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ASSESSMENT OF RADIATION SAFETY MANAGEMENT SYSTEM IN A VOCATIONAL INSTITUTION INDONESIAN POLYTECHNIC OF NUCLEAR TECHNOLOGY X

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List of Abbreviations

BAPETEN	: Nuclear Power Supervisory Agency
DLV	: Dose Limit Value
IAEA	: International Atomic Energy Agency
ICRP	: International Commission of Radiation Protection
ILO	: International Labour Organization
LH	: License Holder
NDT	: Non-Destructive Test
OSH	: Occupational Health and Safety
PPE	: Personal Protective Equipment
RPO	: Radiation Protection Officer
RW	: Radiation Worker
TLD	: Thermoluminescent Dosimete

ABSTRACT

Introduction: Occupational safety and health (OSH) are activities to guarantee and protect the safety and health of all workers through efforts to prevent work accidents and work-related diseases. Indonesian regulation concerning the OSH management system state that every company must implement this system in the work area, particularly nuclear facilities, which have a high potential danger level. **Objective:** The study aims to assesss the efficacy of a radiation safety management system as an effort to protect academic citizens, society, and the environment from the effects of radiation. **Methods:** This case study used a qualitative descriptive method, including observation, interviews, and document analysis on implementation of radiation safety management requirements in accordance to the prescribed regulations. **Result:** The result shown that the institute implemented radiation safety management requirements in accordance to the regulations and international guidelines. **Conclusions:** The radiation safety management system at the institute complies with Indonesian regulations, Indonesia Nuclear Energy Regulatory Agency regulations, and the International Atomic Energy Agency guidelines which require comprehensive evaluation to ensure adequate radiation protection and safety management implementation. Ensuring the everyday radiation culture reduces the risks in disaster situations.

Keywords: management system, radiation safety, radiation hazard, institution, safety culture

INTRODUCTION

The International Labor Organization (ILO) states that every day there are about 6,000 work accidents that cause workers to die. This is proportional to the death of one person every 15 seconds or 2.2 million people per year affected by occupational diseases and accidents. The data also states that from 2016-2018 there have been 395,512 cases of work accidents. In 2018 there was the highest number of accidents with 173,105 cases of accidents (1). Data from the Indonesia Ministry of Manpower in the first quarter of 2018 noted that there was an increase in work accident cases of 5,318 with 87 workers dying, 52 with disability, and 1,361 other workers recovering after medical treatment due to accidents (2).

Educational institutions are similar to companies, due to the number of complex human resources and potential sources of hazards and risks. The Nuclear Polytechnic X is a vocational institution that aims to improve professional and educated human resources in the field of nuclear technology. This institution operates under the Indonesian National Research and Innovation Agency, offering graduates a bachelor’s degree in applied engineering. The program’s outcomes include certifications in radiation protection and industrial radiography operator, which serve as valuable credentials to enhance employment prospects. Vocational education providers must also provide a safe, healthy learning, and work environment for the academic citizens and educational staff. Safety culture should be manifested by effective OSH procedures to minimize risk (3).

The head regulation of Indonesian Regulatory Agency No. 4 of 2013 aims to foster a safety culture in nuclear facilities, optimize radiation protection and exposure limitation, improve qualifications, and minimize biological effects through training. Radiation effects can manifest as stochastic, deterministic, somatic, and genetic effects arising from workers (4). These effects may range from radiation illness and malignancies to hereditary diseases due to prolonged exposure to low-level external radiation (5).

The radiation safety management system is considered for comprehensive understanding and assessment, particularly in educational institutions that utilize ionizing radiation sources and radioactive materials for education, training, and research purposes. The research questions are:

1. What are the management system requirements at Polytechnic of Nuclear Technology X?
2. What protection requirements are implemented at Polytechnic of Nuclear Technology X?
3. What are the technical requirements at Polytechnic of Nuclear Technology X?
4. How is safety verification conducted at Polytechnic of Nuclear Technology X?
5. How are radiation protection and safety programs developed and implemented at Polytechnic of Nuclear Technology X?

Radiation safety and protection play a highly significant role in the utilization of nuclear energy. A review is crucial to assess how the programs of the radiation safety management system are implemented. The study aims to analyze the efficacy of a radiation safety management system as an effort to protect academic citizens, society, and the environment from the effects of radiation.

