Dose Assessment to Workers from Accidents in Industrial Gamma Radiography

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Abstract. Industrial radiography can result in higher radiation exposure in case of bad practice or an accident. Many factors can contribute to accidents in radiography including, inadequate regulatory control, failure to follow operational procedure, inadequate training, inadequate maintenance, human error, equipment malfunction or defect, design flaws, and willful violation. The purpose of this study was to assess the dose to workers from potential hypothetical accidents in industrial gamma radiography. In this study, an Ir-192 industrial gamma radiography source with an activity of 100 Ci simulated the accident. Visual Monte Carlo (VMC) dose calculation software estimated the dose received by the workers using the International Commission on Radiological Protection (ICRP) male phantom to represent the human body. The simulation periods (exposure durations) were 10 minutes and 30 minutes for comparison. From the exposure for 10 minutes, the results were below the ICRP recommended dose limit of 50 mSv/year for occupational exposure. In the case of exposure for 30 minutes, the Effective dose was found to be higher than the ICRP recommended dose limit of 50 mSv/year. However, the organ dose for the testes was approaching the ICRP recommended dose limit of 500 mSv/year. Although these doses were lower than the recommended dose limits, they represented higher doses for a single exposure scenario. Based on the exposure duration and the activity of the gamma source, this exposure scenario could lead to any deterministic health effect. Therefore the handling of industrial gamma sources should adhere to operational procedures, training, maintenance, regular checkup of devices, and regulatory control.

KEYWORDS: Effective Dose, Industrial Radiography, Visual Monte Carlo, and Organ Dose

1. INTRODUCTION

Radioactive sources have various beneficial applications around the world. These applications range from medicine, industry, agriculture, research, and education [1]. Industrial radiography is one of the areas utilizing the use of ionizing radiation for non-destructive testing to check the physical integrity of equipment and structures such as vessels, pipes, welded joints, casting, and other devices [2]. Radiography poses a negligible radiation risk to the public as well as the workers. However, for improper practice or in case of an accident, radiography results in higher radiation exposure due to high dose rates. Exposed to an unshielded source nearby for a few minutes or even seconds can result in severe injury [2]. Gamma-ray radiography generally uses category II Iridium-192 and Cobalt-60 sources. The small size and mobility make them more vulnerable to seizure and hence become a threat to the public and environment [3]. Many different factors contribute to accidents in industrial radiography. These factors can be according to the primary cause. The cause can be inadequate regulatory control, failure to follow operational procedure, inadequate training, inadequate maintenance, human error, equipment malfunction or defect, design flaws, and willful violation [4]. The application of industrial radiography in Tanzania has been increasing, especially in oil and gas exploration and in pipe industries. The increase in radiation sources in the country means an increase in radiological concern for occupational, public, and environment. This study aimed to assess the exposure dose that can be received by the individual (radiographer) when coming nearby an unshielded source.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was assumed to be the place of the gas exploration company using industrial radiography with Iridium-192 source.

2.2 Model Description

Visual Monte Carlo (VMC) - dose calculation software is the mathematical simulation of the human body irradiated from different radiation sources like the point, ground, cloud, or internal sources. Body phantom represents the human body. VMC dose calculation estimates the dose received by the human body when a highly active source comes in contact with the skin for a length of time. VMC-DC is a window-based program that requires defining the geometry of the source, the time of exposure, and the position of the source. It is a useful tool for quick estimation of the dose from radioactive sources in the case of an emergency or accident. It calculates the equivalent dose for the relevant tissues and as well as the effective dose [5].

2.3 Model Input Parameters

This study assumed a hypothetical case. Therefore, VMC-dose calculation used the following inputs to assess the dose received by the phantom: the source of exposure, a radioactive device with Iridium -192 source was selected considering that most of the industrial radiography use Ir-192 and Co-60 sources. The scenario was assumed to involve the source activity of 100 Ci Ir-192 source since the typical activity of Ir-192 in industrial radiography is 100 Ci and the most used in Tanzania [1]. The other input parameter was the ICRP male phantom. The simulation times were 10 and 130 minutes. Table 1 below is a summary of these input parameters.

