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EVALUATION OF OCCUPATIONAL RADIATION EXPOSURE IN A RADIO-DIAGNOSTIC FACILITY IN KATSINA- NIGERIA

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ABSTRACT

Poor implementation of quality assurance programs in the radiation industry has been a major setback in our locality. Several studies revealed that occupational workers are exposed to many potential hazards of ionizing radiation during radio-diagnostic procedures, yet radiation workers are often not monitored. This study aims to evaluate the occupational exposure of the radiation workers in Federal Medical Centre Katsina, and to compare the exposure with recommended occupational radiation dose limits. The quarterly readings of 20 thermo-luminescent dosimeters (TLDs') used by the radiation workers from January to December, 2019 were collected from the facility's radiation monitoring archive, and subsequently assessed and analyzed. The results indicate that the average annual equivalent dose per occupational worker range from 0.74 to 1.20 mSv and 1.28 to 2.21 mSv for skin surface and deep skin dose, measured at 10 mm and 0.07 mm tissue depth respectively. The occupational dose was within the recommended national and international limits of 5 mSv per annum or an average of 20 mSv in 5 years. Therefore, there was no significant radiation exposure to all the occupational workers in the study area. Though, the occupational radiation dose is within recommended limit, this does not eliminate stochastic effect of radiation. The study recommended that the occupational workers should adhere and strictly comply with the principles of radiation protection which includes distance, short exposure time, shielding and proper monitoring of dose limits. Furthermore, continuous training of the radiation workers is advised.

Keywords: Stochastic effect, occupational dose, thermo-luminescent Dosimeter (TLD), Radiation workers.

INTRODUCTION

The medical applications of ionizing radiation such as x-rays, fluoroscopy, mammography and computed tomography represent the second largest contribution to the collective dose of ionizing radiation in the world (*UNSCEAR,* 2000). A justifiable concern has been raised over the increase in the use of ionizing radiation for medical diagnosis (Joseph *et al.*, 2017). Furthermore, associated biological hazards of ionizing radiation which may lead to radiation sickness including damage of skin, tissue, cells, organs, malignancies and cataract formation have been reported at all radiation exposure levels (Mohsen *et al*., 2014). The biological effects due to ionizing radiation exposure can be grouped into two categories: (i) the acute deterministic effect which includes skin injury, sterility and hair loss, and (ii) the stochastic effects on the other hand is a non- threshold dependent effect, with the probability of occurrence proportional to the radiation dose. Stochastic effects are more delayed compared to the acute deterministic effects, which takes years to decades in comparison to hours to months in the acute case. Examples of stochastic effects include radiation induced cancers and genetic mutation (*Dumonceau et al.,* 2012*; Leyton et al.,* 2014).

Several studies have revealed that occupational workers are at higher risk of health effects as a result of occupational radiation exposure during examinations in the radiology departments. In order to reduce these radiation effects, the fundamental principle is always to keep exposure to radiation as low as reasonably achievable (ALARA), (*Wilson-Stewart et al*., 2018). The radiation protection agencies such as International Commission on Radiation Protection (ICRP) recommend that the occupational dose limitation should be in enforced so that the occupational workers are not exposed to a high amount of ionizing radiation. The effective dose limit of 5 mSv a year, eye lens 20 mSv/year, skin 500 mSv/year, hand and foot 500mSv/year are recommended for occupational workers (ICRP, 2017). Thermo-luminescence Dosimetry (TLDs) is generally recognized as the most valuable method for the quantitative measurement of ionizing radiation especially in personnel monitoring. TLDs are made in many different shapes and designs, which include ring, badge and chips. TLDs are not made to provide radiation protection to occupational workers (*Olko*, 2010). The effective dose is best estimated by wearing two or three dosimeters for more exposed individuals. It is suggested to place a main personal dosimeter under the lead apron at chest level, directed to the radiation source; a second dosimeter should be placed above the lead apron at the neck level; and a third dosimeter near the eye or the hand region. For staff monitoring, the use of two dosimeters is recommended but a single dosimeter worn under the protective apron can provide a reasonable estimate (*ICRP*, 2005; *Dumonceau et al*., 2012). Occupational effective dose of personnel is measured in personal dose equivalent of (Hp(10)) for deep skin dose which represent 10 mm depth of soft issue and (Hp(0.07)) for surface skin dose which represents 0.07 mm depth soft issue (*Kuipers et al.*, 2010; *Padovani et al*., 2001).

