Implementation of Job Safety Analysis as Risk Assessment of X-Ray Radiography on Radiography Laboratory National Research and Innovation Agency

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Abstract. The usage of ionizing radiation (radioisotopes and radiation generating equipment) is developed each year worldwide for various industrial applications such as non-destructive test radiography for industrial examinations. Industrial radiography is one of the important and indispensable applications of ionizing radiation, where radiation sources are used to find out any defects in the weld joints or castings. The work systems and work processes on that application on National Research and Innovation Agency will cause a lot of potential hazards and risks such as the use and operation of machinery, equipment, and chemical materials. Some of the worker activities event on preliminary observations when the X-Ray Industrial Radiography operates, and in the darkroom, may cause radiation accidents which is leading to various biological effects. This study aimed to describe the potential hazards and risk assessment by using Job Safety Analysis (JSA) obtained based on direct interviews and observations and provide recommendations on the control of hazards in accordance with the standards. All the potential hazards resulting from each stage of operation were identified and the consequences were mapped. The hazards analyzed followed a semi-quantitative method. As a result, potential hazards are controlled and the safety of workers is fulfilled.

Keywords: *radioisotope, radiation, radiography, Job Safety Analysis, semi-quantitative.*

INTRODUCTION

Radiography inspections are being great demand and have been used worldwide for a lot of contributions. At pipe plants, radiography is used to detect the defect in the weld, in rocket industries radiography is used for checking the crack in the propellant, casting, and other main components [1]–[3]. Radiography testing is also reliable as a quality control and assurance method. Detection defects in the early stage can eliminate the failure and financial loss [1], [2], [4]. Besides detecting the flaw at an early stage, radiography also can use to control the quality of the material from time to time, that is why radiography tests become one of the methods in aging management in some materials [4].

X-Ray Radiography Laboratory of Indonesia National Research and Innovation Agency (BRIN) has three functions i.e., research laboratory, testing laboratory, and laboratory center for personnel certification. Due to the high demand, the laboratory is almost busy every day. In July 2022, X-Ray Radiography teams have done checking the aging management in nuclear research reactor G.A. Siwabessy in Serpong, South Tangerang. The work system and process during radiography testing will cause potential hazards and risks that will harm the worker. That is why an overall assessment needs to be done to minimalize the hazards. To prevent work accidents, in this research Job Safety Analysis (JSA) and semi-quantitative methods were applied.

JSA is a qualitative risk assessment method that is usually applied for identified hazards. This method integrates safety and health principles in every step of the job. In JSA, the basic step is to identify the potential hazards and give recommendations on the safest way to do the job. This method followed principles in ISO 31000 with a simplified approach. To develop the JSA method, analysis, and discussion that gather all the laboratory personnel needs to be done [5]–[10].

For assessment of the risk, a semi-quantitative method has been applied in this research. This method is reliable for early warning and planning the scheme for controlling the hazards in all steps of the radiography operation [11]. Semi-quantitative using risk matrix to set the degree of the hazards [10], [12].

By combining JSA and semi-quantitative methods, this research aims to fulfill the safety of the worker by obtaining the risk value, level of the risk, and recommendations for controlling the risk.

METHOD, DATA, AND ANALYSIS

1. Method

The scope of the research was for identified and controlled the risk in the x-ray radiography process. The research population was all the radiography personnel in the radiography laboratory. Data collection was accomplished with the Forum Group Discussion (FGD) method. the hazards identification followed the step in the JSA method. The assessment of the risk follows a semi-quantitative method.

2. Data and Analysis

1. Job Safety Analysis Process

The job Safety Analysis process followed the steps:

1. Identified and analyzed the risk

Identification and analysis of the risk were conducted by FGD with the population of all members of the radiography Laboratory.

2. Breaking the Job

After identifying and analyzing all the risks, the next step is breaking the job. Based on the result of FGD, the working process in the radiography laboratory is divided into three steps, i.e., Pre-operating, operating, and post-operating. Based on the job that has been breaking, the data of risks were inputted in the JSA Form.

2. Semi-quantitative Method

The semi-quantitative method followed the steps:

1. Value the Risk Level

The value of risks can be obtained by calculating the multiplication of Probability (P), Exposure (E), and Consequence (C). the value of P, E, and C followed by the result of the FGD and the classification from previous researchers [13].

Table 1. Accident occurrence probability criteria.

