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Personnel radiation dose assessment using a novel dosimeter in the department of radiology and dentistry in a medical facility in Delta State, South-South Nigeria: our experience in the last 4 years

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ABSTRACT

Objectives. Large percentages of X-ray facilities in Nigeria do not use radiation monitoring device; a few percentage that use them do not evaluate or carryout out assessment programs to ascertain the detriment to occupationally exposed workers. This study was aimed at evaluating dose reports from 2013 to 2016 for personnel who operate radiation facilities and those that work within radiation field during certain X-ray procedures/examinations in the department of radiology and dentistry respectively; to ascertain if there is correlation between personnel dose and workload in both department and to determine if dose records are within acceptable limit recommended by the International Atomic Energy Agency (IAEA) safety series. ***Methods.*** Direct Ion Storage (DIS) dosimeter was used for a total of 35 occupationally exposed personnel who work in the department of radiology and dentistry. The DIS dosimeter was read every two months and results were authomatically saved on the instadose™ platform. ***Results.*** The mean (total) dose in radiology department for the first, second, third and fourth year was 0.17 ± 0.08 (3.52) mSv, 0.08 ± 0.03 (0.77) mSv, 0.07 ± 0.04 (0.72) mSv and 0.07 ± 0.05 (0.55) mSv and in Dentistry was 0.08 ± 0.02 (0.73) mSv, 0.05 ± 0.02 (0.42) mSv, 0.05 ± 0.02 (0.24) mSv and 0.07 ± 0.04 (0.34) mSv; respectively. There was significant difference in mean personnel dose from 2013-2016 in Radiology (p=0.028) and in Dentistry Department (p=0.004). Correlation of workload and personnel dose in Radiology (p=0.240) and Dentistry Department (p=0.765) wasn't significant. There was no correlation in mean dose between both department (p=0.256). **Conclusion.** Overall mean dose in both department for occupationally exposed personnel were below IAEA annual dose limit of 20 mSv averaged over a period of 5 consecutive years. Dose reports of personnel in both department reduced as the year progressed due to radiation safety awareness.

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Keywords: Direct ion storage dosimeter, ion-chamber, panoramic, cephalometric, workload

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Introduction

In late 1895, X-ray was discovered by Wilhelm Conrad Röntgen; a professor of Physics at the University of Würzburg Germany, ever since this discovery, Medicine and other fields have benefited immensely on its use [1-3]. The use of radiation for medical diagnostic examinations has contributed approximately over 95% of man-made radiation exposure and is only exceeded by natural background as a source of exposure to the world's population [4, 5]. The effect of exposure to ionising radiation became evident only a few years after its discovery. This scenario points to the fact that sites/environment where these machines are used may be under threat of secondary (scatter and leakage) radiation if no safety standards and precautions are followed [6-8]. This has made the International community to look into how this "useful but dangerous particle can be used effectively". In the same vein, several International bodies have been established with several roles on how well to manage ionizing radiations; one of such is the International Atomic Energy Agency (IAEA) [9]. Today, it is widely used in diagnosis and treatment of malignancy like cancer and other tumours. One major casualty of eventual fallout of radiation is the occupationally exposed personnel who spend their life time working within radiation facilities [10-12]. In Nigeria today there are over 4,000 X-ray machines in use [13]. The Nigerian Nuclear Regulatory Authority (NNRA) which is the country's national body is saddled with the responsibility of regulating radiological protection and nuclear safety so as to ensure the protection of life, health, property and the environment from the harmful effect of ionizing radiation [14].

In Nigeria, studies have shown that many hospital-based Radiology/Dental department and privately owned diagnostic X-ray centres do not use radiation monitoring devices; a few that use them do not evaluate their reports/records over a long period of time [15, 16].

Several devices are currently in use for personnel dose measurement, such as the P-Channel Metal-Oxide Semiconductor (pMOS) with Radiation-Sensing Field Effect Transistor (RADFET) dosimeter [17, 18], Direct Ion Storage (DIS) dosimeters [19-23], Thermoluminescent dosimeter (TLD) [24] and Optically Stimulated Luminescent (OSL) dosimeters [25]. Currently in Nigeria only a few X-ray facility use OSL, majority use TLD [14]. More recently, the limitations of TLDs in Nigeria were attributed to problem arising from distances between dosimeter providers and end users, activation of heat while transporting them and the inability of end-users to get readouts at anytime they so desire. The above mentioned problems gave rise to the use of DIS dosimeter which can be read with a mobile device at anytime and anywhere.