The effective dose, E, is a dosimetry parameter which uses the doses received by all irradiated material or radiosensitive organs. It is also used to measure the stochastic effects of ionizing radiation (*ICRP*, 2005). The effective dose is an occupational dose quantity based on time and age of the occupational worker (*Brenner and Walter, 2008*). Annual effective dose limits for occupational workers have been proposed by national and international radiation protection agencies (*Leyton et al.*, 2014).

All individuals participating in the radio diagnostic practices should observe personal monitoring and protection principles. There is a lead apron designed to attenuate 95% of the spread radiation. In addition, lead glasses are also necessary for lens protection (*ICRP*, 2005). The adequate use of radiation monitoring and protection principles can significantly reduce radiation exposure for the occupational workers (*Leyton et al*., 2014). It is important to perform personal monitoring to ensure that occupational workers comply with recommended effective dose limits. Proper personnel monitoring is also imperative in determining the level of radiation exposure to each occupational worker and to recommend appropriate precautions that need to be taken (*Onoja et al.,* 2017).

MATERIALS AND METHODS

The study was carried out in Radiology Department of Federal Medical Center, Katsina state, Nigeria. The radiology department consists of three conventional X-ray modalities, one CT scan modality and one mammography modality. A retrospective cross sectional analysis of the occupational radiation exposure of the staff was conducted. Readings of 20 thermo-luminescence dosimeters film badges for a period of one year (from January 2019 to December 2019) were analyzed. The calibration and reading of the TLDs badges were carried out at the Center for Energy Research and Training, Zaria - Nigeria. The calibration factor of 0.53*exp-53 mSv/count for Hp(10) and 0.51*exp-05 mSv/count for Hp (0.07) was used as the standard dosimetry of exposure. Routinely, the occupational workers has a TLD badge worn under the lead apron placed on the chest while working. And the TLD badge would read and record the exposed radiation.

Dose Algorithms

a. Glow curve analyzer which determines the quality of the glow curve.
b. Glow curve deconvulation which segregates the glow curve into their individual glow peaks.
c. Chain of custody and health physics record system, which updates and maintains dose data.
d. The peak value of the glow curves produced were automatically converted to dose using the formula:

$$\text{Dose} = \frac{\text{Q}\times\text{ECC}}{\text{RSF}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 1$$

Where Q is the charge (the glow peak value, in nano-coulomb), ECC is the element correction coefficient = 3749, RCF is the reader calibration factor = 0.0171

Processing of the TLD

The TLD reader in the Center for Energy Research and Training, Zaria is the Harshaw Model 4500. It has a hardware comprising the following system.

1. The model 4500 Harshaw TLD reader which contains data processing electronic, a sample drawer assembly, a precision light measurement system, a detector heating system, a light voltage power supply and data storage facilities.

2. A video display unit (VDU) for the display of data graphics, operating instruction and messages.

3. Keyboard that provides the interactive central interface with the TLD reader Harshaw model 4500.

4. A set of floppy disk for backup.

The model 4500 Reader is capable of reading a number of forms of thermo luminescence dosimeters, such as the whole body and the environmental dosimeter. The Harshaw Model 4500 Manual TLD Reader with WINREMS is a state-of-art tabletop instrument used for TLD measurement of a wide variety of TL materials in many forms and sizes. This model incorporates two Photomultiplier Tubes in a sliding housing, with both planchet and hot gas (nitrogen or air) heating methods. The TL element may be heated by hot gas or by a planchet. Hot gas is used for whole body and Environmental TL cards and extremity Dosimeters (Chipstrates and Ringlets), while the planchet is used for the unmounted TL elements: chips, disks, rods, and powders. The system consists of two major components: the TLD Reader and the Windows Radiation Evaluation and Management System (WinREMS) software resident on a personal computer (PC), which is connected to the Reader via a serial communications port.