Category	Description	Score
Almost certain	Frequently occurs	10
Likely	Several times occur with a probability of 50:50	6
Unusually	Occasionally occurs	3
Remotely Possible	The probability of occurrence is very low	1

Conceivable	The occurrence probability is very low and rarely happened although getting exposure for years	0,5
Practically Impossible	The occurrence probability never happens	0,1

Table 2. Exposure occurrence criteria.

Category	Description	Score
Continuously	Occurred many times daily	10
Frequently	Approximately once daily	6
Occasionally	Once a week to once a month	3
Infrequent	Once a month to once a year	2
Rare	Has been happened but don't know when	1
Very rare	Rarely happened	0,5

Table 3. Consequence occurrence criteria.

Category	Description	Score
Catastrophic	Fatal and very severe damage, cessation of activities, and very severe environmental damage	100
Disaster	Accidents related to death, as well as minor permanent damage to the environment	50
Very Serious	Permanent disability or disease and temporary damage to the environment	25
Serious	Serious injury but not a permanent severe disease and little impact on the environment	15
Important	Injuries requiring medical treatment, offsite emissions occur but do not cause damage	5
Noticeable	Minor injury or illness, bruises on body parts, minor damage, minor damage, and temporary cessation of work processes but do not cause off-site pollution	1

Table 4. Consequence occurrence criteria.

Risk Level	Category	Action
>350	Very high	The activity is stopped until the risk can be reduced to an acceptable limit

180 - 350	Priority 1	Need control as soon as possible
70 - 180	Substantial	Requires technical improvement
20 - 70	Priority 3	Need to be monitored and noticed on an ongoing basis
< 20	Acceptable	The intensity that poses the risk is reduced to a minimum

2. Evaluate and Control the Risks

Based on the value of the risk and the risk priority, the control measures were recommended. This result will be a reference for all the laboratory personnel in the next project.