METHODS

The research used qualitative methods with descriptive type. The data were collected with observation, in-depth interviews, and document analysis. The research was conducted from August to October 2022. The samples were selected using non-probability sampling, specifically purposive sampling techniques. The research population was technical implementation unit principals, laboratory principals, Radiation Protection Officer (RPO), representatives of students, and radiation workers. The sample size was selected based on the criteria determined with 19 informants participating in this qualitative research.

Investigation of variables included management requirements, radiation protection requirements, engineering requirements, safety verification, radiation protection, and safety programs. The variables data analyzed are based on regulations set by the government, regulators agencies, and international recommendations. Ethical approval was obtained by the

Medical and Health Research Ethics Commission of the Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Indonesia (Ref No: KE/FK/1098/03/10/2024EC/2022). The informants have signed the informed consent form to participate in the research.

RESULTS

The radiation safety requirements met by the institute encompass radiation safety management requirements, radiation protection requirements, technical protection requirements, safety verification, radiation and safety programs in compliance with the Indonesian government regulation and the Indonesia Nuclear Energy Regulatory Agency.

Radiation safety management requirements

Radiation safety management involves a comprehensive set of requirements, including a radiation safety officer, safety culture, health monitoring, personnel, education and training, records or reports. Radiation safety management requirements refer to Indonesian Government Regulation No. 33 Year 2007, Bapeten Regulation No. 7 Year 2009, Bapeten Regulation No. 6 Year 2010, Bapeten Regulation No. 4 Year 2013, Bapeten Regulation No. 16 Year 2014, and Bapeten Regulation No. 3 Year 2020. The components of the radiation safety management requirements identified are figured in Table 1.

Table 1. Radiation safety management components

Components	Findings
Radiation safety	License holder officer as the safety radiation responsible
Safety culture	The challenge in implementing a safety culture at the institute involves enhancing self-awareness to be implemented.
Health monitoring	Conducted before and during employment
Radiation personnel	RPO, RW, Operators, Experts, and/or Medical Personnel
Education and training	Conducted at least once a year
Report and documentation	Archived for 5 years with RW dose records are kept for 30 years

Source: Arifin et al., 2025

Radiation protection requirements

Implementation of radiation protection is an essential element that is the basis for development a radiation safety management system. These radiation protection elements are justification, optimization, and dose limitation. The justification element emphasizes that the advantages of using nuclear power outweigh the potential radiation risks. The utilization of nuclear power in the institute is primarily aimed at supporting learning and educational activities. Industrial radiography using ionizing radiation and radioactive materials is employed for student training in Non-Destructive Test (NDT) to inspect material structure and quality.

The optimization component ensures that radiation workers at the institute receive the lowest possible exposure. This principle involves establishing and implementing the dose limit values for radiation workers, ensuring these limits are not exceeded. The principle of radiation protection and safety optimization at the institution sets a dose limit for radiation workers (RW) ensuring it does not exceed 18 mSv/year.

The dose limitation element scientifically enforces the dose limit value established by the Head of the Nuclear Energy Regulatory Agency, ensuring that these limits are not exceeded under normal operating conditions. The License Holder (LH) ensures dose limits are not exceeded by conducting radiation exposure measurements and monitoring. Table 2. presents the radiation exposure monitoring equipment.

Table 2. Radiation exposure monitoring equipment

Equipment	Findings
Survey-meter	Calibrated for alpha, beta, and gamma radiation, is used to measure radiation exposure rates, while the neutron source surveymeter is under maintenance.
TLD Badges	Calibrated dosimeters are available and consistently used by students when working in radiation fields.
Personnel dosimeters	TLD Badges for employees and RW

Source: Arifin et al., 2025

Engineering protection requirements

The radioactive source storage or boom pit for the gamma camera is located underground (boom pit) at a depth of 95 centimeters with a total width of 80 centimeters. The top cover of the boom pit is constructed using lead (Pb) and iron material, which significantly reduces contamination and radiation exposure levels for workers and society. The exposure rate of the irradiator and industrial radiography building which was taken at a distance of 1 meter from the shielded radiation source, showed 0.1 μSv/hour.

The interview results indicate that the technical requirements for the building facility have successfully minimized the potential for contamination and radiation exposure hazards, ensuring a safe environment for workers and the general public. The technical requirements for ionizing radiation sources and radioactive materials, based on the Indonesian regulatory agency No. 7 of 2009, are reviewed in Table 3.

