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Workplace radiation dose monitoring in diagnostic radiography facilities of the Lake Zone Regions of Tanzania

Ngulimi[a] M.F., Mwimanzi[b] J.M., Ndovi[b] S.T.

[a]*Tanzania Atomic Energy Commission, Lake Zone Office, Mwanza, Tanzania*

[b]*Tanzania Atomic Energy Commission, Headquarters, P. O Box 743, Njiro Area, Arusha, Tanzania*

e-mail: faustine.miguta@taec.go.tz

ABSTRACT

Occupational radiation doses in diagnostic radiology facilities of the Lake Zone Regions of Tanzania were measured and analyzed. Thermoluminescent Dosimeters (TLDs) were distributed to 17 occupationally exposed workers from 8 selected medical diagnostic radiology facilities over a period of three (3) months. The estimated ambient doses in the facilities were measured by using a calibrated survey meter RAM DA-3-2000 of TAEC under SSDL Laboratory. The individual dose recorded ranged from 0.09 to 1.12 mSv which were all below the ICRP limit of 5 mSv for 3 months. The radiation dose (ambient) recorded at 1 m from the control lead glass window ranged from 2.60 μSv/h to 7.45 μSv/h. The ambient doses were compared to the limit of 7.5 μSv/h set by ICRP. Higher values of ambient doses and individual doses were observed in some facilities that had inadequate radiation safety and protection measures. But with the use of personal radiation protection equipment, radiation workers receive lower doses and hence abide by ALARA principle.

Keywords: **occupational radiation workers, ambient dose, individual radiation dose.**

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1. INTRODUCTION

Diagnostic investigations involving ionizing radiation in medical radiology facilities are continuously increasing [1]. The medical personnel involved during examinations are exposed to ionizing radiation and have become a critical feature as it raises concern about the potential risk posed by radiation [2] . Occupationally exposed workers have to abide with radiation protection principles as described in the International Commission for Radiological Protection (ICRP) so as to prevent deterministic effects and minimize the stochastic effects [3]. As a result, each facility is required to develop its own individual radiation monitoring program. The purpose of the individual monitoring program is to provide information on the adequacy of protection measures in place in accordance with the optimization principle and to demonstrate compliance with regulatory or generally accepted dose limits [4, 5].

The individual personnel dose received by occupationally exposed workers as a result of their work is mostly measured by using solid-state detectors mainly thermoluminescent dosimeters (TLDs). Occupationally exposed workers are required to wear TLD during working hours for radiation dose monitoring. A study conducted in Egypt shows that 15.7% of the occupationally exposed workers had poor adherence of wearing TLD which means that radiation worker's practices are unsatisfactory in regard to reducing radiation exposure for patients and themselves [6].

Literature review shows that most studies that are similar to the current study focused on comparing the radiation dose monitoring to standard results. For example, a study conducted by Chinangwa et al. [7] in Malawi on radiation dose revealed that ambient dose in radiation premises and individual dose were different but has similar trends in the same hospital. Korrir et al. [8] conducted dose estimation to radiation professionals in Kenya and found that 17% of the occupationally exposed workers were working in two facilities. Consequently, this can result in wrong reporting and or unrecorded radiation exposures. In Tanzania for instance there are occupationally radiation workers who are employed at more than one facility. If such a person could use the same TLD for both facilities, then the results could be wrongly reported. Moreover, if the person decides not wear the TLD then the dose for the other facility will be unrecorded. Thus, frequent monitoring of doses is required to ascertain the occupational safety of workers. Similarly, the study conducted by Ko et al. [2] suggested that awareness of radiation dose levels, determinants of dose, and protective measures to reduce dose can be improved by providing regular training in radiation protection. However, the magnitude of the individual dose is defined by the nature of the procedure, the individual workload, the level of radiation protection measures, or the methodology of the assessment [9].