a. WinREMS Application software

The data architecture of the system includes both a host computer in the Reader and a Windows based PC connected through an RS-232-C serial communication port. The dosimetric functions divided between the Reader and the Harshaw WinREMS (Windows Radiation Evaluation and Management) software on the PC. All dosimetric data storage, instrument control, and operator inputs are performed on the PC, transport subsystem control, gas and vacuum controls, and signal acquisition and conditioning are performed in the Reader.

RESULTS AND DISCUSSIONS

The results obtained from the retrospective analysis of the occupational radiation exposure from the Radiology Department in Federal Medical Center Katsina were presented in the tables below.

Table 1. First Quarter TLDs film badge dosimeter readings

SN	DEEP SKIN DOSE (mSv)	SURFACE SKIN DOSE (mSv)
TLIA	0.31	0.16
TL2A	0.38	0.27
TL3A	0.25	0.12
TL4A	0.40	0.21
TL5A	0.33	0.17
TL6A	0.41	0.12
TL7A	0.27	0.12
TL8A	0.38	0.10
TL9A	0.27	0.12
TL10A	0.20	0.14
TL11A	0.47	0.13
TL12A	0.49	0.55
TL13A	0.49	0.21
TL14A	0.51	0.21
TL15A	0.32	0.21
TL16A	0.32	0.25
TL17A	0.34	0.21
TL18A	0.35	0.10
TL19A	0.30	0.25
TL20A	0.50	0.21

Table 1 shows the first quarter dosimetry readings of 20 TLD film badges from January, 2019 to March, 2019. The readings were measured in mSv and also categorized into deep skin dose and surface skin dose measured in Hp(10) and Hp(0.007) respectively. It was read as TL1A, which represents the radiation dose of an occupational worker for a period of first quarter months. For the particular occupational worker, the mean value for the first quarter is 0.31 and 0.16 mSv for deep and surface skin dose respectively.

Table 2. Second Quarter TLDs film badge dosimeter readings

SN	DEEP SKIN DOSE (mSv)	SURFACE SKIN DOSE (mSv)
TLIB	0.55	0.15
TL2B	0.21	0.09
TL3B	0.28	0.16
TL4B	0.42	0.13
TL5B	0.17	0.10
TL6B	0.28	0.16
TL7B	0.35	0.10
TL8B	0.29	0.13
TL9B	0.50	0.19
TL10B	0.25	0.38
TL11B	0.33	0.14
TL12B	0.29	0.11
TL13B	0.18	0.10
TL14B	0.33	0.11
TL15B	0.38	0.52
TL16B	0.26	0.10
TL17B	0.34	0.12
TL18B	0.32	0.11
TL19B	0.41	0.20
TL20B	0.45	0.10

Table 2 shows the second quarter dosimetry readings of 20 TLD film badges from April, 2019 to June, 2019. The readings were measured in mSv and also categorized into deep skin dose and surface skin dose measured in Hp(10) and Hp(0.007) respectively. It was read as TL1B, which represents the radiation dose of an occupational worker for a period of second quarter months. For the particular occupational worker, the value for the second quarter was 0.55 and 0.15 mSv for deep and surface skin dose, respectively.

Table 3. Third Quarter TLDs film badge dosimeter readings

SN	DEEP SKIN DOSE (mSv)	SURFACE SKIN DOSE (mSv)
TLIC	0.55	0.19
TL2C	0.21	0.12
TL3C	0.42	0.14
TL4C	0.17	0.16
TL5C	0.28	0.09
TL6C	0.35	0.11
TL7C	0.29	0.10
TL8C	0.50	0.13
TL9C	0.25	0.19
TL10C	0.33	0.28
TL11C	0.29	0.24
TL12C	0.18	0.11
TL13C	0.33	0.16
TL14C	0.38	0.18
TL15C	0.26	0.32
TL16C	0.34	0.20
TL17C	0.25	0.12
TL18C	0.33	0.21
TL19C	0.28	0.20
TL20C	0.45	0.10

