HAZARDS AND RISKS OF NON-DESTRUCTIVE RADIOGRAPHY METHOD FOR THE ENVIRONMENT

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ABSTRACT

In this paper, the effect of radiation hazards on the environment while using the non-destructive radiography method was investigated. The research was carried out by measuring the radiation amounts at 0.5 and 2 m distance from the exposure container with radioactive iridium-192 isotope used for tests with the radiography method. The tests were carried out in different positions in relation to the protective bunkers used in the company STSI Ltd. (Zagreb, Croatia) to reduce the radiation emission of the used radioactive isotope. The effectiveness of the protective bunkers in terms of reducing radiation in the environment is determined. In addition to examining the effects and hazards of radiation, the procedure for proper disposal of hazardous and non-hazardous waste generated by the non-destructive radiography method is described. Research has shown that the storage of exposure containers with radioactive iridium-192 isotope in the large protective bunker and the mini-bunker contributes to the improvement of environmental and personnel protection. The disposal of hazardous and non-hazardous waste after testing with the non-destructive radiography method has also proven to be of enormous importance for environmental protection.

Keywords: *non-destructive testing (NDT), radiography, radiation hazards, environmental protection*

INTRODUCTION

Non-destructive testing (NDT) methods are used in various industries, such as metallurgy, oil and gas industry, energy, construction, transportation, medicine, and many others [1]. These methods are widely used for testing various materials, constructions, machines, equipment, and other metal products. Non-destructive methods are so important because they do not damage the testing material. The use of non-destructive methods in industry is extremely important for detecting possible defects or damage to metallic materials that can lead to harmful consequences. Therefore, non-destructive testing (NDT) methods are known as unavoidable methods for testing materials due to their wide application [2 - 5].

One of the most frequently used non-destructive methods for testing materials is industrial radiography. This method uses ionizing radiation (X-rays and γ-rays) to examine the internal structure of the material and obtain an image of it to check the quality of products, such as welds and other metal products. Radiography is a method that allows a precise and detailed analysis of the tested materials, and it is possible to detect even the smallest defects, such as cracks, that could lead to harmful consequences [2, 6, 7].

The non-destructive radiography method, which is often used in industry to test metallic materials, has numerous advantages, but at the same time exposes the environment and personnel to the risk of radiation. Safety is therefore an extremely important issue while performing tests with this method. Since the use of radiography involves radiation, it poses a serious hazard to the environment and the health of personnel if it is not performed correctly [8].

Radiation on the one hand and ensuring environmental protection, as well as personnel safety on the other hand, represent a challenge during applying and testing with the non-destructive radiography method, considering that the effective dose of personnel being exposed to radiation should not exceed 20 mSv in a year [9 - 11]. Various equipment is used for radiography examinations. Therefore, special exposure containers, dosimeters, and various protective equipment are used to protect the environment and the personnel. Exposure containers play a very important role in radiation protection because they prevent significant penetration of radiation. However, the greatest hazard comes from radioactive isotopes, which are a source of radiation, located inside the exposure container [2, 8]. Therefore, it is important to monitor special rooms, i.e. warehouses in accordance with the law and regulations [9, 12, 13] when exposure containers with radioactive isotopes are not used. Exposure container storage with a radioactive isotope is of great importance and represents the main source of hazard not only during the radiography examination, but after its use as well. Considering the high radioactivity that can be generated by exposure container with radioactive isotopes, safety during and after use and handling is of great importance.

In [14], Lugarić et al. investigated the influence of the use of protective procedures on the radiation dose received by exposed medical workers. It was found that the radiation doses received by exposed healthcare workers were in compliance with legal regulations when they followed basic radiation protection measures and the rules of the profession. The authors in [15] established a system for occupational health and safety with regard to exposure to ionizing radiation during a radiographic examination of welds. In the study [16], a risk assessment of radiation during the inspection of welds using a non-destructive radiography method was carried out. Recommendations and advice were given on how to reduce the effects of radiation by using personal protective equipment and conducting the training of NDT personnel.

This paper aims to determine how to contribute to the reduction or even minimization of the hazards and risks of radioactive radiation for the environment and personnel when using equipment for testing with the non-destructive radiography method, i.e. with radioactive isotopes. In addition, the procedure for the disposal of hazardous and non-hazardous waste, generated from used radiographic films within the STSI Ltd. was defined. The paper examines the effectiveness and contribution of protective bunkers as protection against the radiation from exposure containers with radioactive isotopes used in testing with the non-destructive method of industrial radiography.

EXPERIMENTAL

In this research, the hazards of radiation to the environment from the equipment used in non-destructive radiography method in STSI Ltd. were established. The hazards of chemicals used to develop radioactive films and their disposal after use were also investigated. For this purpose, previously recorded radiographic films Structurix Vacupac D5 Pb, Agfa, were used. Structurix G-128 developer and Structurix G-328 fixer were used for the development of radiographic films.