This study would focus only on occupational exposed personnel who are assigned a new type of dosimeter called the DIS dosimeter. Also, the study will evaluate dose records of occupationally exposed personnel and those who occasionally work close to X-ray facilities both in Radiology and Dentistry Department and will determine if personnel radiation dose have direct correlation with workload which is a function of the X-ray output per week at a well defined point in each department and to determine if personnel mean effective doses are within acceptable dose limits, specified in the IAEA Safety Series and International Commission on Radiation Units and Measurements (ICRU) publication 60 and 103 [6, 7, 26, 27].

Methods

This research was a retrospective study, which was carried out from 2013 to 2016. The personnel involved in this study were permanent staffs of the hospital. In Radiology Department they include: Radiologist, Radiographers, Imaging Technicians, Health Attendants/Nurses, Porters and a Medical Physicist. Exempted from this study were Intern Radiographers, undergraduate Clinical Radiography student, undergraduate Imaging Technicians, cleaners and clerical officers. In the same vein, personnel involved in this study from Dentistry Department were: Dental Surgeons and Dental Technicians. Exempted were undergraduate Dental Technicians. Intern and student were also monitored but their dose data/records were not included in this study. The reason for this exemption was because of their short stay in both departments. Ethical approval was granted by the institution where the research took place.

The material used for this study was Forty pieces of Direct Ion Storage Dosimeter (25 pieces of it was used in Radiology and 15 pieces was used in Dentistry department). The DIS dosimeter can be activated and assigned to a user. It can also be deactivated if a user no longer works with the X-ray facility and can be reassigned to another user.

