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Assessment of Radiation Dose for Patients during X-ray Procedures in University of Maiduguri Teaching Hospital, Nigeria

Aliyu Adamu[1,], Mary Morris[1], Emmanuel D. Langa[2] and Garba Ibrahim[1]*

[1]Department of Physics, University of Maiduguri, P. M. B. 1069, Maiduguri, Nigeria

[2]Basic Science and Technology Department, Mohmed Lawan College of Agriculture, Maiduguri – Nigeria

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Abstract: Humans have always been exposed to natural or artificial radiation such as X-rays and gamma rays. Exposure to X-ray radiation is dangerous as it transfers a certain amount of energy to biological system when it interacts with them. Recently, great attention has been paid to monitor and estimate the dose limits of public exposure to X-ray radiation in order to provide an appropriate protection of the public. In this work, the X-ray radiation exposure parameters such as kV_p, mAs, FSD, tube output voltage, etc., were recorded for chest, skull, abdomen, pelvic, lumbosacral and cervical spine X-ray procedures of fifty (50) male and female patients underwent X-ray examination in University of Maiduguri Teaching Hospital (UMTH). The recorded parameters for chest antero-posterior (AP), postero-anterior (PA) and lateral (LAT), abdomen AP/PA, skull AP/PA/LAT, cervical spine AP/LAT lumbosacral spine AP/PA/LAT and pelvic AP X-rays examinations were converted to entrance surface dose (ESD). The mean ESD values measured for patients undergoing X-ray examination in UMTH using a conventional X-ray machine, ranges from 0.2261 mGy for cervical spine LAT to 2.6865 mGy for lumbasacral spine LAT for female patient and ranges from 0.372 mGy for abdomen PA to 2.0436 mGy for lumbosacral spine PA for male patient. These ranges of ESD values were much lower compare to guidance levels set by international radiation protection bodies. Thus, there is no any significant health risk to the female and male patient underwent X-ray procedures in UMTH. Such ESD assessment is essential to prevent health risks of X-ray exposures during the radiological procedures.
Keywords: Entrance Surface Dose, Estimation, Examination, Maiduguri, Radiology, X-ray.

1 Introduction

One of the most powerful and indispensable diagnostic tools in modern medicine is X-ray examinations. X-ray examinations are carried out using modern diagnostic equipment/machines. Diagnostic X-ray radiation produces images of patients with essential details and sufficient image quality to guide practitioners for effective and efficient diagnosis, and for the treatment of various diseases during medical examinations [1-3]. It has been estimated that about 30% - 50% of critical medical decisions are based on X-ray examinations. Therefore X-ray examination has proved to be very useful in the service of humanity. Due to the ionizing nature of the X-ray radiations, its increasing application in radio-diagnostic examination involves some potential health risks to personnel/patients being exposed.

Recently, great attention has been made worldwide to monitor the release of radiation and to estimate the dose limits of public exposure so as to protect personnel/patients against radiation hazard [4-9].

It is suggested that the harmful effects of X-ray radiation could be avoided or minimized by knowing the radiation dose received by public [10-17]. Therefore, this work aimed at assessing the X-ray radiation dose received by patients undergoing X-ray examination in UMTH by comparing the measured ESD with that recommended by NRPB (2000), UK (2010), EC (1999), IAEA (2007) and IPSM (1992) [18-22].

2 Materials and Methods

*Corresponding author e-mail: aliyuadamu703@gmail.com

The materials used in this research work are control panel which comprises of exposure parameters such as kV_p, *mAs*, body type etc. Then a conventional X-ray machine, erect Bucky, CR cassettes which are of different sizes base on the type of body part to be expose. Conventional radiography room with X-ray machine General Electronics (G.E), 2.5 $mm{\cdot}Al$ total filtration, maximum and minimum tube voltage of 150 kv_p and 0.50 kV_p and maximum and minimum current intensity of 630 *mAs* and 0.50 *mAs* respectively. The X-ray exposure parameters such as tube potential (kV_p), , tube current-time product (*mAs*), FFD and tube output voltage of each patient and projection were recorded directly from the control panel. Another parameter, FSD which is the distance between X-ray tube and patient skin is calculated from

$$\mathrm{FSD} = \mathrm{FFD} - \tau \quad (1)$$

where τ is the standard patient thickness for each projection.