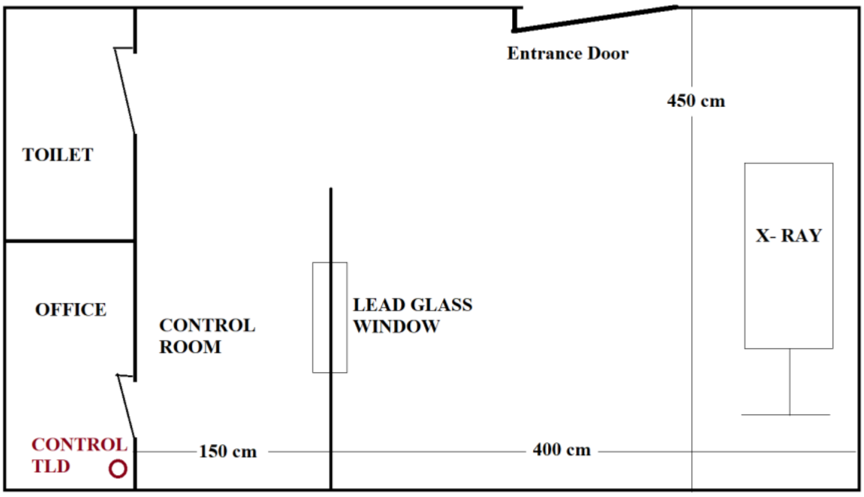
In Lake Zone Regions of Tanzania, there has been no report published concerning the radiation workplace monitoring but reports from the Tanzania Atomic Energy Commission (TAEC) have shown improper storage of TLD badges by the occupationally exposed workers and a lack of radiation safety procedures, especially in medical facilities in Tanzania. Therefore, the study was conducted to determine the workplace ambient dose and individual dose received by occupationally exposed workers and evaluate their relationships and suggest the proper ways for radiation protection and monitoring.

2. MATERIALS AND METHODS

2.1. The use of TLD

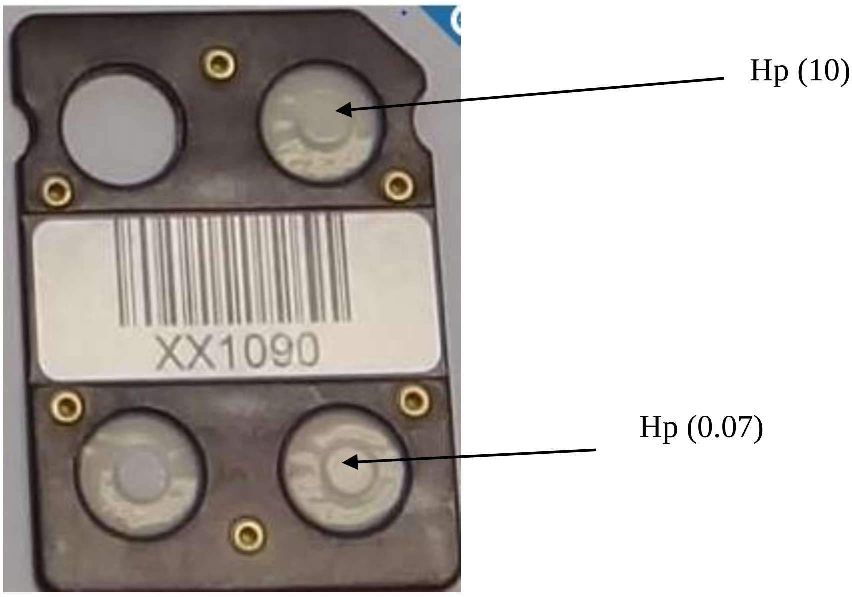
TLD consisting of lithium fluoride doped with titanium and magnesium was worn (at the upper torso) by each radiographer at the facility for a period of 3 months (i.e. May to August, 2021). Personal dose measured as (Hp (10)) and ambient dose (H*(10)) were used in this study to allow comparison and analysis of data. The control TLD's which are calibrated as (Hp (10)) were installed at specific point in the vicinity of each radiology building (Figure 1) at all facilities to record the background radiation dose at the facility and during transportation of TLD's. In this study the control TLD's dose ranged from 0.02 to 0.09 mSv.