Table 3. Industrial radiography engineering requirement

Radiation sources	Components	Findings
Ionizing radiation sources	Tubes`	Tube is per the standard
	Diaphragm and Filter	Available and used
	Radiation leakage does not exceed 10 mGray / hour at a distance of 1m	Radiation leakage does not exceed the standard
	The generator tube has a stable system	Secured on a table with a support system to prevent it from collapsing, sliding, or vibrating during operation
	Control panel	Contains radiation hazard labels, key switches, on/off switches, and indicators showing voltage and current strength
Radioactive sources (Gamma camera)	Secure and lock the divider	Gamma cameras are given a strong barrier and locked in a special room
	Radiation level outside the storage area	Radiation level measurement outside the storage area of 0.1 μSv / hour
	Monitoring by Radiation Protection Officer (RPO)	Monitoring is carried out by Radiation Protection Officer (RPO) Personnel
	Radiation sign	Clear radiation markings have been given
	Equipment placement	Radiographic equipment is positioned in a safe location, away from sources

Source: Arifin et al., 2025

The technical requirements for the use of irradiation are based on regulatory agency No. 3 of 2020, with the results detailed in Table 4.

Table 4. Irradiator engineering requirement

Utilization	Requirements	Findings
Category I Irradiator	Room	A stable foundation that can support the weight of the irradiator equipment
	Design	An interlock safety system and a containment area for radioactive substances

Source: Arifin et al., 2025

Safety verification

Safety verification is differentiated by the type of nuclear power utilization according to the regulations set by the regulatory agency. Table 5. presents the findings of the safety verification for industrial radiography.

Table 5. Safety verification industrial radiography

Radiation sources	Components	Findings
Ionizing radiation sources	Radiation exposure monitoring	The radiation exposure rate of 1.65 μSv/hour
	Inspection of the condition of radiographic and supporting equipment	There were connections between equipment and cables
	Physical inspection of high-voltage tubes and cables	Assessment of physical conditions of the tube as specified
Radioactive sources (Gamma camera)	Radiation exposure monitoring	The measurement of radiation exposure rate in the boom pit of 1.39 μSv/hour
	Inspection of the condition of radiographic and supporting equipment	Warning labels and connections between equipment and cables are available
	Radioactive leakage test	Contamination level below 185 Bq

Source: Arifin et al., 2025

Radiation protection and safety programs

The radiation and safety programs outline the management responsibilities in this element based on the nature and severity of the risk. Radiation protection and safety programs are subject to periodic development by situations and conditions. Table 6. presents the findings of the radiation protection and safety programs.

Table 6. Radiation protection and safety program

Components	Findings
Radiation protective equipment	Equipment used to protect workers
Determination of work area	The work area has been divided into supervision and control areas under the regulation
Radiation exposure monitoring	Monitoring of the external radiation exposure and contamination
Dose constraint determination	The dose constraint is determined at 18 mSv/year
Environmental radioactivity monitoring	The institution's environment is in the Yogyakarta Nuclear Area where it has a team that monitors and measures the level of radiation exposure in the environment.
Emergency management plan	An emergency response document, along with designated personnel, and the implementation of emergency drills.

Source: Arifin et al., 2025

DISCUSSION

The radiation safety management system implemented by the institution has been aligned with several requirements and international recommendations. However, some findings should be addressed regarding the implementation of radiation safety and protection by RW and the civitas academic.

Radiation safety management requirements

The safety management requirements comprise six components: radiation safety officer, safety culture, health monitoring, personnel, education and training, and documentation. Implementation of radiation safety in the institution has been organized from the top level to the technical management. The results indicated that two components require more comprehensive follow-up, which are safety culture and health monitoring.

Safe work behavior should be a culture adopted by every element at the institution, including students with play a role in shaping a safety culture. The safety culture potentially has an impact on the academic community environment in embodying the culture instilled by leadership. Effective management commitment to safety will influence the level of safety compliance that will enhance the safety culture (6). Management of an institution's commitment to implementing a safety culture must mediate the relationship between safety motivation, awareness, and employee competence and safety behavior. Management commitment can influence personnel behavior in supporting workers to adopt safe working practices (7).