Table 3 shows the third quarter dosimetry readings of 20 TLD film badges from July, 2019 to September, 2019. The readings were measured in mSv and also categorized into deep skin dose and surface skin dose measured in Hp(10) and Hp(0.007) respectively. It was read as TL1C, which represents the radiation dose of an occupational worker for a period of third quarter months. For the particular occupational worker, the value for the third quarter was 0.55 and 0.19 mSv for deep and surface skin dose respectively.

Table 4. Fourth Quarter TLDs film badge dosimeter readings

SN	DEEP SKIN DOSE (mSv)	SURFACE SKIN DOSE (mSv)
TLID	0.80	0.47
TL2D	0.83	0.49
TL3D	1.11	0.54
TL4D	1.03	0.70
TL5D	0.64	0.44
TL6D	0.55	0.40
TL7D	0.71	0.42
TL8D	0.54	0.40
TL9D	0.91	0.34
TL10D	0.96	0.72
TL11D	0.19	0.39
TL12D	0.85	0.40
TL13D	0.93	0.41
TL14D	0.76	0.44
TL15D	0.54	0.44
TL16D	0.55	0.41
TL17D	0.99	0.35
TL18D	0.75	0.39
TL19D	0.54	0.42
TL20D	0.55	0.34

Table 4 shows the fourth quarter dosimetry readings of 20 TLD film badges from October, 2019 to December, 2019. The readings were measured in mSv and also categorized into deep skin dose and surface skin dose measured in Hp(10) and Hp(0.007) respectively. It was read as TL1D, which represents the radiation dose of an occupational worker for a period of fourth-quarter months. For the particular occupational worker, the value for the fourth quarter was 0.80 and 0.47 mSv for deep and surface skin dose respectively.

Table 4. Annual Accumulated TLDs Film badge Records.

SN	DEEP SKIN DOSE (mSv)	SURFACE SKIN DOSE (mSv)
TLI	0.31+0.55+0.55+0.80 = **2.21**	0.16+0.15+0.19+0.47= **0.97**
TL2	0.38+0.21+0.21+0.83 = **1.63**	0.27+0.09+0.12+0.49= **0.97**
TL3	0.25+0.28+0.42+1.11 = **2.06**	0.12+0.16+0.14+0.54= **1.05**
TL4	0.40+0.42+0.17+1.03 = **2.02**	0.21+0.13+0.16+0.70= **1.20**
TL5	0.33+0.17+0.28+0.64 = **1.42**	0.17+0.10+0.09+0.44= **0.80**
TL6	0.41+0.28+0.35+0.55 = **0.59**	0.12+0.16+0.11+0.40= **0.79**
TL7	0.27+0.35+0.29+0.71 = **1.62**	0.12+0.10+0.10+0.42= **0.74**
TL8	0.38+0.29+0.50+0.54 = **1.71**	0.10+0.13+0.13+0.40= **0.76**
TL9	0.27+0.50+0.25+0.91 = **1.93**	0.12+0.19+0.19+0.34= **0.84**
TL10	0.20+0.25+0.33+0.96 = **1.74**	0.14+0.38+0.28+0.72= **1.52**
TL11	0.47+0.33+0.29+0.19 = **1.28**	0.13+0.14+0.24+0.39= **0.90**
TL12	0.49+0.29+0.18+0.85 = **1.81**	0.55+0.11+0.11+0.40= **1.17**
TL13	0.49+0.18+0.33+0.93 = **1.93**	0.21+0.10+0.16+0.41= **0.88**
TL14	0.51+0.33+0.38+0.76 = **1.98**	0.21+0.11+0.18+0.44= **0.94**
TL15	0.32+0.38+0.26+0.54 = **1.50**	0.21+0.52+0.32+0.44= **1.49**
TL16	0.32+0.26+0.34+0.55 = **1.47**	0.25+0.10+0.20+0.41= **0.96**
TL17	0.34+0.34+0.25+0.99 = **1.92**	0.21+0.12+0.12+0.35= **0.80**
TL18	0.35+0.32+0.33+0.75 = **1.75**	0.10+0.11+0.21+0.39= **0.81**
TL19	0.30+0.41+0.28+0.54 = **1.53**	0.25+0.20+0.20+0.42= **1.07**
TL20	0.50+0.45+0.45+0.55 = **1.95**	0.21+0.10+0.10+0.34= **0.75**