Figure 1 *: Sketch Diagram of the radiology facility that shows the location of the Control TLD. The Contro TLD was placed in Occupational radiation workers offices*



The TLD badges used have two chips for recording personal dose equivalent Hp (0.07) for skin dose and Hp (10) for the whole body as shown in Figure 2. Personal dose equivalent (PDE), Hp (d), is defined as the dose equivalent in soft tissue below a specified point on the body at a depth d mm [10].

Figure 2 *: Diagram of Thermoluminescent Dosimeter TLD (LiF: Mg,Ti)*



The background radiation dose obtained from the control TLD that were installed at each facility (Control TLD Dose) was subtracted from the direct reading of the individual badge (Measured Dose) in order to determine the true dose received by the individual occupationally exposed worker for a period of 3 months as shown in equation 1 below:

True Dose (Hp(10)) =Measured Dose (Hp (10)) – Control TLD Dose (Hp (10)) (1)

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2.2. Harshaw reader

Harshaw 6600 plus Automatic TLD Reader with a serial number 1705468 which is one of the most technically advanced dosimetry system was used in this study. The thermoluminescent reader of type Harshaw 6600 plus readout system was used for TL signal measurements, as shown in Figure 3.

Figure 3 : *Harshaw 6600 Plus TL Reader [10]*

The TLD cards were annealed thermally at a temperature of 300 ºC, and then the annealed TLDs were packed in TLD holders dispatched to the 16 facilities according to the number of occupationally exposed workers. During the reading process the TLDs were treated for 5 seconds at a preheat temperature of 150 ºC, and the heating rate of 15 ºC s^{-1} to attain a temperature of 300 ºC at a time of 13.3 s. The glow curve of field TLDs is proportional to the dose receive at the field which measure the whole body dose i.e. the higher the irradiated dose the stronger TL readout signal [11].

2.3. Calibrated Survey Meter for Ambient Dose Measurement

A calibrated survey meter Model RAM DA-3-2000 of Tanzania Atomic Energy Commission (TAEC) under Secondary Standard Dosimetry Laboratory (SSDL) which is traceable to the network of SSDL of IAEA was used to measure the ambient dose in the control cubicle of each X-ray room used in this study. The measurements were done at 1 meter from the control lead glass and about 1.0 meter above the floor where occupational radiation worker stand during exposure.

2.1. Data Processing and Analysis

In this study the Microsoft Excel, Statistical Package for the Social Sciences (version 20; SPSS Inc; New York, USA) and Windows Radiation Evaluation and Management System (WinREMS) were used to analyze the collected data.

3. RESULTS AND DISCUSSION

Eight (8) diagnostic radiology facilities with a total of seventeen (17) occupationally radiation workers were selected in this study based on high patients' workload of more than 40 patients per week. Table 1 below shows diagnostic radiation facilities (F) containing occupationally radiation workers (W) with the X-ray machine used in this study. In the facility F2 and F3, mobile X-ray machines are used in the normal X-ray rooms which consist with Control Room and Lead Glass window for the protection of the Occupational radiation workers. Mobile X-ray machine in F2 was installed with a short exposure cable which cannot be extended to the Control room for exposure as a result parts of the Occupational radiation workers are exposed during administering of radiation to patients while the mobile X-ray in F3 uses remote when exposing which enables proper positioning of the radiation workers.

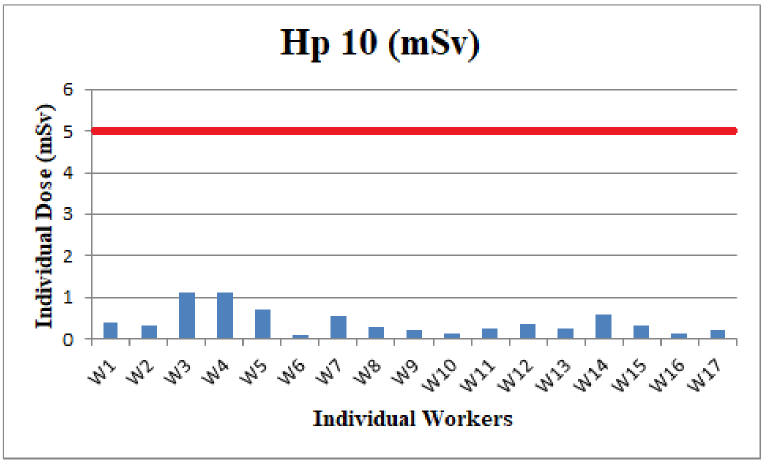
Table 1: The number of Radiation Facilites, Occupationally Radiation Workers and Type of installation (fixed/mobile) used in the study