The FSD is measured in *cm*. Fifty different X-ray examinations with various projections were calculated. Patient dosimetery is a functional operation parameter such as high voltage or kilovolt (kV_p), current intensity or milli-amperage (*mAs*), antero-posterior (AP), postero-anterior (PA), lateral (LAT) and focus-skin distance (FSD), filtration and thickness. The patient dose is usually specified by means of determining entrance surface dose (ESD) for patient being exposed to diagnostic X-rays.

The ESD in conventional radiography can be obtained either by calculation from mathematical methods based on the X-ray machine output or by direct measurements using thermoluminescent dosimeters stacked on the patient's skin. These methods have relatively small differences. Application of thermoluminescent dosimeters in measuring the ESD involves time consuming and using special equipments which may not be available at the most radiographic centers. The mathematical method appears reliable and is an effective alternative for measuring the entrance skin dose [23,24].

The ESD values for patients undergoing five routine X-ray examinations from the hospital were calculated mathematically using the recorded outputs (i.e., kV_p, *mAs*, and FFD) through the following equation [7]:

$$\mathrm{ESD}(mGy) = \mathrm{BSF} \times \mathrm{OP} \times \left(\frac{kV_p}{80}\right)^2 \times \left(\frac{100}{\mathrm{FSD}}\right)^2 \times mAs \quad (2)$$

where OP (*mGy*/*mAs*) is tube output measured from the X-ray tube at 80 kV_p settings at distance of 1 *m*, kV_p is peak tube voltage applied, *mAs* is exposure current (the product of the tube current (*mA*) and the exposure time (*s*) and BSF is back scatter factor. The backscattered value (BSF) of 1.25 is used for skull and cervical spine, 1.3 for chest and 1.4 for abdomen and pelvis examinations [25-35]. The values of ESD calculated using the formula (2) were presented in Table 3 and Table 4.

3 Results and Discussion

The data obtained was analyzed using excel 2016 and are presented in Table 1 – 5. According to Table 1, the most frequent examination was the chest X-ray having 65%, and there was no any examination for pelvic. The females happened to have the highest number of chest X-ray examination than the men. In Table 2 it can be observe that chest X-ray having 29.4% is still the most frequently occurring type of examination, then follow by abdomen (23.5%) which is mostly carried out on females. In AP projection there was 1 examination for pelvic with men having 5.88%. Table 3 showed the number of patients undergoing LAT X-ray projection. The most frequent examination was the chest X-ray having 30.7%, and there was no any male examination for lumbosacral spine. The females (8) happened to have the highest number of LAT X-ray examination than the men (4).

Table 4 showed the calculated values of the mean ESD for chest AP (0.6484 *mGy*), chest PA (0.3747 *mGy*), chest LAT (0.5269 *mGy*, abdomen AP (1.4905 *mGy*), cervical spine AP (0.4108 *mGy*), cervical LAT (0.2261 *mGy*), skull PA (1.7100 *mGy*), skull LAT (0.6465 *mGy*), lumbosacral spine AP (1.6889 *mGy*) and lumbosacral spine LAT (2.6865 *mGy*) of female patients undergoing X-ray examination procedures in UMTH Maiduguri. The international standard reference values for International Atomic Energy Agency (IAEA) for chest PA is 0.2 *mGy*, abdomen AP is 5.0 *mGy*, skull PA is 2.5 *mGy*, skull LAT is 1. 5 *mGy*, lumbosacral spine AP is 5.0 *mGy* and lumbosacral LAT is 15.0 *mGy*. It can also be observed from Table 4 that the ESD values for female undergoing chest PA X-ray examination (0.3747 *mGy*) is higher than the diagnostic reference values given by IAEA but less than that of NRPB.

Table 5 showed the calculated values of the mean ESD for chest PA (0.4515 *mGy*), chest LAT (0.7056 *mGy*), abdomen AP (0.7980 *mGy*), abdomen PA (0.3272 *mGy*), skull AP (0.9884 *mGy*), skull PA (1.0119 *mGy*), skull LAT (0.7290 *mGy*), pelvic AP (0.4612 *mGy*), lumbosacral spine AP (2.0436 *mGy*) and lumbosacral spine PA (1.5614 *mGy*) of male patients undergoing X-ray examination procedures in UMTH Maiduguri. Table 5 also showed that the mean ESD values for male undergoing chest PA X-ray examination (0.7056 *mGy*) is higher than the diagnostic reference values given by IAEA but less than that of NRPB. This does not have any significant health risk to the male undergoing X-ray procedures in UMTH.

Table 1: Relatives contributions of different X – ray examination for PA projection.