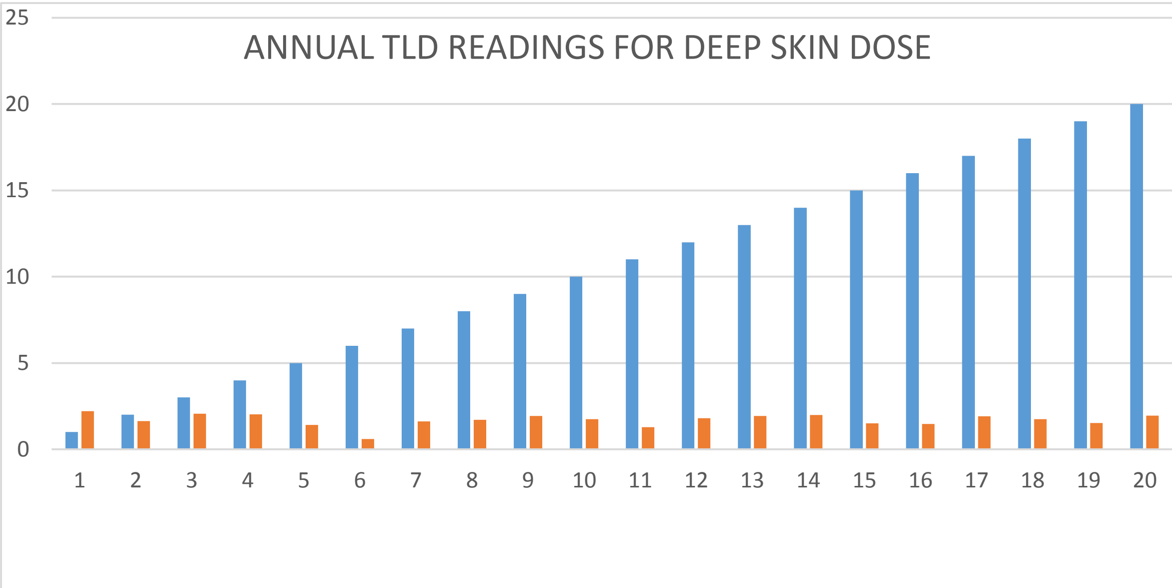


Figure 3. Annual TLD readings for Deep skin dose