Detailed research was carried out by monitoring the radiation hazards from exposure containers with radioactive isotope as a source of ionizing radiation, located inside the exposure container (Figure 1). The exposure container Radioactive Teletron, SU 50N, type B (U), Nuclear GmbH, Dusseldorf, and the radioactive isotope iridium (Ir-192) were used (Figure 1). The RadEye G-10 gamma meter, ThermoScientific, was used to measure the actual radiation dose. The measurements were carried out by professionally trained employees of STSI Ltd. who were constantly under dosimetry monitoring.

Figure 1. Exposure container Radioactive Teletron, SU 50N, type B (U), containing the radioactive isotope Ir-192

In order to meet the legal requirements and regulations [9, 12, 13], the company STSI Ltd. has developed a solution to protect the environment and personnel by storing the exposure containers with radioactive isotope Ir-192 in a large protective bunker, which is partially located under the soil layer (Figure 2). The protective bunker is made of reinforced barite concrete blocks. It has a protective metal door and a security key. The protective bunker is used to store the functional exposure containers with radioactive isotope Ir-192, but also for exposure containers that are not currently in use, because this equipment emits a low dose of radiation when not in use. They are stored under strict protection and monitoring to ensure the safety of the environment and personnel.

a) b)

Figure 2. Large protective bunker during radiation measurement: a) closed door, b) open door

The tests were carried out during storage of the exposure container with the radioactive isotope at various locations. The tests were carried out at 6 different positions outside and inside the large protective bunker in which the exposure container with the radioactive isotope Ir-192 is stored (Figures 2 and 3). Measurements were also carried out in a steel mini-bunker, lined with 5 mm thick lead sheet, located inside a large protective bunker (Figure 3). A larger number of positions were chosen for measuring radiation with a gamma meter, because it is necessary to determine whether there is a difference in the influence of radiation during measurements at different positions inside and outside the large protective bunker, and to determine the effectiveness of the protective bunker in terms of reducing radiation emission into the environment.

The test positions were chosen in such a way that measurement positions 1 and 2 were located within a large protective bunker at a 0.5 m distance from the exposure container with radioactive isotope Ir-192. Position 1 refers to measurements with the mini-bunker door closed (Figure 3a), while in position 2 the mini-bunker door is open (Figure 3b). Measurement positions 3 - 6 are located outside the large protective bunker at a 2 m distance from the main door of the large protective bunker. Position 3 refers to the measurements of the radiation amounts when the door of the mini-bunker and the main door of the large protective bunker are open (Figures 2b and 3b), while position 6 refers to the situation when both doors are closed (Figures 2a and 3a). Position 4 refers to the measurements of radiation amounts when the door of the mini-bunker is closed (Figure 3a), and the main door of the large protective bunker is open (Figure 2b). In position 5, the door of the mini-bunker is open (Figure 3b), and the main door of the large protective bunker is closed (Figure 2a). The measurements at the above-mentioned positions were carried out in the period from October to November 2023.

a) b)

Figure 3. Mini-bunker inside a large protective bunker: a) closed door, b) open door

RESULTS AND DISCUSSION

After the development of the radiographic films used in the radiographic examination, the hazardous and non-hazardous waste from the developer, the fixer, and the radiographic films were properly disposed of. The chemicals from the used developers and fixers, classified as hazardous waste, were disposed of in appropriate 250 l plastic containers labelled as hazardous waste (Figure 4a). The containers are cleaned at regular intervals. Emptying and removal are carried out by an authorized company, based on the contract on the disposal of hazardous waste. In addition to hazardous waste, non-hazardous waste, i.e. used radiographic films containing silver or silver compounds, was also disposed of in suitable plastic containers (Figure 4b).

a)

b)

Figure 4. Plastic containers for waste collection: a) hazardous waste and b) non-hazardous waste

The environmental hazards of non-destructive radiographic examinations include radiation exposure and the risk of contamination of soil, air, and water. There is a possibility of damage to the exposure containers, which can lead to contamination of the environment by the radioactive isotope Ir-192.

The radiation amounts at different positions 1 - 6, appearing during the storage of the exposure container with radioactive isotope Ir-192, were investigated. The exposure container with the radioactive isotope Ir-192 was stored in a mini-bunker (Figure 3), which is located in the large protective bunker (Figure 2). In the mini-bunker, the accuracy of the gamma meter was checked by measuring the radiation amounts near the exposure container with radioactive isotope Ir-192. The gamma meter gave a warning of an increased radiation dose by a visual signal (red light) but also with a sound signal, measuring a radiation amount of 17.6 μSV/h (Figure 5).