Type of Examination	Projection	Patients age (years)		No. of patient		Total	Frequency of the exams (%)
		Range	Median	Male	Female		
Abdomen	PA	25-47	36	02	00	02	10
Chest	PA	21-47	34	04	09	13	65
Lumbosacral spine	PA	21-47	34	01	00	01	05
Skull	PA	25-47	36	03	01	04	20
Total				**10**	**10**	**20**	

Table 2: Relatives contributions of different X – ray examination for AP projection.

Type of Examination	Projection	Patients age (years)		No. of patient		Total	Frequency of the Exams (%)
		Range	Median	Male	Female		
Abdomen	AP	21-48	35	2	2	4	23.5
Chest	AP	25-47	36	0	5	5	29.4
Pelvic	AP	25-47	36	1	0	1	5.88
Cervical spine	AP	21-47	34	1	2	3	17.6
Lumbosacral spine	AP	21-47	34	1	1	2	11.7
Skull	AP	25-47	36	2	0	2	11.7
Total				**7**	**10**	**17**	

Table 3: Relatives contributions of different X – ray examination for LAT projection.

Type of Examination	Projection	Patients age (years)		No. of patient		Total	Frequency of the Exams (%)
		Range	Median	Male	Female		
Chest	LAT	21-47	34	2	2	4	30.7
Cervical spine	LAT	21-47	34	1	2	3	23.1
Lumbosacral spine	LAT	21-47	34	0	3	3	23.1
Skull	LAT	25-47	36	2	1	3	23.1
Total				**4**	**8**	**13**	

Table 4: The mean value of X-ray examination procedures for female.

Type of Examination	Projection	Mean Values			Mean ESD (*mGy*)
		kV_p	*mAs*	FSD (*cm*)	
Chest	AP	76.75	18.20	123.75	0.6484
Chest	PA	73.00	13.72	134.44	0.3747
Chest	LAT	80.00	20.00	150.00	0.5269
Abdomen	AP	82.00	18.00	90.00	1.4905
Cervical spine	AP	67.00	8.67	90.00	0.4108
Cervical spine	LAT	69.00	8.00	120.00	0.2261
Skull	PA	90.00	20.00	90.00	1.7100
Skull	LAT	70.00	12.50	90.00	0.6465
Lumbosacral spine	AP	80.00	25.00	90.00	1.6889
Lumbosacral spine	LAT	94.50	28.50	90.00	2.6865

Table 5: The mean value of X-ray examination procedures for male.

Type of Examination	Projection	Mean Values			Mean ESD (mGy)
		kV_p	mAs	FSD (cm)	
Chest	PA	75.5	14.90	132	0.4515
Chest	LAT	69.0	16.00	100	0.7056
Abdomen	AP	80.0	18.00	120	0.7980
Abdomen	PA	67.5	11.25	125	0.3272
Skull	AP	85.0	16.00	100	0.9884
Skull	PA	80.2	18.40	100	1.0119
Skull	LAT	73.0	16.00	100	0.7290
Pelvic	AP	68.0	10.00	100	0.4612
Lumbosacral spine	AP	88.0	25.00	90	2.0436
Lumbosacral spine	PA	86.0	20.00	90	1.5614

Table 6: The ESD (mGy) values recommended by the relevant organizations.

Type of Examination/ Projection Position	The Mean Entrance Surface Dose (mGy)						
	This Study		Organization with Reference Dose Levels				
	Female (mGy)	Male (mGy)	NRPB [18]	UK [19]	EC [20]	IAEA [21]	IPSM [22]
Chest AP	0.6484	0.4515	-	0.15	-	-	-
Chest PA	0.3747	0.7056	2.0	0.15	0.3	0.2	0.3
Chest LAT	0.5269	-	-	0.5	1.5	-	1.5
Abdomen AP	1.4905	0.7980	-	4.00	10	5.0	-
Abdomen PA	-	0.3272	-	4.00	-	4.0	-
Pelvic AP	-	0.4612	4.0	4.00	4.0	5.0	-
Cervical spine AP	0.4108	-	-	-	-	-	-
Cervical spine LAT	0.2261	-	-	-	-	-	-
Skull AP	-	0.9884	5.0	-	5.0	-	5.0
Skull PA	1.7100	1.0119	3.0	1.8	-	2.5	5.0
Skull LAT	0.6465	0.7290	1.5	1.1	3.0	1.5	3.0
Lumbosacral spine AP	1.6889	0.4612	6.0	5.7	10	5.0	-
Lumbosacral spine PA	-	2.0436	-	5.7	-	-	-
Lumbosacral spine LAT	2.6865	1.5614	14.0	10.0	30	15	-