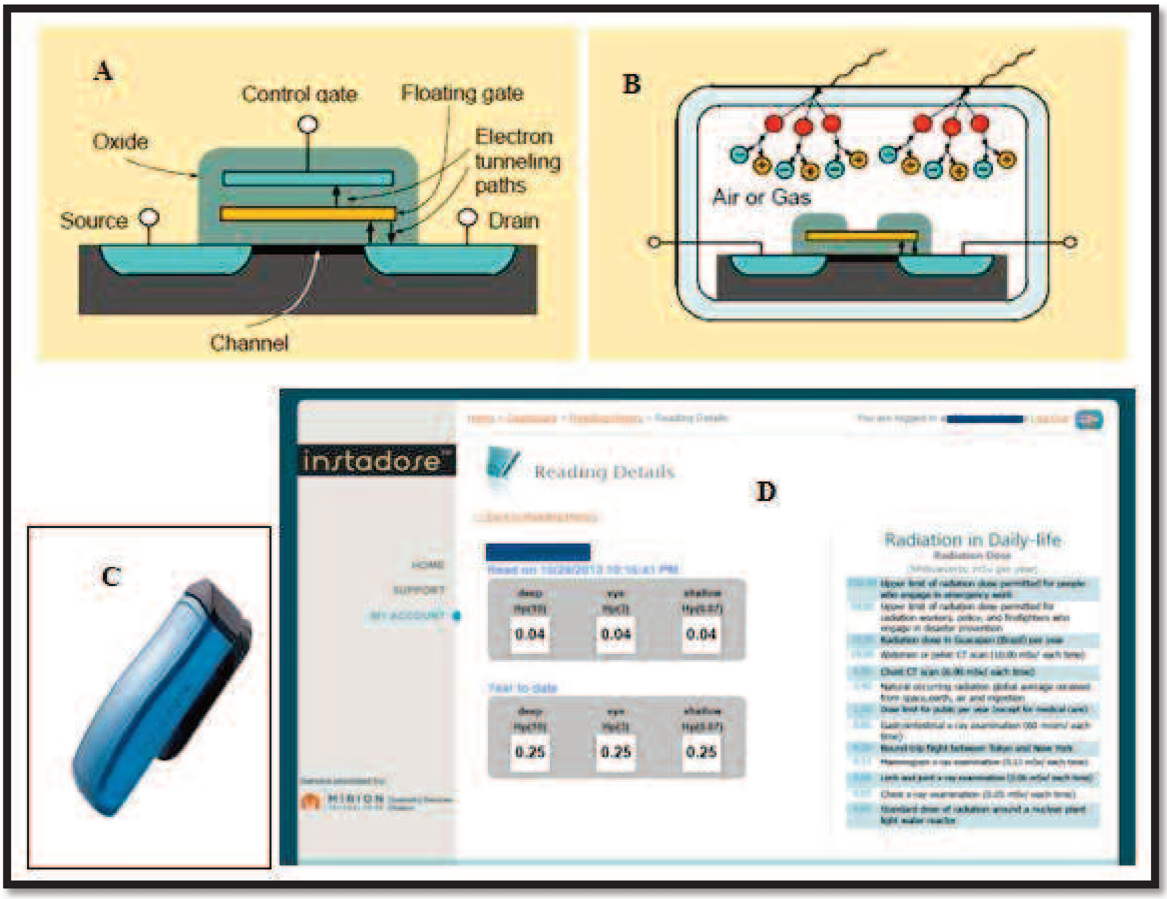

Figure 1. (A) Analog EEPROM memory cell, (B) DIS memory cell with the formation of a conductive wall (ion chamber), (C) DIS Dosimeter, (D) instadose^{TM} Readout platform

The Radiological equipment used were two Conventional (both floor mounted) X-ray machine with maximum voltage/current of 125kVp/500mAs and 150kVp/630mAs respectively, one Fluoroscopy X-ray machine with maximum voltage/current of 150kVp/800mAs and one Mammography X-ray machine with maximum voltage/current of 35kVp/500mAs. The dental equipment used were five wall mounted intra-oral (IO) X-ray machine each of anode voltage and current of 70kVp and 7mA, one Panoramic/Cephalometric X-ray machine with maximum anode voltage and current of 90kVp and 10mA and exposure timer of 13 sec for Panoramic and 15sec for Cephalometric . The mentioned equipment was used throughout the study.

The principle of operation of the Direct Ion Storage (DIS) dosimeter is a combination of a hybrid of ion chamber and Floating Gate Metal-Oxide-Semiconductor Field-Effect Transistors (FGMOSFETs). In the DIS memory cell, the oxide layer surrounding the floating gate has an opening allowing the surface of the floating gate to be in direct contact with the surrounding air (or any other gas). The ionising radiation incident in the air or gas produces electron-ion pairs which is effectively formed between the wall and the floating gate by surrounding the entire structure with a conductive wall (ion chamber) with extremely high mobility and in case there is an electric field surrounding the floating gate, these charge carriers will be transferred efficiently to the gate before any recombination occurs [Figure 1A]. The DIS dosimeter contains an Analog-Electrical Erasable and Programmable Read Only Memory (EEPROM) cell [Figure 1B]. The charge in the floating gate can be set to a predetermined level by tunnelling electrons through the oxide layer. The charge is then stored permanently in the gate due to the fact that in the normal operating temperature range the electrons have a very low probability of exceeding the energy barriers in the metal-oxide and oxide-silicon interfaces carriers, of which Na-ions are usually the most dominant. Today it is possible to manufacture memory cells that are capable of retaining a stored charge for hundreds of years. Reading the stored information is carried out by measuring the channel conductivity of the transistor without disturbing the stored charge.