Table 1: Input Parameters

Parameter	Value (s) chosen
Source	External Source
Radionuclide	Iridium-192
Radionuclide activity	100Ci
Phantom	ICRP adult male
Geometry	Point source
Exposure time	10 & 30 minutes

2.4 Scenario Description

There are so many scenarios that can cause the source to be exposed. However, the assumption for this study was that the radiation source left the guide tube during returning to the shielding position. The guide tube broke, resulting in exposing the radiation source. An attempt to return the source to the shielding position resulted in exposing the radiographer because of being near the highly active radiation source.

2.5 Procedure

The first step was to enter the input parameters of Table 1 into the VMC dose calculation project. Then, the simulation was made for 10 and 30 minutes to calculate the phantom dose for these times. 100,000 histories were selected during the simulation to represent the run option from the available options. After choosing the histories, then the software analyzed the data. The results of these analyses are in the next section.

3. RESULTS AND DISCUSSION

As shown in Figure 1, the exposure from close distance with ^{192}Ir of 100Ci for 10 minutes results in a dose of 26.76 mSv. Also, this figure shows exposures to different organs like skin, bone surface, and testes. These organs received higher exposure compared to other organs. The skin received 123.93 mSv while the bone surface and testes received 118.21 mSv and 136.03 mSv, respectively. These values (the total effective dose and the organ doses) are below the ICRP recommended dose limit for occupational exposure. For example, by comparing the effective dose from this result with that of the recommended annual effective dose. However, since this was a short time exposure, it could represent a high amount of exposure by comparing the dose limit of 50 mSv/year. On the other hand, assuming that the source took a relatively long time of 30 minutes to be returned to the guide tube, the person would receive the dose higher than in the first scenario of 10 minutes. Therefore, the results of this exposure scenario (30 minutes) are in Figure 2.