Note: - indicates data not available

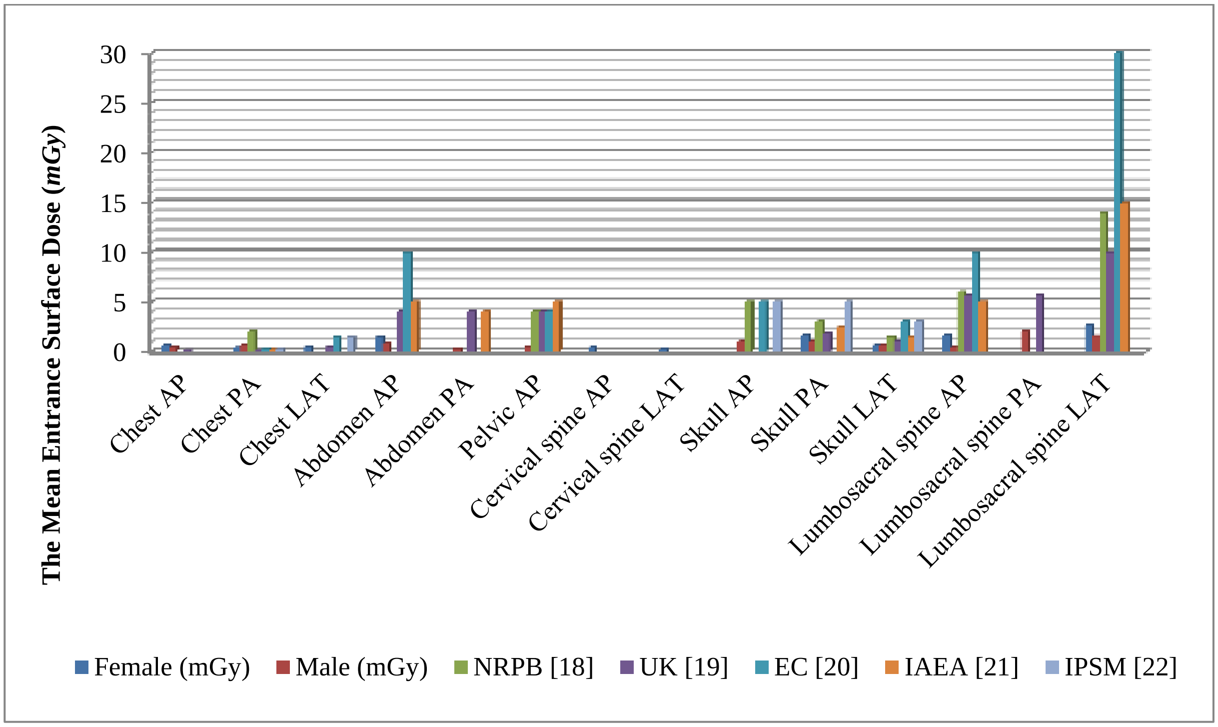

Fig. 1: The comparison of ESD (*mGy*) values measured from the present study with the recommended values given by the relevant organizations.

Figure 1 showed that the international standard reference values for National Radiation Protection Board (NRPB) for chest PA is 2.0 *mGy*, pelvic AP is 4.0 *mGy*, skull AP is 5.0 *mGy*, skull PA is 3.0 *mGy*, skull LAT is 1.5 *mGy*, lumbosacral spine AP is 6.0 *mGy* and lumbosacral spine LAT is 14.0 *mGy*. The mean ESD values for chest, abdomen, cervical spine, skull and lumbasacral spine measured for female undergoing X-ray procedures in UMTH were generally lower than the guidance given by NRPB, UK, EC, IAEA and IPSM. Thus, there is no any significant health risk to the female undergoing X-ray procedures in UMTH.