Facility	Radiation Worker	X-Ray MachineType	Exposure Means
F1	W1, W2	Fixed	Switch
F2	W3, W4	Mobile	Switch
F3	W5, W6	Mobile	Remote
F4	W7, SW, W9	Fixed	Switch
F5	W10, W11	Fixed	Switch
F6	W12, W13	Fixed	Switch
F7	W14, W15	Fixed	Switch
F8	W16, W17	Fixed	Switch

3.1. Individual Dose

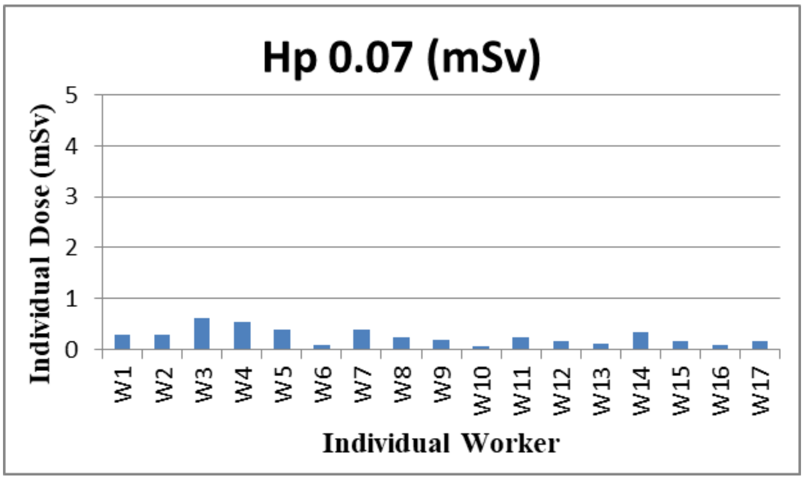
The results shows that the individual doses for the whole body (Hp (10)) ranged between 0.09 to 1.12 mSv (mean = 0.41, median = 0.33, Standard Deviation = 0.31) for a period of 3 months. The dose to the skin ranged from 0.06 to 0.62 (mean = 0.25, median = 0.24, Standard Deviation = 0.16). The whole body dose (Hp (10)) for all 17 workers (W1 –W17) was found below the ICRP 1997 dose limit of 5 mSv for 3 months period (Figure 4).

Figure 4 *: Individual whole body radiation dose to workers for the period of 3 months. The red line shows the quarterly radiation dose limit of 5 mSv*



Consequently, the skin dose for radiation workers was found to be below the ICRP limit of 125 mSv for 3 months period (Figure 5). This entails that the radiation protection mechanism is effective in the selected 8 facilities. However, the whole body individual dose recorded for worker W3 and W4 from the facility F2 was 1.11 mSv and 1.12 mSv respectively, which is sought to be higher than all others. This is suggested to be contributed by improper positioning of radiographer during exposure due to the short exposure cable of the mobile X-ray machine which cannot be extended to the Control cubicle when exposing.

Figure 5 *: Individual skin radiation dose to workers for the period of 3 months*



It was revealed that the frames of the lead glass window were not effectively shielded. This led to leakages of radiations which were detected by radiation survey meter through the edges of the lead glass window of the facility F2. It was observed that the window was fitted without adequate overlapping into the wall and thus leads to the increased radiation exposure to workers W3 and W4. However, the doses for other workers were found to be lower, which confirm that the ALARA (As Low As Reasonably Achievable) principle is well observed as well as physical radiation safety measures in the working environment is available.