Figure 1: Body phantom under exposure time of 10 minutes

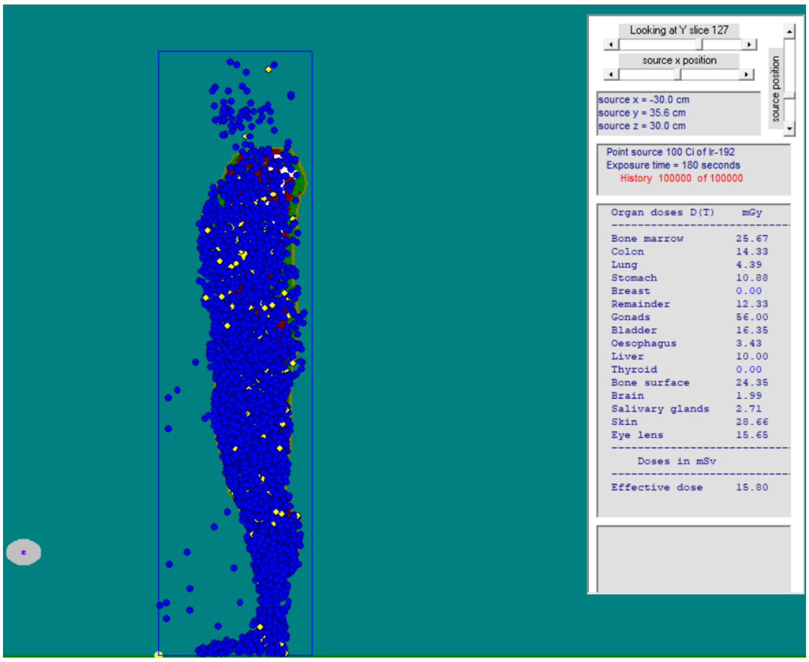

Figure 2: Body phantom under exposure time of 30 minutes

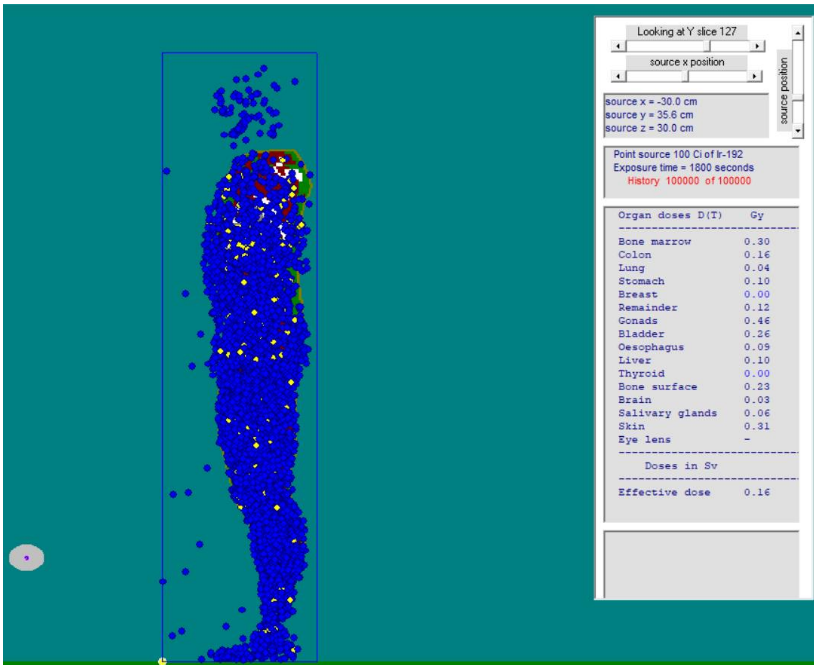

Figure 2 above represents the exposure of the body phantom from the Ir-192-point source with 100Ci for 30 minutes nearby this radiation source. Like in the first scenario, the organs which received a high amount of dose in comparison with other organs are the testes, bone surface, and skin with 408.09 mSv, 354.63 mSv, and 371.79 mSv, respectively. The effective dose received is 80.29 mSv. In this scenario, the effective dose is higher than the ICRP recommended dose limit for occupational exposure. The

effective dose should not exceed 50 mSv, and the equivalent dose to the skin should not exceed 500 mSv during an emergency operation of recovery and restoration [6].
Therefore, the dose received in this scenario of 80.29 mSv is higher than the recommended value of 50 mSv, On the other hand, the testes received an equivalent dose of 408.09 mSv. This value is approaching the recommended dose limit of 500 mSv.
Although fatality and cases of serious accidents that involve industrial radiology sources are rare, this should not be taken for granted because once it occurs can result in deterministic exposure. Therefore, whenever dealing with the radiation source, care must be taken to make sure that the integrity of the radiation source is maintained and the handling protocol and procedures have adhered. The results of the two calculations are shown in Table 2 below for the effective dose and the three organs that received highest dose.

Table 2. Radiation doses (mSv) for two exposure durations

	10 minutes	30 minutes
Effective dose	26.76	80.29
Equivalent dose to the skin	123.93	371.79
Equivalent dose to the bone surface	118.21	354.63
Equivalent dose to the testes	136.03	408.09

4. CONCLUSION

This study aimed to assess the exposure dose that can be received by the individual (radiographer) when coming nearby an unshielded radiation source. The body phantom was exposed for 10 and 30 minutes by the Ir-192 with 100 Ci. The exposure of 10 minutes caused an effective dose of 26.76 mSv, and the skin, bone surface, and testes received 123.93 mSv, 118.21 mSv, and 136.03 mSv, respectively. In this scenario, the doses were below the ICRP recommended dose limit for occupational exposure. The exposure for 30 minutes caused an effective dose of 80.29 mSv. The skin, bone surface, and testes received 371.79 mSv, 354.63 mSv, and 408.09 mSv, respectively. This study shows how radiography sources can be harmful because of the radiation doses they give to people when they are exposed. The unshielded industrial radiography source can cause deterministic exposure depending on the time an individual spends near the highly active source like the one in this study (I-192 source). Therefore, it is important to take care when handling these radiation sources. Also, the handling of these radiation sources should follow the operational procedures, adequate regulatory control, training, maintenance, and regular checkup of the devices.

5. ACKNOWLEDGEMENTS

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6. 6. REFERENCES

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