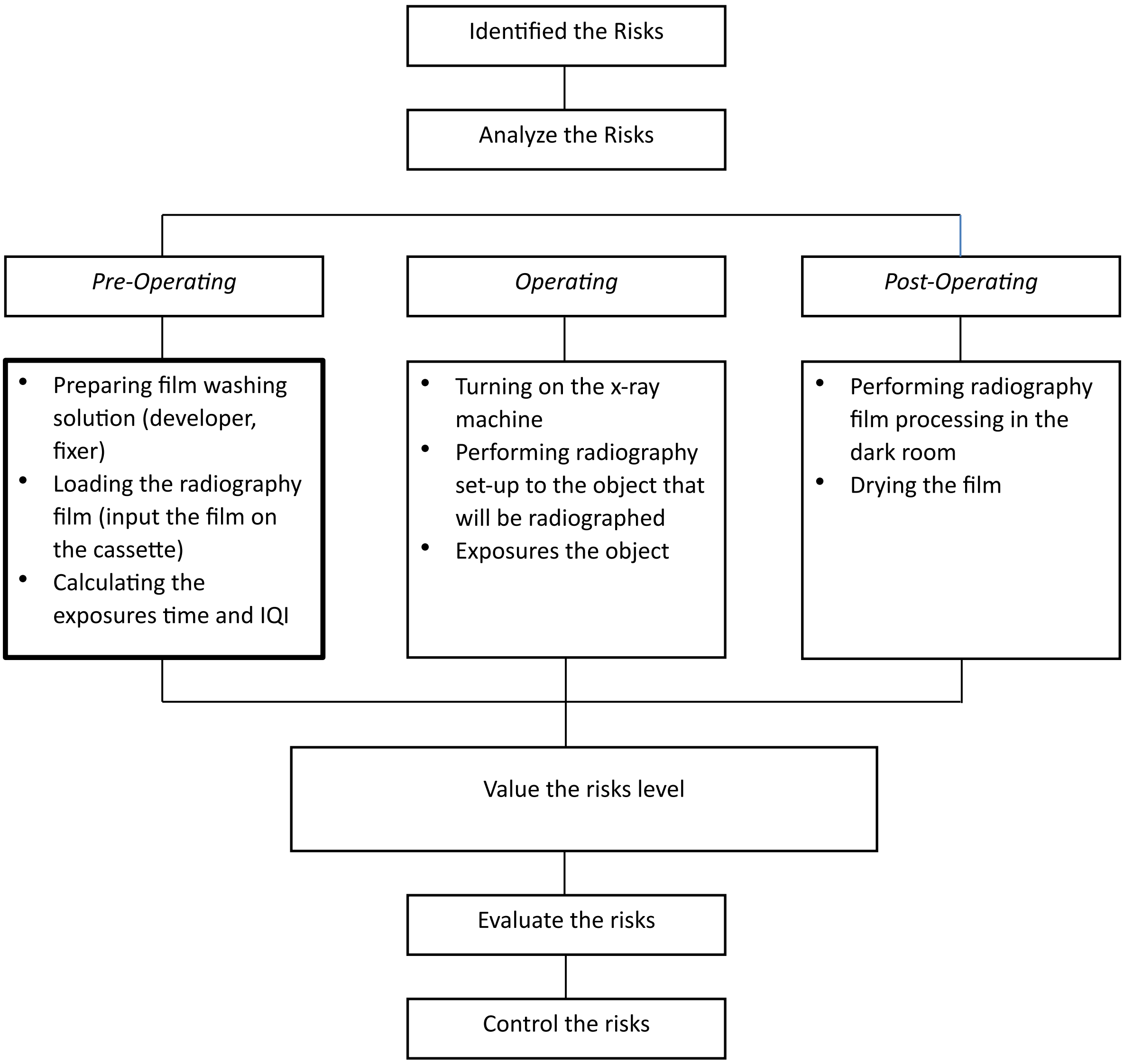

Fig. 1. The method of this research.

RESULT AND DISCUSSION

Based on the result of the FGD, the risks were identified and analyzed. The process of x-ray radiography breaks into three steps and the result was inputted in the JSA Form in table 1.

Table 5. Risks identification in the x-ray radiography process.

	Task	Risk	Probability	Exposure	Consequence
Pre-Operating					
1.	Preparing film washing solution (developer, fixer)	Inhaling developer and fixer solution vapor	• Lack of ventilation • Lack of PPE • Not using PPE	Frequently	Respiratory disorders
		Skin irritation	• Not using PPE • Not washing hands	Frequently	Itchy reddened skin, skin disease
		Slip	Slippery floor	Frequently	Bruises, Injuries
2.	Loading the radiography film	burnt radiographic film	• Lack of skill and knowledge • no procedure	Frequently	Film reject
3.	Calculating the exposures time and IQI number used	Error determining exposure time and IQI number	• Lack of skill and knowledge • no procedure	Frequently	Repeat exposure, film reject
Operating					
4.	Turning on the x-ray machine	Electric shock	• Non-standard power cord • Not using PPE • Lack of knowledge	Frequently	Pain, electric shock
		Short circuit	• Non-standard power cord • Wet socket • Socket overload	Frequently	Burning
5.	Performing radiography set-up to the object that will be radiographed	False posture	An ergonomic body position	Frequently	Low back pain
		Error doing radiography set-up	• Lack of skill and knowledge • no procedure	Frequently	Repeat exposure, film reject
6.	Exposures the object	Exposure to radiation	• The automatic timer (timer) on the control unit does not work • Dysfunction of the safety equipment in x-ray machines or radiation protection equipment	Frequently	Late effect
Post-Operating					
7.	Performing radiography film processing in the darkroom	burnt radiographic film	• Lack of skill and knowledge • no procedure	Frequently	Film reject

		Film density under or over	• Error calculating exposure time • Lack of skill and knowledge	Frequently	Repeat exposure, film reject
		Hand skin irritation	• Not using PPE • Not washing hands	Frequently	Itchy reddened skin, skin disease
		Slip	Slippery floor	Frequently	Bruises, Injuries
		Inhaling developer and fixer solution vapor	• Lack of ventilation • Lack of PPE • Not using PPE	Frequently	Respiratory disorders
8.	Drying the film	Electrocution from the film dryer	• Non-standard power cord • Not using PPE • Lack of knowledge	Frequently	Pain, electric shock

Based on the table above, the risks were assessed with the semi-quantitative method. The value of the risk can be obtained from the equation (1):

Risk = Probability x Exposure x Consequence (1)

The value of probability, exposure, and the consequence have followed the value in Tables 1-4 and inputted in the risk assessment table.

Table 6. Risk assessment in the x-ray radiography process.