3.2. Ambient Dose

The radiation survey around the workplace was conducted to determine the ambient radiation dose reaching the radiographer at the control panel. The radiation survey helps to determine whether the radiation doses received by the workers are within recommended dose limit or not. Table 2 shows that the ambient doses at all diagnostic radiology facilities (F1 to F8) are below the recommended limit of 7.5 µSv/hr [12]. However, the doses in facilities F2 and F8 are close to the limit and that gives an alarm that the radiation protection is not effective in the two radiology facilities. The Ambient Doses for 3 months was obtained by using the equation 2 below:

$$\text{Ambient Dose for 3 months} = W * [H^*(10)] * \frac{12\ week}{3\ months} * \frac{1\ hr}{60\ min} * 1/I \quad (2)$$

Where: W is the weekly workload in (mA.min/week) per 3 months, H*(10) is the measured ambient dose in µSv/hr, I is the x-ray anodic current used on measurement.

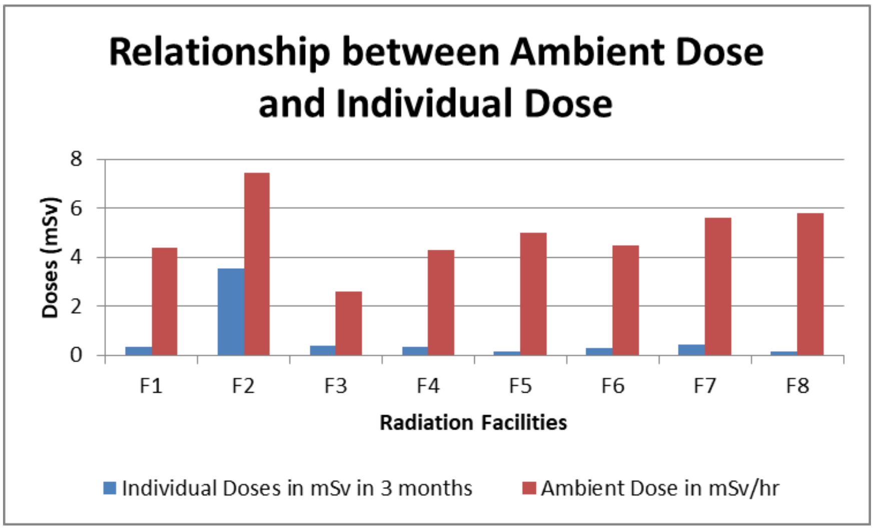
Table 2: Ambient Doses for 3 months at each Diagnostic Radiation Centre

Centre	Measured	
	Ambient Dose, H*(10) in µSv/hr	**Ambient Dose for three (3) months (mSv/3 months)**
F1	3.38 ± 1.07	4.41
F2	7.27 ± 2.30	7.45
F3	2.15 ± 0.68	2.60
F4	4.34 ± 1.37	4.30
F5	4.23 ± 1.34	5.01
F6	3.49 ± 1.10	4.48
F7	5.17 ± 1.63	5.62
F8	6.23 ± 1.97	5.8

The ambient dose and the individual dose have registered a positive correlation of 0.69 which suggest that they have the same trend in radiation working environment. An exception is shown in facility F8 where ambient dose is high and individual dose is low (Figure 6). This can be explained by the tendency of wearing lead apron by radiation workers (W16 and W17) when exposing radiation to patients. The protective lead apron is worn on top of the TLD thus obscure radiation from reaching the radiation workers.

Comparison with other international studies shows that the annual average individual dose in this study falls within the range of other studies. The study in Saudi Arabia revealed an annual dose 0.66 mSv [13] which is lower than that prescribed in this study which is 1.6 mSv (obtained after multiplying quarterly average dose which is 0.4 mSv by 4) and studies from Malawi [7] showed an annual individual dose of 2.96, which is higher than that of this study.

Figure 6 *: Relationship between Ambient dose and Individual dose*



4. CONCLUSION

The ambient and individual dose are presented and showed that they are all below the international limits set by international organizations. However, some improper radiation safety and protection measures in radiation facilities were noted and have contributed to unnecessary higher ambient and individual doses. But with the use of protective gears, radiation workers are much safer in the bad alarming radiation environment. The regulator should emphasize more on radiation protection training to radiation workers as well as licensees and engage more enforcement actions so as to abide with ALARA principle.

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