It can be seen from Figure 1 that the international standard reference values for International Atomic Energy Agency (IAEA) for chest PA is 0.2 *mGy*, abdomen AP is 5.0 *mGy*, skull PA is 2.5 *mGy*, skull LAT is 1.5 *mGy*, pelvic AP (5.0 *mGy*), lumbosacral spine AP is 5.0 *mGy* and lumbosacral spine LAT is 15.0 *mGy*. The international standard reference values for National Radiation Protection Board (NRPB) for chest PA is 2.0 *mGy*, pelvic AP is 4.0 *mGy*, skull AP is 5.0 *mGy*, skull PA is 3.0 *mGy*, skull LAT is 1. 5 *mGy*, pelvic AP is 4.0 *mGy*, lumbosacral spine AP is 6.0 *mGy* and lumbosacral spine LAT is 14.0 *mGy*. In general, the mean ESD values for chest, abdomen, cervical spine, skull and lumbasacral spine measured for male undergoing X-ray procedures in UMTH were lower than the guidance given by NRPB, UK, EC, IAEA and IPSM.

4 Conclusions

The results presented in this research work indicate that the mean ESD values measured for X-ray radiation received by patients undergoing X-ray examination in UMTH using a conventional X-ray machine, ranges from 0.2261 *mGy* for cervical spine LAT to 2.6865 *mGy* for lumbasacral spine LAT for female patient and ranges from 0.372 *mGy* for abdomen PA to 2.0436 *mGy* for lumbasacral spine PA for male patient. These values were much lower compare to guidance levels set by radiation protection bodies. Thus, there is no any significant health risk to the female and male patient underwent X-ray procedures in UMTH. This information would be beneficial to improve the practice with technical parameters and the quality assurance in optimizing the dose received by patients during X-ray examination. The knowledge of the radiation dose received by the patient during the radiological examination is also essential to prevent health risks of X-ray exposures.

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References

[1] K. Shamsi, A. S. Monfared, M. R. Deevband, B.