Figure 5. Checking the gamma meter during the measurement in the mini-bunker near the exposure container with the radioactive isotope Ir-192

Further measurements were carried out at a 0.5 m distance from the exposure container with radioactive isotope Ir-192 inside the large protective bunker at positions 1 and 2. Since the exposure container with radioactive isotope Ir-192 and the outside area are separated by two doors (large protective bunker and mini-bunker), the remaining measurements were carried out at positions 3 - 6 at a 2 m distance from the main door of the large protective bunker (Figure 2).

The results of the radiation measurements at the various measurement positions 1 - 6 are shown in Table 1.

Table 1. Results of the measured radiation amounts at positions 1 - 6

	Measurement position	Result of radiation measurement (μSv/h)	Mean value of radiation measurement results (μSv/h)	Standard deviation
The 0.5 m distance from the gamma meter to the exposure container with radioactive isotope Ir-192	position 1 - mini-bunker door closed	1.92	2.23	0.262
		2.56		
		2.20		
	position 2 - mini-bunker door opened	2.99	2.33	0.993
		0.93		
		3.08		
The 2 m distance from the gamma meter to the main door of the large protective bunker	position 3 - mini-bunker door opened/main door of the large protective bunker opened	0.17	0.27	0.078
		0.28		
		0.36		
	position 4 - mini-bunker door closed/main door of the large protective bunker opened	0.11	0.12	0.045
		0.07		
		0.18		
	position 5 - mini-bunker door opened/main door of the large protective bunker closed	0.10	0.09	0.009
		0.10		
		0.08		
	position 6 - mini-bunker door closed/main door of the large protective bunker closed	0.09	0.09	0.025
		0.07		
		0.13		

The difference in the radiation amounts can be seen in the measurements at positions 1 - 6 (Table 1). The highest measured mean value of the radiation amount at a 0.5 m distance from the exposure container with radioactive isotope Ir-192, which is located inside the large protective bunker, is in position 2, when the door of the mini-bunker is open, and is 2.33 μSv/h. In position 1, when the door of the mini-bunker was closed, slightly lower radiation amounts were measured compared to position 2, namely 2.23 μSv/h (Table 1). It can be concluded that storing the exposure container with radioactive isotope Ir-192 in a protective mini-bunker with the door closed contributes to the protection of the environment and personnel, because the radiation amounts released into the environment are reduced.

Further analysis of the radiation amounts measured at a 2 m distance from the main door of the large protective bunker clearly shows that the highest radiation amounts were measured when the doors of the large protective bunker and the mini-bunker were open. The mean value of the amount of radiation when the doors of the large protective bunker and the mini-bunker were open is 0.27 μSv/h, taking into account the free emission of radiation into the environment. A more significant reduction in radiation amounts was achieved by closing the door of the large protective bunker, where the amount of 0.09 μSv/h was measured, which is within the permissible limits for the environment and personnel (Table 1). The determined radiation amounts showed the expected decrease at a greater distance from the protective bunker compared to the radiation amounts measured near the exposure container with radioactive isotope at a 0.5 m distance, where greater radiation amounts were measured. Therefore, it follows that a large protective bunker contributes to the protection of the environment and personnel. It reduces the emission of radiation into the environment, which is very important for larger amounts of radiation caused by exposure containers with radioactive isotopes that are currently in use, but also for those that have already been used and need to be stored properly.

The results of this research have shown that the storage of the exposure containers with radioactive isotope in large protective bunkers and mini-bunkers after testing by the non-destructive method of industrial radiography contributes to the improvement of reduction of the hazards and risks of radiation both for the environment and the working personnel in order to meet requirements according to [9, 12, 13]. In addition to reducing the risk of radiation, the proper disposal of hazardous and non-hazardous waste has also proven to be a very important part of environmental protection in the use of equipment and radiographic examinations.

CONCLUSION

Research on the effects of radiation on the environment and personnel while using the equipment for the non-destructive radiography method, i.e. exposure containers with radioactive isotopes, has shown that storage of exposure containers with radioactive isotope in large protective bunkers and mini-bunkers is important and contributes to the reduction of radioactive emissions into the environment. The measured amounts of radiation during the storage of exposure containers with radioactive isotopes with the doors of the large protective bunker and the mini-bunker closed resulted in lower amounts of radioactive radiation emitted into the environment. In this way, the effects of the harmful radioactive radiation emitted by the exposure container with radioactive isotope Ir-192 are reduced to a minimum, making it harmless to the environment and personnel.

In addition to appropriate storage of the exposure container with radioactive isotope, the importance of proper disposal of hazardous and non-hazardous waste resulting from used radiographic films and chemicals after examination by the non-destructive radiography method was also established.

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