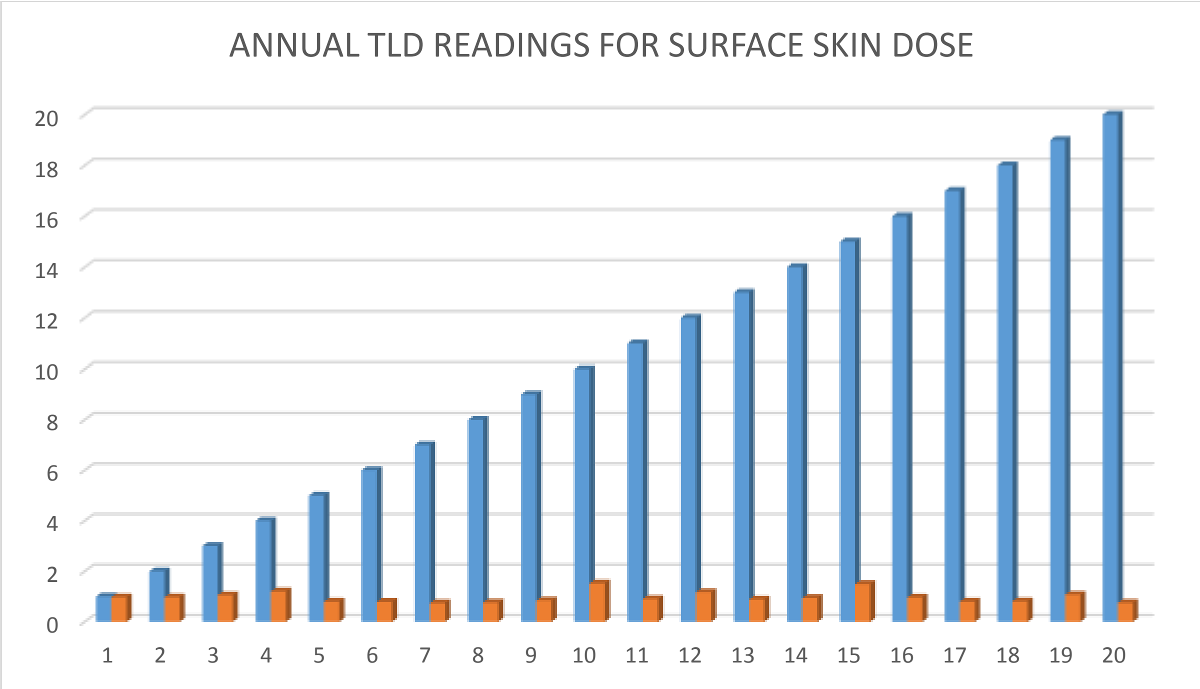
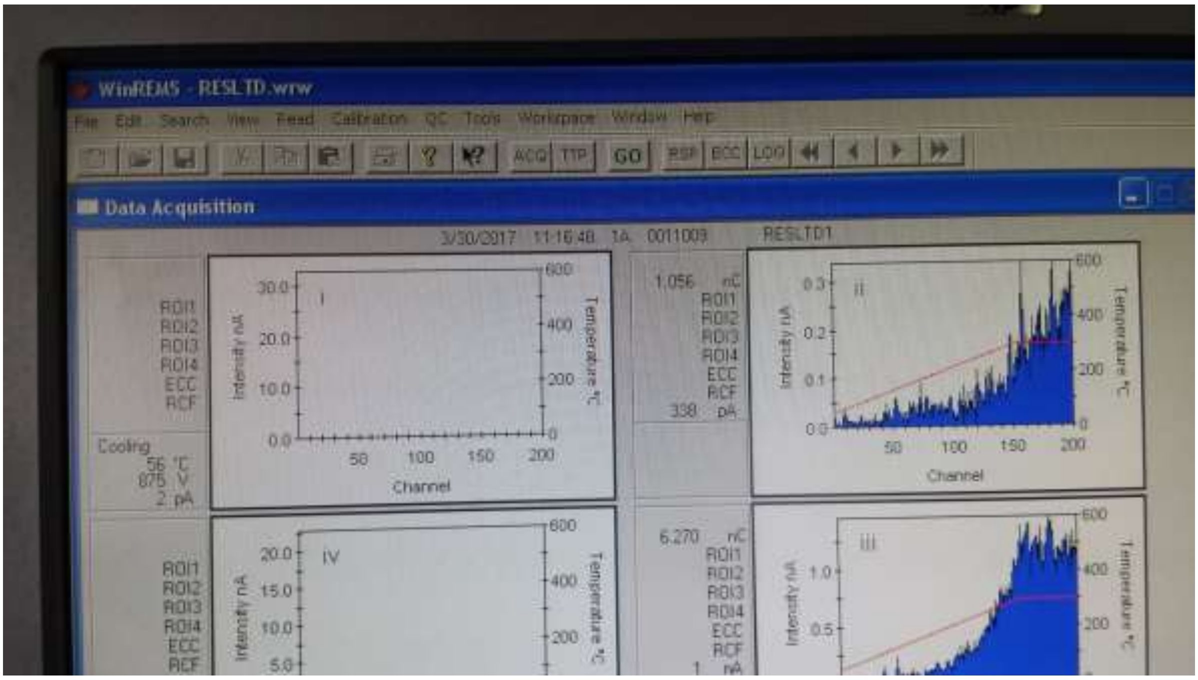