The DIS dosimeter has the capacity to measure

Table 1. Radiology mean personnel dose for year 2013 & 2014

Assigned user	Group	X-ray Equipment used	$H_P(10)$ Deep dose (mSv)	$H_P(0.07)$ Shallow dose (mSv)	$H_P(3)$ Eye dose (mSv)	Body Region
Year 2013						
R_1	Radiographer	C	0.10	0.10	0.10	Torso
R_2	Radiographer	C/M	0.10	0.10	0.10	Torso
R_3	Radiographer	C/M/F	0.17	0.17	0.17	Torso
R_4	Radiographer	C/M/F	0.13	0.13	0.13	Torso
R_5	Radiographer	C/M/F	0.20	0.20	0.20	Torso
R_6	Radiographer	C/F	0.17	0.17	0.17	Torso
R_7	Radiographer	C/F	0.18	0.18	0.18	Torso
R_8	Radiographer	C/F	0.12	0.12	0.12	Torso
R_9	Radiographer	C/F	0.15	0.15	0.15	Torso
R_{10}	Radiographer	C/F	0.11	0.11	0.11	Torso
R_{11}	Radiographer	C/F	0.15	0.15	0.15	Torso
R_{12}	Porter	***	0.09	0.09	0.09	Torso
R_{13}	Health. A/Nurse	C/M/F	0.07	0.07	0.07	Torso
R_{14}	Technicians	***	0.05	0.05	0.05	Torso
R_{15}	Technicians	***	0.10	0.10	0.10	Torso
R_{16}	Technicians	***	0.08	0.08	0.08	Torso
R_{17}	Technicians	***	0.09	0.09	0.09	Torso
R_{18}	Technicians	***	0.07	0.07	0.07	Torso
R_{19}	Radiologist	C/F	0.44	0.44	0.44	Torso
R_{20}	Radiologist	C/F	0.45	0.45	0.45	Torso
R_{21}	Radiologist	C/F	0.50	0.50	0.50	Torso
Year 2014						
R_1	Radiographer	C	0.07	0.07	0.07	Torso
R_2	Radiographer	C/M/F	0.04	0.04	0.04	Torso
R_3	Radiographer	C/F	0.09	0.09	0.09	Torso
R_4	Radiographer	C/M/F	0.10	0.10	0.10	Torso
R_5	Radiographer	C/M/F	0.09	0.09	0.09	Torso
R_6	Radiographer	C/F	0.05	0.05	0.05	Torso
R_7	Porter	***	0.04	0.04	0.04	Torso
R_8	Technicians	***	0.06	0.06	0.06	Torso
R_9	Radiologist	C/F	0.12	0.12	0.12	Torso
R_{10}	Radiologist	C/F	0.11	0.11	0.11	Torso

*** Personnel proximal to the facility, C/M/F = Conventional/Mammographic/Fluoroscopic, A = Attendant

deep, shallow and lens dose. Measurements at the deep dose equivalent [HP (10)] are a concept that applies to external whole body radiation. It is the dose equivalent at a tissue depth of 1 centimetre. This quantity is usually determined using a "whole body" dosimeter. It does not apply to weakly penetrating radiation such as alpha particles or low-energy electrons. Also, the shallow dose equivalent [HP (0.07)] applies to external exposure of the skin of the whole body or the skin of an extremity. It is the dose equivalent just below the cornified layer of the skin at a tissue depth of 0.007 centimetre averaged over an area of 10 square centimetres. Thirdly, the lens or eye dose equivalent [HP (3)] applies to external exposure to the lens of the eye. It is the dose equivalent at a tissue depth of 0.3 centimetres. This quantity is usually determined using a "whole body" dosimeter worn at or near the torso level. It does not apply to weakly penetrating radiation such as alpha particles or low-energy electrons. The DIS minimum reportable dose is 3 rem [0.03 millisievert (mSv)] and 1rem (0.01 mSv) upon reset, with low limit of detection of 1 rem (0.01 mSv). The useful dose range is 0.01 mSv-5 Sv, with energy response of 5 keV-6 MeV [Figure 1C&1D]. The algorithm of the instadose™ platform will only compute dose whenever equivalent dose is 0.03 mSv and will record "below reportable dose (BRD)" which is clearly shown on the readout of the instadose™ platform whenever dose is < 0.03 mSv. The X-ray machine used by radiographer (C/F/M) and

Table 2. Radiology mean personnel dose for year 2015 & 2016

Assigned user	Group	X-ray Equipment used	H_P (10) Deep dose (mSv)	H_P (0.07) Shallow dose (mSv)	H_P (3) Eye dose (mSv)	Body region
Year 2015						
R_1	Radiographer	C/M/F	0.04	0.04	0.04	Torso
R_2	Radiographer	C/F	0.04	0.04	0.04	Torso
R_3	Radiographer	C/M/F	0.03	0.03	0.03	Torso
R_4	Radiographer	C/M/F	0.08	0.08	0.08	Torso
R_5	Radiographer	C/F	0.10	0.10	0.10	Torso
R_6	Radiographer	C/F	0.03	0.03	0.03	Torso
R_7	Health. A/Nurse	C/M/F	0.04	0.04	0.04	Torso
R_8	Technicians	***	0.03	0.03	0.03	Torso
R_9	Technicians	***	0.09	0.09	0.09	Torso
R_{10}	Radiologist	C/F	0.10	0.10	0.10	Torso
R_{11}	Radiologist	C/F	0.14	0.14	0.14	Torso
Year 2016						
R_1	Radiographer	C/M/F	0.06	0.06	0.06	Torso
R_2	Radiographer	C/M	0.03	0.03	0.03	Torso
R_3	Radiographer	C/F	0.15	0.15	0.15	Torso
R_4	Radiographer	C/M/F	0.03	0.03	0.03	Torso
R_5	Radiographer	C/M/F	0.04	0.04	0.04	Torso
R_6	Technicians	***	0.04	0.04	0.04	Torso
R_7	Radiologist	C/F	0.12	0.12	0.12	Torso
R_8	Radiologist	C/F	0.08	0.08	0.08	Torso

