field-based inspection and assessment approach to evaluate radioactive source security practices in Ghana's mining industry. The methodology combined radiation monitoring, facility inspections, answering of structured questionnaires by facility staff, and interviews with facility personnel.

B. *Study Area and Facilities*

Mining companies across Ghana were visited during the assessment. Most of the facilities were located in the middle belt of the country. These companies operated nuclear gauges used for industrial measurement.

C. *Equipment Used*

Two primary radiation detection instruments were used during the field assessments.

➤ *Radiation Detection Backpack (ATOMTEX AT6101C).*

The backpack radiation detection system consisted of a gamma spectrometric detector using a NaI(Tl) scintillation crystal, a neutron detection unit, and a portable computer with ATAS Scanner Mobile software. The system measures gamma radiation within an energy range of 20–3000 keV and can identify naturally occurring radioactive materials (NORM) and artificial radioactive sources.



Fig 1 Radiation Detection Backpack (ATOMTEX AT6101C)

➤ *Personal Radiation Detectors*

Polimaster PM1703M-01 pagers were used during inspections. These devices detect gamma-emitting sources such as Cs-137, Am-241, and Co-60, with a dose-rate measurement range up to 9999 µSv/h.



Fig 2 Model PM1703M (PRD) Gamma Personal Radiation Detector

D. *Data Collection Procedures*

The assessment process consisted of four elements:

➤ *Security Questionnaire*

A structured questionnaire was administered to gather information on source inventory, hazard and vulnerability assessment, physical protection, source accounting, emergency and incident planning, personnel reliability, and information security.

• *Staff Interviews*

Interviews were conducted with management and operational staff to assess knowledge, perceptions, and institutional understanding of nuclear security practices.

• *Facility Inspections*

The project team conducted walk-down a walk-down observation of operational and storage areas where radioactive sources were installed and/or stored.

• *Environmental Radiation Monitoring*

Background radiation dose rate measurements were taken around source locations and across facility environments to establish baseline environmental radiation levels for such environments.

IV. RESULTS

➤ *Distribution of Radioactive Sources in Mining Facilities*

A total of seventeen mining facilities were assessed. These facilities collectively operated more than 100 nuclear gauges, primarily containing sealed Cs-137 sources used for density and level measurements in mineral processing plants with activities totalling up to 18.5 GBq.

Most of the assessed facilities were located in the center of the country reflecting the locations and the concentration of mining activities in the country.

➤ *Environmental Radiation Monitoring*

Environmental radiation measurements across all facilities showed background dose rates below 0.2 µSv/h. These values are consistent with normal natural background radiation levels and indicate that the installed radioactive sources were adequately shielded and did not contribute significantly to environmental dose outside operating locations.

➤ *Security Practice Assessment*

Answered questionnaires, interviews, and inspections (walk-downs) revealed uneven performance across the assessed security domains. Inventory management and basic physical protection were generally better developed than personnel reliability, emergency and incident preparedness, and security culture.

So we can have 4.3a: Security Practice Assessment from Observations.

Table 1 Summary of Security Practice Observations Across Assessed Mining Facilities

Security element	General observation
Source inventory management	Present in all facilities, though some source details were illegible or inaccessible
Physical protection systems	General facility security systems for access controls, intrusion sensing and surveillance were in place in most facilities
Personnel reliability measures	Recruitment screening present, but no continuous monitoring in most facilities
Security culture training	Basic awareness was evident, but not systematically embedded in operations
Emergency and Contingency preparedness exercises	Plans existed at all facilities, but nuclear security drills had never been conducted

The evaluation of Facility data in compliance with nuclear security regulatory requirements is tabulated below.

Table 2 Summary of Nuclear Security Regulatory Compliance Across Mining Facilities

Security Element	Facilities Compliant (%)	Facilities Partially Compliant (%)	Facilities non-compliant (%)
Source Inventory Management	88	12	0
Physical Protection Systems	76	18	6
Personnel Reliability Programmes	41	29	30
Security Culture Training	35	47	18
Emergency and contingency Preparedness Exercises	24	41	35
Source Movement Documentation	53	35	12

These outcomes (Table 1 and 2) indicate that inventory management and basic physical protection systems are generally well established across the mining facilities. However, personnel reliability programmes, security culture training, and emergency preparedness exercises show significantly lower compliance levels.

➤ *Identified Vulnerabilities*

Facility walk-downs and discussions with facility staff identified recurring vulnerabilities.