Figure 4. Annual TLD readings for surface skin dose



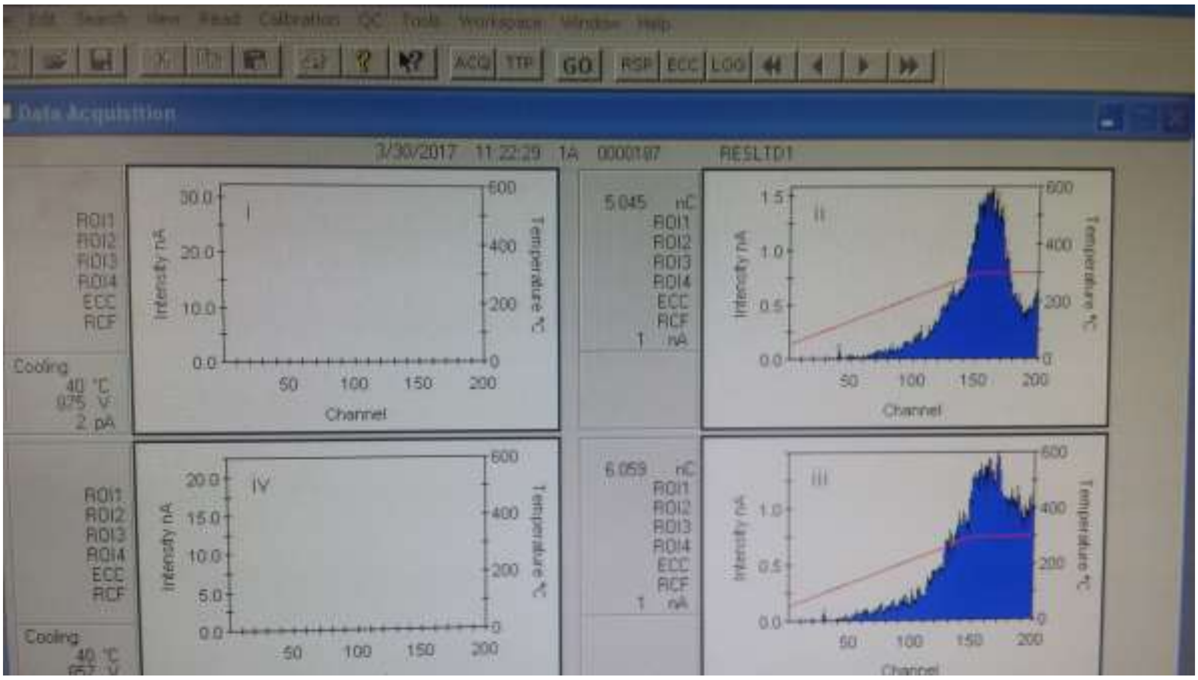


Figure 5. Thermo-luminescent dosimeter profile

Table 4 shows the annual accumulated TLD film badge readings of 20 occupational workers from January, 2019 to December, 2019. The values obtained are those for the occupational worker working in the radiology department which are read quarterly. TL1, for instance, refer to the radiation dose of a particular occupational worker for a period of one year. For this particular radiographer, the values are: 0.31, 0.55, 0.55 and 0.80, totaling 2.21 mSv for deep skin dose and 0.16, 0.15, 0.19 and 0.47, totaling 0.97 mSv for surface skin dose. The results for deep skin dose and surface skin dose are lower than the recommended annual dose limit of 5 mSv per annum.

The results from this study are similar to that of the study by *Peter, et al.* (2016), conducted on the Assessment of Radiation Protection Measures in a Nigerian Tertiary Health Care Center. The following results was obtained 1.34 and 1.03 mSv per annum for deep skin dose and surface respectively. is The results were also similar to the study by *Wiam et al.* (2019), conducted on the Occupational Dose and Radiation Protection Practice in United Arab Emirate. The results show that the occupational workers radiation exposure level was within the recommended national and international dose rate.

