Assessment of Occupational Radiation Exposure from Industrial Radiography Practice

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1. Introduction

Reports of high radiation-related accidents have been linked with industrial radiography than any other radiography sub-specialty, mainly due to deviation from standard operating procedures (SOP) and radiation protection practices resulting to workers exposure [1]. Industrial gamma radiography is one of the most commonly used non-destructive testing (NDT) methods that employs a technique of inspecting materials for hidden flaws by using high activity sealed radioactive source housed in a shielded exposure device (commonly known as source projectors) for used in imaging of weld joints and castings and must be managed safely and securely [2]. The devices are operated manually by spinning the controller unit to project the gamma source outside the shielding, in a projection casing. Thus, Improper management of high-activity sources as a result of faulty equipment or deviation from SOP may result in potential occupational radiation exposure (ORE) to workers [3]. The International commission for Radiation Protection (ICRP) annual effective dose limit for occupational individual should not exceed 20 mSv averaged over five consecutive years (100 mSv in 5 years). Therefore, Consistent assessment of ORE is important in determining the changes over time as a result of technological advancement. Because of the potential hazards involves in the use of radioactive materials, a system of categorization has been developed by the International Atomic Energy Agency (IAEA), based on the potential for radioactive sources to cause deterministic health effects thereby providing a relative ranking and grouping of sources and practices, on which decisions can be based [4]. Optimizing the radiation exposure through the "As Low As Reasonably Achievable (ALARA)" principle is a very important procedure in Industrial gamma radiography practice which reduces external exposure by applying the principles of time, distance and shielding (TDS) thereby ensuring every realistic approach in keeping workers exposure below the prescribed limits consistent with the purpose for which the activity was undertaken in relation to benefits to the workers' health and safety, and other socio-economic considerations. Using appropriate techniques for dose planning and estimation are vital phases of implementing ALARA principle that allow for reducing the personnel's collective dose [5]. Using VISIPLAN 3D ALARA planning tool, this study aims at assessing the occupational radiation exposure from industrial radiography practice in Nigeria. resulting from exposure to direct radiation. In Nigeria, Sentinel model 880 series source projectors among others are widely used for industrial gamma radiography applications to inspect materials and structures in the density range of approximately 2.71 g/cm^3 through 8.53 g/cm^3. The exposure device body is shielded with depleted uranium (DU) or Tungsten (W) shield is encased within a welded tubular stainless-steel shell end plates, aluminum, brass, tungsten and polyurethane with labels, comprises details of radioactive material and transportation package type among others as shown in Fig. 1 [6]. The authorized contents of Sentinel model 880 series source projectors parameters are shown in Table I.

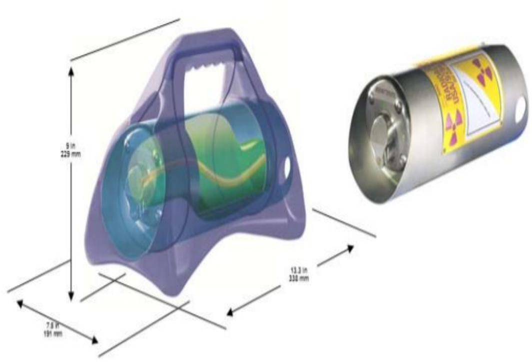

Fig. 1. Sentinel 880 configuration view [6].

Table I: Model 880 delta authorized contents [6].

Isotope	Source Max. Activity	$T_{1/2}$
Ir-192	5.55 TBq	74 d
Se-75	5.55 TBq	120 d
Yb-169	4.50 TBq	32 d
Co-60	2.40 GBq	5.27 y
Cs-137	14.0 GBq	30 y

2. Materials and Method

The VISIPLAN 3D ALARA planning tool is a new calculation tool developed to facilitate the planning of the work based on 3D geometrical material and radiological information. The tool considers dose assessments for external exposure to gamma radiation. The dose calculations are based on a point-kernel method with a build-up correction, whereby each small source is called a kernel, and the process of integration, where the contribution to the dose of each point is added up, is called "point kernel" integration [7]. The VISIPLAN methodology consists of four steps: model building, general analysis, detailed planning and follow-up. A 3D modeling was conducted using VISIPLAN planning code for external dose assessment involving Iridium 192 (Ir-192) radioactive source with activity of 90 Ci placed at 15 cm from the centre origin (x direction), shielded with DU and lead as shown in Fig. 2.

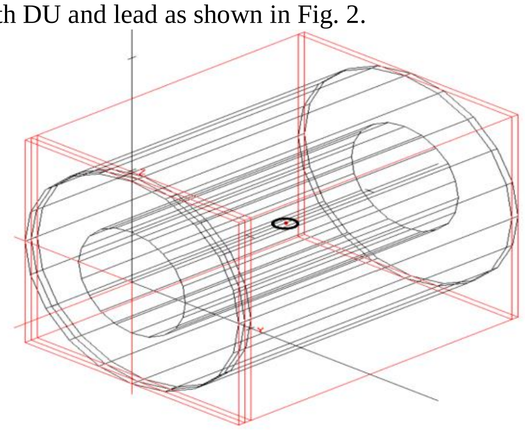

Fig. 2. VISIPLAN 3D modeling of projector tube.