*** Personnel proximal to the facility, C/M/F = Conventional/ Mammographic/ Fluoroscopic, A = Attendant

technicians (C/P/IO) were indicated in the tables and personnel categorized as those that work proximal to facility operators (radiographer and dental technicians) were left empty [Table 1, 2 and 3].

Statistical Analysis

Data analysis was done using Microsoft Excel and SPSS Version 16.0 Software. A p value <0.05 was considered to be statistically significant.

Results

The mean/total dose in Radiology Department in 2013 was 0.17± 0.08 (3.52) mSv, 2014 was 0.08± 0.03 (0.77) mSv, 2015 was 0.07± 0.04 (0.72) mSv and 2016 was 0.07± 0.05 (0.55) mSv. The highest readout was noticed from the Radiologist unit (0.5 mSv) [Tables 1 and 2]. One-Sample T Test in Radiology department show that in 2013 the mean dose report among personnel had statistically significant difference (p=0.000), this was also similar in 2014 (p=0.000) [Table 1], 2015 (p=0.000) and 2016 (p=0.003) [Table 2]; respectively. Personnel mean dose from the first year of study (2013) to the fourth year of study (2016) showed that there was significant difference in dose value (p=0.028).

The mean/total dose in Dentistry Department in 2013 was 0.08± 0.02 (0.73) mSv with the highest readout from the Dental Technician, 2014 was 0.05± 0.02 (0.42) mSv with the highest readout from the Dental Surgeon, 2015 was 0.05± 0.02 (0.24) mSv with the highest readout from the Dental Technician and 2016 was 0.07± 0.04 (0.34) mSv with the highest readout from the Dental Surgeon (Table 3). In the same vein, One-Sample T Test in Dentistry department show that in 2013 the mean dose among personnel had statistically significant difference (p=0.000), this was also similar in 2014 (p=0.002), 2015 (p=0.003) and 2016 (p=0.012) (Table 3); respectively. Similarly, personnel mean dose from the first year of study (2013) to the fourth year of study (2016) showed that there was generally significant difference in dose value (p=0.004)

The average number of patient per week/workload in Radiology Department in 2103 was 187/340mA–min/Wk, 2014 was 159/290mA–min/Wk, 2015 was 185/328mA–min/Wk and 2016 was 160/242mA–

Table 3. Mean dose from 2013-2016 in the dental department using Panoramic, Cephalometric and Intra-Oral X-ray machine