Lawrence Green's theory, an individual's behavior is influenced by three factors, one of which is reinforcement, with supervision being a form of reinforcement. Supervision of the use of PPE is one example of reinforcement, where activities or guidance are provided so that safety can be achieved (8). The radiation safety management requirements have been appropriate with the regulations by the Indonesian Government, Indonesia Nuclear Energy Regulatory Agency, and several international recommendations, with the research findings should be comprehensively reviewed which safety culture and health monitoring.

The radiation safety management requirements have been implemented in alignment with the findings of interviews, document analysis, and observations. However, several components have to be evaluated.

Radiation protection requirements

Radiation protection comprises three aspects according to the Indonesian regulations and ICRP recommendations: justification, limitation, and dose optimization. Radiation protection aims to prevent non-stochastic effects and limit the possibility of stochastic effects to an acceptable level (9). The principle of justification in practices involving radiation exposure is fundamental to radiation protection, ensuring that benefits outweigh risks to protect both RW and the public (10). The interview findings indicate that justification processes are based on assessing greater educational benefits and are reported to regulatory bodies for nuclear energy utilization permits, aligning with justification protection principles required by regulations and international recommendations. Observations confirm that all uses of ionizing radiation sources and radioactive materials are primarily for educational purposes, including industrial radiography. The principle of justification is fundamental in radiation protection, aimed at preventing unnecessary radiation exposure to protect RW and the public (11).

Dose limitation is implemented by adhering to the DLV set by the Indonesia regulatory agency, which is 20 mSv per year on average, with not exceeding 100 mSv over 5 years for RW. If the dose limit is uncontrolled, it can accumulate a dose that drastically reduces the number of lymphocytes (12). The study document at the institution shows that the evaluation of individual dose monitoring by TLD at the laboratory has a three-month frequency, which remains below the established DLV. Enhancing radiation protection to minimize the radiation dose received by radiation personnel as much as possible, despite the current low dose levels, which can still have future radiological effects (13). The control of radiation exposure levels for RW during activity utilization must not exceed the limit by using the principles of distance, time, and radiation shielding or PPE (14). The standard for PPE requires the use of lead-based materials, including aprons, goggles, gonad shields, thyroid shields, and gloves, and radiographers and RW must comply with the law in using these PPE (15). Radiation PPE such as lead aprons and thyroid shields can significantly reduce radiation exposure for operators utilizing ionizing radiation source (16).

The optimization principle is implemented by setting dose limit values (dose constraints) established by the License Holder (LH) with approval from the head of regulatory authority. The institution's dose constraints value was already set, adhering to the As Low As Reasonably Achievable (ALARA) principle, aiming to minimize radiation exposure to the lowest achievable level. The ALARA is designed to ensure that all measures for reducing radiation exposure are seamlessly integrated into the use of nuclear energy, serving as the cornerstone of radiation protection. It aims to minimize the possibility of exposure, the number of exposed individuals, and the individual dose to the lowest achievable level (17)(18).

Engineering protection requirements

The facilities of the institutions are designed to minimize the potential hazards of contamination and radiation exposure. The measurements indicate that the average radiation exposure rate is below the specified value at a distance of 1 meter from outside the facility buildings. Industrial radiography with radioactive substances requires equipment storage facilities. These facilities must be designed to meet specific requirements, including strong and locked barriers, radiation levels outside the storage area not exceeding 0.5 μSv/hour, monitoring by an RPO, proper radiation signage, and orderly equipment placement. Gamma cameras must be placed in a special room (boom pit) with strong, locked barriers, and access control restricted to authorized personnel only.

The utilization of Category I irradiators requires a room with a stable foundation and controlled access for authorized personnel, with building construction based on risk analysis to manage ozone gas release through ventilation. Engineering requirements include radiation warning signs, and the irradiator system's design ensures radioactive materials are enclosed, minimizing contamination and radiation exposure risks (19) (20). The building is equipped with security measures to prevent sabotage and unauthorized access, including Close Circuit

Television (CCTV) and alarm systems, which comply with the requirements of the Indonesian regulatory agency No. 3 of 2020 on Radiation Safety in the Use of Irradiators for Irradiation.