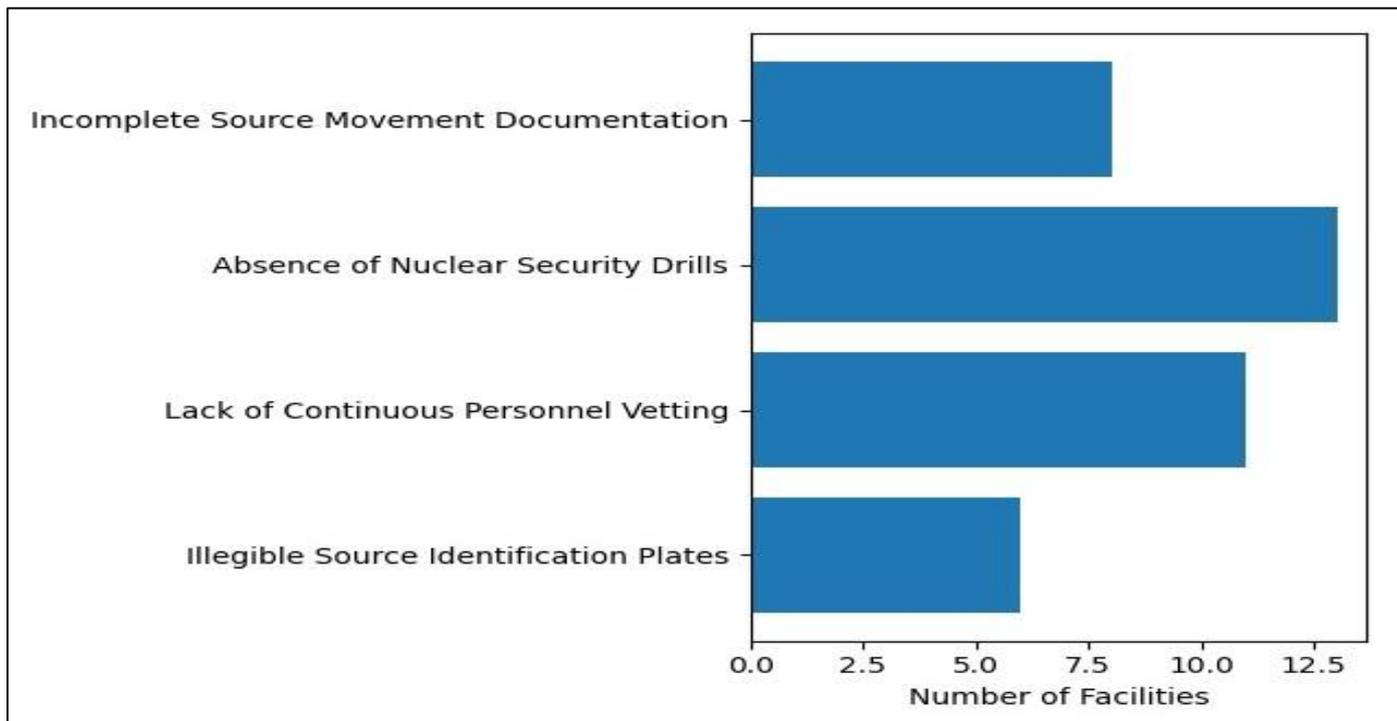


Fig 3 Observed Radioactive Source Security Vulnerabilities

The observed vulnerabilities affecting radioactive source security in the assessed mining facilities is graphically represented in Figure 1. The absence of nuclear security drills and lack of continuous personnel reliability monitoring were

the most frequently observed weaknesses. Table 3 considers potential security consequences that may results from these vulnerability outcomes.

Table 3 Identified Vulnerabilities and Potential Consequences

Vulnerability	Frequency observed	Potential consequence
Illegible source identification plates	6 facilities	Reduced traceability and verification difficulty
Lack of continuous personnel vetting	11 facilities	Increased insider threat risk
Absence of nuclear security drills	13 facilities	Delayed or ineffective response to nuclear security incident(s)
Incomplete source movement documentation	8 facilities	Source accountability difficulty and lost of regulatory control

V. DISCUSSION

The findings indicate that Ghana’s mining industry generally demonstrates stronger performance in radiation safety and basic industrial security than in dedicated nuclear security governance. This pattern is consistent with international observations that industrial operators often meet operational safety requirements while giving less systematic attention to malicious-threat scenarios [2,6,7].

A major finding is the distinction between general site security and source-specific security. Most facilities-maintained perimeter controls, surveillance, alarms, and guards. However, these systems were generally designed to

protect equipment, property, and personnel rather than radioactive sources specifically. IAEA guidance recommends a graded approach in which protection measures are proportional to the potential consequences of unauthorized access, theft, or sabotage [2,3]. Where radioactive sources are embedded in larger industrial systems, operators may assume that general plant security is sufficient, but such an assumption can overlook source-specific vulnerabilities.

The results also highlight important weaknesses in source accountability and traceability. Although source inventories were generally maintained, illegible identification plates and incomplete movement documentation indicate that accountability systems are not yet fully robust. This is

significant because effective inventory control is one of the central pillars of international source security. [1–3].

A second important vulnerability concerns personnel reliability. Recruitment background checks were common, but continuous monitoring of personnel reliability was not. This creates a gap in insider threat mitigation. International guidance increasingly emphasizes that authorized individuals may pose security risks if screening is static rather than ongoing [5]. In industrial settings, where staff turnover, contractor access, and operational pressures may be high, continuous personnel reliability measures are particularly important.