Assigned user	Group	X-ray Equipment used	$H_P(10)$ Deep dose (mSv)	$H_P(0.07)$ Shallow dose (mSv)	$H_P(3)$ Eye dose (mSv)	Body region
Year 2013						
R1	Dental technician	C/P/IO	0.05	0.05	0.05	Torso
R2	Dental technician	C/P/IO	0.08	0.08	0.08	Torso
R3	Dental technician	C/P/IO	0.05	0.05	0.05	Torso
R4	Dental technician	C/P/IO	0.12	0.12	0.12	Torso
R5	Dental technician	C/P/IO	0.08	0.08	0.08	Torso
R6	Dental technician	C/P/IO	0.08	0.08	0.08	Torso
R7	Dental technician	C/P/IO	0.07	0.07	0.07	Torso
R8	Dental Surgeon	***	0.10	0.10	0.10	Torso
R9	Dental Surgeon	***	0.10	0.10	0.10	Torso
Year 2014						
R1	Dental technician	C/P/IO	0.04	0.04	0.04	Torso
R2	Dental technician	C/P/IO	0.03	0.03	0.03	Torso
R3	Dental technician	C/P/IO	0.03	0.03	0.03	Torso
R4	Dental technician	C/P/IO	0.04	0.04	0.04	Torso
R5	Dental technician	C/P/IO	0.06	0.06	0.06	Torso
R6	Dental technician	C/P/IO	0.05	0.05	0.05	Torso
R7	Dental Surgeon	***	0.10	0.10	0.10	Torso
R8	Dental Surgeon	***	0.07	0.07	0.07	Torso
Year 2015						
R1	Dental technician	C/P/IO	0.04	0.04	0.04	Torso
R2	Dental technician	C/P/IO	0.07	0.07	0.07	Torso
R3	Dental technician	C/P/IO	0.06	0.06	0.06	Torso
R4	Dental technician	C/P/IO	0.03	0.03	0.03	Torso
R5	Dental Surgeon	***	0.04	0.04	0.04	Torso
Year 2016						
R1	Dental technician	C/P/IO	0.04	0.04	0.04	Torso
R2	Dental technician	C/P/IO	0.03	0.03	0.03	Torso
R3	Dental technician	C/P/IO	0.12	0.12	0.12	Torso
R4	Dental Surgeon	***	0.05	0.05	0.05	Torso
R5	Dental Surgeon	***	0.10	0.10	0.10	Torso

P= Panoramic, C= Cephalometric, IO = Intra-Oral, *** Personnel proximal to the facility

min/Wk, with 2013 having the highest number of patient per week [Table 4].

The average number of patient per week in Dentistry Department in 2013 was 62/7.1mA–min/Wk, 2014 was 83/9.3mA–min/Wk, 2015 was 65/7.3mA–min/Wk and 2016 was 47/5.2mA–min/Wk, with 2013 having the highest number of patient per week [Table 4].

Discussion

Total effective dose received by radiographers in Radiology Department in 2013 was the highest (1.58 mSv) which represent 44.9% of the total dose received in that year; radiologist had a total dose of 1.39 mSv which was 39.5% of the total dose; followed by technicians who had a total dose of 0.39 mSv which was 11.1% of the total dose, while porters and health attendance /Nurse had 0.16 mSv corresponding to 4.5% of the total dose. The highest recorded dose was from Radiologists who were engaged with special examination while using the fluoroscopy unit.

In 2014, radiographers dose reduced by 72.2% against 2013 dose value and radiologist dose reduced by 83.5% in 2014 against 2013 dose value. This reduction was attributed to dose values that were below reportable dose (BRD) from the instadose™ readout of some personnel which was necessitated by awareness and compliance with simple radiation safety rules during exposure. The highest dose in 2014

Table 4. Average workload from 2013-2016 in Radiology and Dentistry Department

Year	Average number of patient per week	Workload (W) (mA-min/Wk)
Radiology Department		
2013	187	340
2014	159	290
2015	185	328
2016	160	242
Dentistry Department		
2013	62	7.1
2014	83	9.3
2015	65	7.3
2016	47	5.2

was from the radiologist unit (0.12 mSv) which was 76% lower than the highest dose value in 2013. Although, the highest dose value was far below 20 mSv IAEA limit in a year [6, 7, 26, 27].

Radiographers dose record further reduced by 79.7% in 2015 against 2013 record and radiologist dose slightly increased from 16.6% to 17.3% from 2014 to 2015. The highest dose was still seen to be among the radiologist, while the least dose was from the health attendant/ nurse (0.04 mSv). In 2016, radiographer dose record was 80.4% lower than 2013 record with that of the radiologist being 85.6% lower than 2013 dose record. The highest (radiologist) and least dose (technician) were 0.2 mSv and 0.04 mSv, respectively. In general, radiologist effective doses were the highest. The next are radiographer who must times stay behind the lead screen or shield during radiographic, mammographic and fluoroscopic examinations. The dose received by the radiologist, radiographer and health attendance who work closely with the patient might largely be due to secondary radiation which are usually scatter radiation from patient or any other material in the X-ray room or leakage radiation from the tube head.