	Variable	**Risk**	**C**	**E**	**P**	**Risk Value**	**Risk Level**
Pre-Operating							
1.	Preparing film washing solution (developer, fixer)	Inhaling developer and fixer solution vapor	5	6	3	90	Substantial
		Skin irritation	1	6	3	18	Acceptable
		Slip	1	6	6	36	Priority 3
2.	Loading the radiography film	burnt radiographic film	1	6	3	18	Acceptable
3.	Calculating the exposures time and IQI number used	Error determining exposure time and IQI number	1	6	3	18	Acceptable
Operating							
4.	Turning on the x-ray machine	Electric shock	1	6	1	6	Acceptable
		Short circuit	15	6	0,5	45	Priority 3
5.	Performing radiography setup to the object that will be radiographed	False posture	1	6	10	60	Priority 3
		Error doing radiography set-up	1	6	3	18	Acceptable
6.	Exposures the object	Exposure to radiation	15	6	10	900	Very high

Post-Operating							
7.	Performing radiography film processing in the darkroom	burnt radiographic film	1	6	3	18	Acceptable
		Film density under or over	1	6	6	36	Priority 3
		Hand skin irritation	1	6	3	18	Acceptable
		Slip	1	6	6	36	Priority 3
		Inhaling developer and fixer solution vapor	5	6	3	90	Substantial
8.	Drying the film	Electrocution from the film dryer	1	6	1	6	Acceptable

From table 6 we can conclude that in the pre-operating step, skin irritation while preparing the solution, burn radiographic film, and error determining the exposure time is an acceptable risk, inhaling developer and fixer solution vapor is a substantial hazard that needs to be controlled with PPE. Slip while preparing the solution is also a priority because it happened frequently and can cause injury.

In the operating step, electric shock and error doing radiography setup are acceptable risks. Short circuits while turning on the machine and false set-up posture are priority risks that will harm the workers. Radiation exposure is a very high risk that will lead to deterministic and stochastic effects.

In the post-operating step, burning radiographic film, hand skin irritation, and electrocution from the film dryer are acceptable risks. Inhaling developer and fixer solution vapor is a substantial risk that needs to be controlled by using PPE. Film density under or over and slipping in the darkroom is a priority because it happened frequently.

Based on table 6 and the above description, the recommendation of controlling the risks were made to make sure all the risk are controlled until the consequences are acceptable and will not harm the workers.

Table 7. Risk assessment in the x-ray radiography process.

	Risk	**Controlled Hierarchy**				
		Elimination	**Substitution**	**Engineering**	**Administration**	**PPE**
1.	Inhaling developer and fixer solution vapor		Using automatic film processing	Installed exhaust fan	Giving chemical safety training	Half masker
	Skin irritation				• Increased knowledge of workers • Hand	Hand Gloves
	Slip			Floor anti-slip installation	• Increased knowledge of workers • Giving safety sign	
2.	Burnt radiographic film		Using Film digital or Radiography digital		• Procedure for loading film • Increased knowledge of workers	

3.	Error determining exposure time and IQI number				• SOP for exposure time and IQI number • Enhancement knowledge of workers	
4.	Electric shocked				Increased knowledge of workers about safety electricity	Using of PPE blocking for electric current
	Short circuit			Installation of fire extinguishers in the area around the radiation room	Increased knowledge of workers about safety electricity	
5.	Odd body posture				Increased knowledge of workers about ergonomics	
	Error doing radiography set-up				Increased knowledge of workers regarding work procedures	
6.	Exposure to radiation				Increased knowledge of workers about radiation safety	Application of shielding
7.	Film burnt		Using digital radiography		• SOP for film processing • Enhancement for knowledge of workers regarding on film processing	
	Film density under / over requirement		Using digital radiography		• SOP for film processing • Enhancement for knowledge of workers regarding on film processing	
	Hand skin irritation				• Pay attention to the process of washing hand • Enhancement for knowledge of workers regarding on film processing	Gloves usage

	Slipped caused by the solution		Floor anti-slip installation	• Giving safety sign • Enhancement for knowledge of workers regarding on film processing	
	Inhaling developer and fixer solution vapor	Using automatic processing film	Installed exhaust fan	Giving training on safety working on chemistry site	Half masker
8.	Electrocution from the film dryer			Increased knowledge of workers about radiation safety	Using of PPE blocking for electric current

CONCLUSION

. All possible dangers stemming from each stage of the process were recognized and mapped. As a consequence, possible risks are managed and worker safety is ensured, but it is still necessary to improve on every event that has a high priority and a high risk level.

SUGGESTIONS

The scope of this study is confined to manual film processing using chemical solutions and pertains to the functioning of the X-Ray equipment. So, while the risk assessment is carried out especially in laboratories of the National Research and Innovation Agency, it may still be applied to other radiography facilities that employ manual film processing. After reading this document, it is intended that staff in the Radiography Laboratory would be able to identify possible dangers and know what steps may be taken to mitigate them. Further research may be conducted to develop it for risk assessment in radiography laboratories that currently utilize cutting-edge film processing, such as automatic film processing.

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