The findings also show that nuclear security culture remains relatively underdeveloped. Staff generally understood basic security principles, but security responsibilities were not always internalized as a distinct part of radioactive source management. This matters because weak security culture can result in complacency, underreporting, poor procedural discipline, and limited threat awareness [5].

The absence of nuclear security emergency exercises in most facilities is another significant gap. Although documented emergency and incident response plans existed, they had not been tested through drills or tabletop exercises involving theft, sabotage, or loss of control scenarios. Plans that are not exercised may be difficult to implement effectively during a real event. This gap suggests that emergency preparedness remains more formal than functional in many of the assessed facilities.

Overall, the findings suggest that source security in Ghana's mining sector is partially developed but unevenly institutionalized. The basic elements of source control are present, but important governance functions such as ongoing vetting, security culture, exercise programmes, and documentation discipline require further strengthening.

➤ *Study Limitations*

This study focused on mining facilities operating radioactive sources in Ghana and therefore reflects operational conditions and regulatory practices specific to the national context. The findings may not be fully generalizable to other industrial sectors or countries with different regulatory frameworks. In addition, part of the assessment relied on self-reported information from facility personnel, which may introduce response bias. Finally, the study assessed practices at the time of inspection and does not capture subsequent improvements that may have been implemented after the assessment period.

VI. CONCLUSION

This study evaluated the security practices associated with radioactive sources used in Ghana's mining industry. The findings show that while most facilities maintain acceptable radiation safety practices, source inventories, and general physical security arrangements, important weaknesses remain in nuclear security governance.

The most significant gaps identified include limited integration of nuclear security culture, absence of regular emergency and incident preparedness exercises, incomplete source movement and maintenance records, and lack of continuous personnel reliability measures. As the mining industry continues to expand and radioactive source use increases, strengthening these areas will become increasingly important for preventing loss of control of radioactive sources and supporting international nuclear security objectives.

RECOMMENDATIONS

There are several aspects of concern in a growing industry such as mining, thus the following recommendations are specific to such areas:

➤ *Strengthening Regulatory Oversight*

The national regulatory authority should enhance periodic inspections and adopt a risk-informed oversight approach, with particular attention to higher-activity sources and facilities with identified documentation or preparedness weaknesses.

➤ *Improving Source Accountability*

Operators should strengthen inventory systems through clearer labeling, updated source registers, and complete documentation of source movement, maintenance, and disposal.

➤ *Improving Nuclear Security Culture*

Mining companies should integrate nuclear security culture into organizational practice through regular awareness training, leadership engagement, and internal reporting mechanisms.

➤ *Enhancing Emergency Preparedness*

Facilities should conduct periodic drills and tabletop exercises covering loss, theft, unauthorized access, and other radioactive source security scenarios.

➤ *Introducing Continuous Personnel Reliability Measures*

Operators should supplement pre-employment checks with ongoing reliability measures proportionate to source risk and access level.

REFERENCES

- [1]. International Atomic Energy Agency. Code of Conduct on the Safety and Security of Radioactive Sources. Vienna: IAEA; 2004. (International Atomic Energy Agency)
- [2]. International Atomic Energy Agency. Nuclear Security Recommendations on Radioactive Material and Associated Facilities. IAEA Nuclear Security Series No. 14. Vienna: IAEA; 2011. (IAEA Publications)
- [3]. International Atomic Energy Agency. Security of Radioactive Material in Use and Storage. IAEA Nuclear Security Series No. 11-G (Rev. 1). Vienna: IAEA; 2019. (IAEA Publications)

- [4]. International Atomic Energy Agency. The Radiological Accident in Goiânia. Vienna: IAEA; 1988.
- [5]. International Atomic Energy Agency. Nuclear Security Culture. IAEA Nuclear Security Series No. 7. Vienna: IAEA; 2008. (IAEA Publications)
- [6]. Garcia ML. The Design and Evaluation of Physical Protection Systems. 2nd ed. Burlington, MA: Butterworth-Heinemann; 2008.
- [7]. Khan S, Haines R, Sheahan P. The interrelationship between safety and security in nuclear facilities. In: Proceedings of the International Conference on Nuclear Security. Vienna: IAEA; 2017.
- [8]. World Institute for Nuclear Security. Security Management of Radioactive Sources. Vienna: WINS; 2018.
- [9]. International Atomic Energy Agency. Establishing a National Nuclear Security Support Centre. IAEA Nuclear Security Series No. 21. Vienna: IAEA; 2015.
- [10]. International Atomic Energy Agency. Technical and Functional Specifications for Border Monitoring Equipment. Vienna: IAEA; 2006.
- [11]. Mensah EA, Adu S, Amoah PA, Adjei DN, Agalga R, Appiah K. Security of Radioactive Sources: Observations and Recommendations from the Mining Industry in Ghana. Technical Report 2015/RPI/NSSSC/TR No:001. Accra: Radiation Protection Institute, Ghana Atomic Energy Commission; 2015.
- [12]. World Institute for Nuclear Security. Insider Threat Mitigation. Vienna: WINS; 2019.