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Research Article

Identifying Factors for Reducing Radiation Accidents in Radiography Companies using a Data-Driven Approach

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Abstract

The present study aims to identify the factors influencing the reduction of radiation incidents in radiography companies using the Grounded Theory method. The research was conducted in an active radiography company located in Asaluyeh. The statistical population consisted of experts and specialists from the Ravesh Novin Radiography Company and university professors, including four academic experts and eleven professionals from the radiography field. Purposeful sampling was employed based on specific criteria. This qualitative study utilized a three-stage coding process according to Grounded Theory to analyze the data. Data collection was carried out using a structured questionnaire completed in collaboration with experts. The findings resulted in 93 final codes, which were categorized into 30 groups and ultimately distilled into five main dimensions. These dimensions represent the key factors effective in reducing radiation incidents in radiography companies. The results can assist managers and officials in improving safety processes and preventing radiation-related accidents. Moreover, the findings provide a foundation for developing practical solutions and effective management strategies in this field.

Keywords: Accidents, Radiography, Safety, Grounded Theory.

Highlights

- Application of Grounded Theory methodology for in-depth identification of factors reducing radiation incidents through qualitative data analysis.
- Use of three-stage coding within the Grounded Theory framework to extract precise codes and categorizations.
- Classification of factors into five key dimensions to enhance safety and reduce radiation accidents.
- Development of a management framework based on Grounded Theory findings to improve safety processes and accident prevention.

Citation: [in Persian].

1. Introduction

Industrial radiography, as updated by the International Atomic Energy Agency in 2024, is a widely used nondestructive testing method to detect defects in manufactured products such as castings and welded pipelines [1]. Radiation sources are produced by X-ray generators or sealed radioactive materials enclosed in small capsules, and the transmitted radiation is captured on films or detectors placed behind the object. Since its emergence in the early 1900s and significant growth during the 1940s with artificial isotopes like Cobalt-60 and Iridium-192, industrial radiography has played an important role in industries such as oil, gas, and petrochemicals [1]. However, as noted in IAEA reports, incidents involving radiation sources have occurred throughout history, often resulting in serious injuries or fatalities, particularly in countries lacking proper infrastructure for regulatory oversight and data collection [1]. Several studies and analyses have highlighted that the primary factors contributing to these accidents include insufficient use of radiation monitoring devices, improper maintenance or replacement of radiography equipment, poor management of safety and alarm systems, lack of clear recovery procedures, and weak communication with clients [3]. Moreover, other reports point to inadequate supervision, noncompliance with operational procedures, lack of operator training, equipment failures, design flaws, and even intentional violations as recurring causes [4]. Despite advancements in equipment design and safety systems, accidents still occur mainly due to human error and insufficient training [2, 5]. Given the critical consequences of unsafe use of radiation sources—from doses below threshold levels to fatal exposures—there is a strong research need to identify and analyze factors that can effectively reduce radiation-related accidents in industrial radiography companies.

2. Innovation and contributions

This research introduces a novel approach by applying the Grounded Theory Method to analyze and categorize the key factors influencing accident reduction in the field of industrial radiography. Unlike previous studies that have focused primarily on technical improvements or isolated training initiatives, this study comprehensively combines expert experiences, case studies, and literature analysis to develop an integrated model. The resulting framework offers practical recommendations for enhancing safety management systems, improving operator training, and establishing stronger supervisory practices. Ultimately, this study provides a structured, evidence-based tool for managers and safety professionals to systematically mitigate radiation risks in industrial radiography operations.

3. Materials and Methods

In this study, which employed a qualitative approach, the factors contributing to the reduction of radiation accidents in radiography companies were identified using the Grounded Theory method. The research was conducted in an active industrial radiography company located in Assaluyeh. Initially, through a comprehensive literature review of recent articles and books related to industrial radiography, the required variables were extracted. Then, to identify the factors reducing radiation accidents, a three-step coding process within the Grounded Theory framework was carried out. Qualitative data were collected through exploratory, semi-structured interviews where predetermined questions were posed equally to all participants, allowing them to freely express their perspectives on the study topic. Following the interviews, additional survey methods were used to validate expert opinions and propose preventive strategies. The research population consisted of experts and specialists from the Roshnovin Radiography Company as well as university professors—specifically, four academic specialists and eleven industry experts. A purposive sampling technique was used to select participants, ensuring that those chosen had the most relevant knowledge about radiation accidents. Data collection relied on unstructured interview questionnaires, and the analysis was performed using Grounded Theory. Compared to other statistical methods, Grounded Theory offers significant advantages, as it enables researchers to discover concepts and develop conceptual models directly from qualitative data without relying on pre-existing theoretical frameworks. Unlike statistical methods that require an initial model and predefined hypotheses, Grounded Theory adopts an inductive approach, making it highly suitable for exploratory studies. Additionally, its flexibility in data analysis helps achieve a deeper understanding of complex human and social phenomena, which makes it especially valuable for research aimed at theory generation or uncovering hidden patterns.

4. Results and Discussion

As evident from the results, data analysis using axial coding led to the extraction of 93 sub-components categorized into 30 groups, which were ultimately classified under five main dimensions: causal conditions, contextual conditions, intervening conditions, strategies, and outcomes. Together, these dimensions represent the dependent variable of the study, namely the identification of factors influencing the reduction of radiation accidents in radiography companies using the grounded theory approach in the company under study. The findings reveal that the central phenomenon, i.e., the occurrence of radiation accidents, is influenced by a set of various conditions and factors. Through the implementation of control strategies, it is possible to achieve positive outcomes such as improved safety and health, enhanced organizational performance, better economic and social

results, and reduced environmental impacts. Key strategies include strengthening specialized training, promoting a safety culture within the organization, utilizing advanced monitoring and control technologies, strictly enforcing safety standards and regulations, and conducting continuous inspections. These results highlight the importance of synergy between managerial, technical, human resource, and legal support factors for effective safety management in the industrial radiography sector.

5. Conclusion

Reducing radiation accidents in industrial radiography companies requires a comprehensive, multidimensional approach that integrates advanced technologies, specialized training, safety management, stringent regulations, and process improvements. Effective measures include the use of intelligent leak detection systems, radiography robots, modern protective equipment, virtual reality training, artificial intelligence applications, simulation, alternative imaging methods, and digital monitoring systems. Moreover, fostering a strong safety culture, encouraging employees to follow protective practices, developing specific guidelines, and promoting collaboration between industry and research centers are crucial for sustainable safety. Addressing causal conditions across technical, managerial, educational, supervisory, and cultural dimensions is essential, such as ensuring equipment quality, managerial commitment, continuous staff training, safety monitoring systems, and strict law enforcement. Contextual factors like management policies, regulatory oversight, financial support, standardized equipment, and environmental design also play foundational roles. Intervening factors—such as legislation enforcement, economic conditions, technological access, organizational culture, and stakeholder cooperation—can either facilitate or hinder safety efforts. Coordinated strategies encompassing legal, technical, educational, cultural, and managerial actions are necessary to enhance safety and reduce ionizing radiation risks. The positive outcomes of these efforts span human health, economic savings, organizational performance, social reputation, environmental protection, and legal compliance. This study's findings align with and complement previous research by emphasizing not only technical and human factors but also managerial, cultural, and regulatory dimensions, thereby offering a holistic framework for improving radiation safety in industrial settings.

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