Safety verification

The assessment of the safety verification is conducted by measuring the radiation exposure rate in each institution laboratory to identify any potential or normal exposure. The identification of potential exposure considers possible source accidents or equipment failures and includes monitoring worker health monitoring, while radiation exposure rate measurements determine the duration of both intentional and accidental exposure from external and internal sources (21)(22). The radiation exposure monitoring was conducted using an environmental survey meter, which measured the radiation rate at the gamma camera storage area to be 1.39 μSv/hour, still below the established dose limit and dose constraint values. The Ir-192 gamma camera passed the radioactive contamination test with a value below 185 Bq. The industrial radiography process utilizing ionizing radiation sources requires radiation exposure monitoring around the installation, with the logbook study revealing an average radiation rate of 1.65 μSv/hour at 160 kV, still below the established dose limit and dose constraint values.

The gamma camera has been inspected and tested for safety, including key system testing, connection checks, and radiation exposure measurements, ensuring compliance with regulations and safety standards. The results show that the camera can be safely used for radiography processes, with all cables and guide tubes functioning properly and radiation levels within acceptable limits. Components of the safety verification process, based on observations and document studies, comply with Indonesian regulation No. 33 of 2007, Indonesia regulatory agency No. 7 of 2009, and No. 3 of 2020. The interview results show that the safety verification components have been reported to the regulatory body and the records of the verification results have been properly stored by the radiation safety team.

Radiation protection and safety programs

The radiation protection and safety program includes radiation protection equipment, delineation of work areas, radiation exposure monitoring, dose limit setting, environmental radioactivity monitoring, and emergency response planning. The aspect of radiation protective equipment and tools involves inspecting the availability and suitability of equipment, which is used based on the type of nuclear energy utilization and has a high quality, with evidence of individual radiation exposure measurements showing very low doses. The use of PPE is crucial for mitigating stochastic and deterministic health effects from ionizing radiation sources, emphasizing the importance of proper and consistent use supported by availability and proficiency in applying PPE procedures (23)(24).

The work areas are classified into supervision and control zones, each with specific hazard potentials requiring monitoring by authorized teams and personnel. Zone delineation at the institution is adhering to regulations outlined in Regulation No. 4 of 2013. Regular monitoring of work areas, including radiation source-specific and individual dose assessments, is a crucial aspect of radiation protection programs in nuclear energy applications, ensuring compliance with safety regulations by authorized personnel (25)(26). The findings from a document study on the applications of nuclear energy utilization indicated that personnel were exposed to an average radiation dose of 1.62 mSv/year, significantly below the established DLV. Radiation exposure monitoring is conducted to assess the implementation of radiation safety measures, which have been successfully executed.

The interview results indicate that environmental radiation monitoring is conducted in the nuclear area due to the significant potential for radiation exposure in the nuclear reactor section, with the study having limitations in environmental radiation monitoring components due to the secrecy of the monitoring documents managed by the nuclear area team, which are not publicly accessible. Environmental radioactivity monitoring aims to assess and minimize potential negative impacts from inadequate nuclear safety practices, including releasing radioactive materials into the environment, which could lead to radioactive contamination. Monitoring covers air, water, soil, and biota, due to identified high-risk areas near the nuclear reactor. Radionuclides present in the environment can pose a risk to humans if not handled promptly and properly, as they can enter the human body through ingestion (plants, meat, animals), inhalation, or open wounds, leading to internal or external radiation exposure if not managed effectively (27).

Minimizing workplace accident risks in OSH is achieved through various efforts to mitigate and minimize risks by controlling hierarchies and conducting risk assessments. The document study on emergency response covers accident classification, emergency procedures, equipment maintenance, and response simulations. Emergency preparedness simulations involve stakeholders coordinating effectively in nuclear emergency control and response, conducted regularly every two years, ensuring workers are trained to manage emergencies swiftly. The training/simulation provided to workers aims to equip them to handle emergencies quickly and effectively (28).

LIMITATION

The limitations of this research include, that the review was conducted by comparing national regulations and international recommendations. The study specifically focused on the application of nuclear power utilization in industrial radiography and irradiators. For the disaster health management purpose of this journal, the fundamental educational policy in a vocational institute is very important. This study clarified the importance of non-healthcare education in increasing the safety culture in this area.

CONCLUSION

The institution has implemented radiation safety management requirements following Indonesian regulations, nuclear energy agency regulations, and international guidelines from the IAEA. The institution's commitment to radiation protection is underscored by stringent adherence to international safety standards and continuous improvement through periodic assessments and training programs. Ensuring the everyday radiation safety culture reduces the risks in disaster situations.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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APPENDIX A

Figure 1. Radiation measurement

Source: Arifin et al., 2025

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