CONCLUSION

This study found that the level of radiation exposure for occupational workers at the Federal Medical Center Katsina, were within the acceptable level, meeting the national and international standards. Though the results revealed that the occupational radiation dose is within the recommended limits, it does not eliminate stochastic effect of radiation. Therefore, continues training of the radiation workers on the safety precautions is advised.

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REFERENCES

Dumonceau, J. M., Andriulli, A., Elmunzer, B. J., Mariani, A., Meister, T., Deviere, J.,… &Kapral, C. Radiation protection in digestive endoscopy, ESGE. (2014). Endoscopy, 46(09), 799-815

Elshami, W., Abuzaid, M., Piersson, A. D., Mira, O., AbdelHamid, M., Zheng, X., & Kawooya, M. G. (2019). Occupational Dose and Radiation Protection Practice in UAE: A Retrospective Cross Sectional Cohort Study (2002-2016). Radiation Protection Dosimetry. 45(4), 145-148

Eshiet, P., Dlama, J., Tom, A., Musa, G., Kpaku, G., & Mundi, A., (2016). Assessment of Radiation Protection Measures in a Nigerian Tertiary Health Care Center. Journal of Radiology and Medical Science, 31.

Huda, W., & Gkanatsios, N. A. (1997). Effective dose and energy imparted in diagnostic radiology. Medical Physics, 24(8), 1311-1316.

Kuipers, G., Velders, X. L., & Piek, J. J. (2010). Exposure of cardiologists from interventional procedures. Radiation protection dosimetry, 140(3), 259-265.

International Commission on Radiological Protection (ICRP) (2005). Draft; recommendations of the International Commission on Radiological Protection, Sweden

Leyton, F., Canevaro, L., Dourado. A., Castello, H., Bacelar, A., Navarro, M. T.,..& Lykawka, R. (2014). Radiation risks and the importance of radiological protection in interventional cardiology: a systematic review. Revista Brasileira de Cardiologia Invasiva (English edition), 87-98.

Abdullahi, G. (2018). CPQ Medicine (2018) 1:2 Research Article. National Council on Radiation Protection and Management. NCRP (2005). Structural Shielding Design and Evaluation for Medical use of X-rays and Gamma rays of Energies up to 10MeV, Bethesda, MD;

Olko, P. (2010). Advantages and Disadvantages of luminescence dosimetry. Radiation Measurements, 45(3-6), 506-511.

Onojo, R.A., Idoko, E.E., Onojo, R.O., & Ageda, V.I., (2017). Evaluation of Radiation Exposure Level from the use of Diagnostic Facilities at the Ahmadu Bello University Teaching Hospital, Zaria- Nigeria. International Journal on Medical Sciences. 5(1), 001-007

Joseph, D. S., Gloria, I. I., Ibrahim, Z. Y., & Zira, J. D. (2017). Radiographic Room Design and Layout for Radiation Protection in Some Radio-Diagnostic Facilities in Katsina State, Nigeria. Radiographic Room Design and Layout for Radiation Protection in Some Radio-Diagnostic Facilities in Katsina State, Nigeria, 31, 1-9.

Padovani, R., Le Heron, J., Cruiz-Suarez, R., Duran, A., Lefaure, C., Miller, D. L.,… & Czarwinski, R. (2011). International project on individual monitoring and radiation exposure levels in interventional cardiology. Radiation protection dosimetry, 144(1-4), 437-441

United Nation Scientific Committee on Effects of Atomic Radiation (UNSCEAR), (2000). Medical Radiation Exposure. Newyork: United Nations. Annex A.

Wilson-Stewart, K., Shanahan, M., Fontanarosa, D., & Davidson, R. (2018). Occupational radiation exposure to nursing staff during cardiovascular fluoroscopic procedures: A review of the literature. Journal of applied clinical medical physics, 19(6), 282-297. AAPM