Annual mean effective dose in radiology department (using conventional, fluoroscopic and mammographic X-ray) varied in the range of 0.03-0.50 mSv over four years. This value was seen to be below a study conducted in 2010 using TLDs by Jabeen *et al.*[28] in Pakistan whose annual average effective dose in Diagnostic Radiology (DR) using conventional, fluoroscopic and mammographic X-ray machines from 2003-2007 ranged from 1.22-1.71mSv. Also this study's mean annual dose (0.17 mSv) in radiology department was lower compared to Nassef and Kinsara's study [29] whose annual mean dose was 0.66 mSv in diagnostic radiology using TLDs. Radiologist mean effective dose in this study was 0.23 mSv with range of 0.08-0.5 mSv; it was lower compared to Nassef and Kinsara's study [29] whose mean effective dose was 0.39 mSv with a range of 0.09-1.49 mSv.

Evaluation of dose value in Radiology Department between 2013 and 2014 show that difference existed in personnel dose (p=0.001), similar result was noticed between 2013 and 2015 in personnel dose (p=0.002), continuous trend was noticed between 2013 and 2016 likewise in personnel dose (p=0.002). There was no difference in personnel dose between 2014 and 2015 (p=0.171), also no significant difference was noticed between 2014 and 2016 (p=0.643) and between 2015 and 2016 in personnel dose (p=0.970).

The average number of patient per week and workload from 2013-2016 in Radiology Department were: 187/340, 187/290, 187/328 and 187/242mA-min per week; respectively with no significant correlation between personnel dose and workload (p=0.394) [Table 3]

Dental technicians in 2013 had a total dose of 0.53 mSv which accounted for 72.6% of the total dose received and the total dental surgeon dose was 0.2 mSv which translated to 27.4% of total dose received. Reduction of dose was noticed in 2014 for technicians (with total wearer of eight) which were 42.5% lower than those obtained in 2013 with total wearer of nine. It was noticed that two technicians dose value were below reportable dose throughout the year. Total dose in 2015 for technicians were 0.2 mSv with a dose reduction of 20% from 2014 (where technicians total dose was 0.25 mSv). There was reduction in the number of technician and dental surgeon because their dose values were below reportable dose throughout the year. 2016 technician dose value was 5% lower than 2015. There was gradual reduction in the number technicians (Table 3), this was due to the fact that some personnel dosimeters were below reportable dose. Generally dose values in the dental department were below 20 mSv annual dose limit [6, 7, 26, 27].

A study conducted by Gray *et al.* [30] using TLD investigated the dose received by dental staff using Intra-oral X-ray unit. Measured mean monthly dose was 0.0078 mSv; this value was lower compared to our study which was 0.005 mSv/month with the DIS dosimeter.

Evaluation of dose value between 2013 and 2014 show that difference existed in personnel dose (p=0.021), deviation in result was noticed between 2013 and 2015 in personnel dose (p=0.274), between 2013 and 2016 personnel dose was different (p=0.038). There was no difference in personnel dose between 2014 and 2015 (p=0.627), also no significant difference was noticed between 2014 and 2016 (p=1.000) and between 2015 and 2016 in personnel dose (p=0.484).

The average number of patient per week and workload from 2013-2016 in Dentistry Department were: 62/7.1, 83/9.3, 65/7.3 and 47/5.2mA-min per week respectively with no significant correlation between personnel dose and workload (p=0.413) [Table 4].

The Limitations of the Study

Personnel not regularly wearing their DIS dosimeter was challenging in getting accurate dose record most especially among radiographers, radiologist and dental surgeons. Another limitation was "below reportable dose" which eventually count personnel dose as insignificant.

Conclusions

The first year of the DIS dosimeter had the highest dose in both departments but as the year progresses personnel dose gradually reduces due to radiation protection training that was implemented. Personnel dose report in radiology and dentistry department was generally below IAEA/ICRU annual dose limit of 20 mSv averaged over a period of 5 consecutive years.

Authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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Contributions

ADO: involved in concept, design, literature search, data acquisition and analysis, statistical analysis and manuscript preparation, editing and reviewing, MOA: involved in design, literature search, data acquisition and analysis, statistical analysis and manuscript preparation, editing and reviewing, SOA: involved in literature search, data analysis, statistical analysis and manuscript preparation, UPA: involved in literature search, data analysis and statistical analysis, MIA: involved in data analysis and statistical analysis, MEE: involved in literature search and manuscript reviewing and CBM: involved in data acquisition and manuscript editing

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