3. Results and Discussion

The distribution of dose around the X grid during industrial radiography operations involving 90Ci of Ir-192 radioactive sources using two shielding materials comprises of DU and lead at operation distance from 0.5 to 2 meters respectively is shown in Fig. 3. The result of the simulation shows that the maximum dose from direct exposure involving the use of sentinel 880 projectors for radiography inspection with 90 Ci activity of Ir-192 source, using lead and DU shielding in close contact is 5.0E-03 mSv/h equivalent to 9.6mSv/y (using 8 hours/day, 5 days/week and 48 working weeks/year). However, the distribution of dose decreases with increasing distance as shown above. The table below shows the distribution of dose around the trajectory for various task and time interval ranging from 60 to 260 minutes respectively is shown in the Table II below.

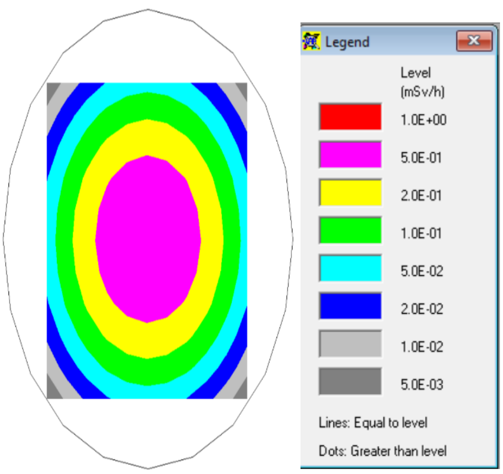

Fig. 3. Distribution of dose during NDT inspection.

Table II: External dose distribution along trajectory.

Task description	Duration (min)	Dose rate (mSv/h)	Task dose (mSv)	Acc. dose (mSv)
Calibration of Equipment	60	4.10E-04	4.10E-04	4.10E-04
Inspection work	260	4.10E-04	1.80E-03	2.20E-03
Inspection work	260	4.80E-05	2.10E-04	2.40E-03
Task Verification	60	9.10E-05	9.10E-05	2.50E-03

The result above, Assuming the radiation worker worked for a maximum of 8 hours/day, 5 days/week and 48 working weeks/year, the result of dose evaluation to workers for various task during industrial radiography inspection is below the recommended ICRP annual occupational dose limit of 20mSv. In order to further validate the result of the simulation and for the purpose of ensuring strict adherence to the standard operation procedures and radiation protection principles during industrial radiography practice work in Nigeria, the occupational dose records of radiation workers from the period of 2012 to 2016 were collated and analyzed as shown in Fig. 4 [8]. Comparing the result of the simulation with the analysis of occupational dose records of radiation workers from the period of 2012 to 2016, the highest dose received are all below the ICRP annual occupational dose limit of 20 mSv.

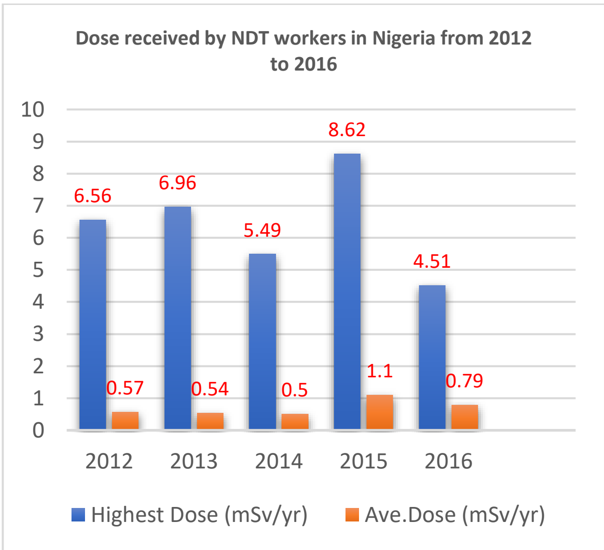

Fig. 4. Bar chart showing dose received by industrial radiography workers in Nigeria from 2012 to 2016.

4. Conclusion

In this study, assessment of occupational radiation exposure from the use of sentinel 880 source projector containing 90 Ci Ir-192 sources during industrial radiography practice in Nigeria has been conducted using VISIPLAN 3D ALARA tool for various task description alongside time, distance and shielding respectively. The result of the simulation shows that highest dose received is 9.6mSv/y. Comparing the result of the simulation using VISIPLAN 3D ALARA tool and analysis of occupational dose records for industrial radiography workers in Nigeria from 2012 to 2016, the result shows that the highest dose received for each analysis is below the ICRP annual occupational dose limit of 20mSv. Considering the worst-case scenario where the workers task is above the normal working hours, the annual dose that the worker will receive after working for 9, 10 and 12 hours/day are 10.8 mSv/yr, 12 mSv/yr and 14.4 mSv/yr, respectively.

Acknowledgement

This research supported by the 2021 Research Fund of the KEPCO International Nuclear Graduate School (KINGS), the Republic of Korea.

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