Mohsenzadeh, M. Ghorbani, K. E. Gorji and F. Niksirat, Evaluation of effective dose and entrance skin dose in digital radiology, The Journal of Polish Society of Medical Physics., 26 (2), 119-125 (2020).
[2] R. Davoodi, M.-R. Eydian, H. Karampour, M. Nassarpour, R. Rezazadeh-Farokh, A. Maraei and M. Chavideh, Application of Dose Area Product (DAP) to Estimate Entrance Surface Dose (ESD) in Pediatric Chest X-Rays, Modern Health Science., 3(2), (2020).
[3] U. Ibrahim, I. H. Daniel, O. Ayaninola, A. Ibrahim, A. M. Hamza and A. M. Umar, Determination of Entrance Skin Dose From Diagnostic X-Ray of Human Chest at Federal Medical Centre Keffi, Nigeria, Science World Journal., 9 (1), (2014).
[4] Z. Arifin, E. Hidayanto and Suhardi, Calculation Application of Patient's Dose on Fluoroscopy X-Ray Machine. Journal of Physics: Conference. Series 1217 (2019) 012024.
[5] A. Alghoul, M. M. Abdalla and H. M. Abubaker, Mathematical evaluation of entrance surface dose (ESD) for patients examined by diagnostic X-rays. Open Access Journal of Science., 1 (1), 8 – 11(2017).
[6] S. F. Moey, Z. A. Shazli and I. Sayed, Dose Evaluation for Common Digital Radiographic Examinations in Selected Hospitals in Pahang Malaysia. Iranian Journal of Medical Physics., 14, 155-161 (2017).
[7] A. Aliasgharzadeh, E. Mihandoost, M. Masoumbeigi, M. Salimian and M. Mohseni, Measurement of Entrance Skin Dose and Calculation of Effective Dose for Common Diagnostic X-ray Examinations in Kashan, Iran. Global Journal of Health Science., 7(5), (2015).
[8] D. Shahbazi-Gahrouei. Entrance surface dose measurements for routine X-ray examinations in Chaharmahal and Bakhtiari hospitals. Iran. J. Radiat. Res., 4(1), 29-33 (2006).
[9] Ibitola G., Ilori A.O., Ajanaku O., Utomewore R.D. (2018) Entrance Skin Dose (Radiation) Measurement and Evaluation (for all age group) at the State Specialist Hospital, Okitipupa, Nigeria. Open Science Journal 3(2)
[10] S. S. Rubai, Md S. Rahman, S. Purohit, Md K. A. Patwary, AKM Moinul, H. Meaze and A. A. Mamun, Measurements of Entrance Surface Dose and Effective Dose of Patients in Diagnostic Radiography, Biomedical Journal of Scientific and Technical Research., 12(1), (2018).
[11] A. Brindhaban and C. U. Eze, Estimation of Radiation Dose during Diagnostic X-Ray Examinations of Newborn Babies and 1-Year-Old Infants. Medical Principles and Practice., 15, 260–265 (2006).
[12] A. Alghoul and M. Yasir, Alternative Mathematical Form for Determining the Effectiveness of High-LET Radiations at Lower Doses Region. International Journal of Radiology and Imaging Technology., 2(1), 1–4 (2016).
[13] H. Y. Yacoob and H. A. Mohammed, Assessment of patients X-ray doses at three government hospitals in Duhok city lacking requirements of effective quality control. Journal of Radiation Research and Applied Sciences., 10, 183 – 187(2017).
[14] E. D. Langa, A. Adamu and O. Meludu, Occupational Radiation Dose Evaluation in University of Maiduguri Teaching Hospital, Maiduguri, Nigeria. Journal of Radiation and Nuclear Applications., 5(3), 181-186 (2020).
[15] M. T. Taha, F. H. Al-ghorabie, R. A. Kutbi and W. K. Saib, Assessment of entrance surface Doses for patients undergoing diagnostic X-ray examinations in king Abdullah medical Medical city, Makkah, KSA. Journal of Radiation Research and Applied Sciences., 8, 100-103 (2015).
[16] Y. Musa, S. Hashim and M. K. Abdulkarim, Direct and indirect entrance surface dose Measurement in X-ray diagnostic using nanoDot OSL dosiemeters., IOP Conf. Series: Journal of Physics: Conf. Series 1248 (2019) 012014.
[17] M. M. Orosun, M. R. Usikalu, J. O. Kayode, Radiological Hazards Assessment of Laterite Mining Field in Ilorin, North-central Nigeria. International Journal of Radiation Research., 18 (4), (2020).
[18] NRPB (2000). "Reference Doses and Patients Size in Pediatric Radiology". National Radiation Protection Board, NRPB-R318.
[19] D. Hart, M. Hillier and P. Shrimpton, Health Protection Agency, Center for Radiation, Chemical and Environmental Harzards: HPA CRCE-034. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK- 2010 review.
[20] European Commission: Guidance on diagnostic reference levels (DRLs) for medical exposures. Geneva, Switzerland, Director-General, Environment, Nuclear Safety and Civil Protection, 1999.
[21] IAEA Tech. Rep. (2007). Dosimetery in diagnostic radiology: an interventional code of practice, Technical Report series No 457 (IAEA) pp: 20-25. IAEA, Vienna.
[22] K. Faulkner, A. P. Jones and A. Walker A, Safety in diagnostic radiology. National Radiological Protection Board Report., vi (72), 119 pages (1995), The Institute of Physical Sciences in Medicine (IPSM), York: UK.
[23] G. G. Fouda, H. P. Ekobena, J. Mbo. Amvene and M. Guena, Neossi Exposure Levels of Adult Patients during Radiographic Examinations: Sinuses and Coastal Grill Cases at the Ngaoundere Regional Hospital, Cameroon, Hindawi Radiology Research and Practice., Volume 2019, Article ID 5452149, 5 pages.
[24] E. M. E. Ajbna, (2017). Assessment of Entrance Skin Dose and effective Dose during Pelvis conventional

X-ray Procedure Examinations. Thesis submitted for partial fulfillment of M.Sc degree in Medical Physics. College of Graduate Studies, Sudan University of Science and Technology.

[25] C. J. Martin, Management of patient dose in radiology in the UK. Radiation Protection Dosimetry., 147(3), 355-372 (2011).

[26] W, Reif Alharbi, Adel GE Abbady, and A, El-Taher., Radon Concentrations Measurement for groundwater Using Active Detecting Method American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), 15, (1) , 1-11 (2015).

[27] A, Alharbi and A El-Taher, Measurement of natural radioactivity and radiation hazard indices for dust storm samples from Qassim region, Saudi Arabia Life Sci J 11 (9), (2014).

[28] A, El-Taher, LA Najam, AA Abojassim and H Mraity Assessment of Annual effective Dose for Different Age Groups Due to Radon Concentrations in Groundwater Samples at Qassim, Saudi Arabia. Iranian Journal of Medical Physics; 17: 15-20, (2020).

[29] F, Alshahri, Atef El-Taher and Abd Elmoniem Ahmed Elzain., Characterization of Radon Concentration and Annual Effective Dose of Soil Surrounding a Refinery Area, Ras Tanura, Saudi Arabia. Journal of Environmental Science and Technology, (2017).

[30] S. A. Alashrah and A. El-Taher Assessment of natural radioactivity levels and radiation hazards in Wadi Al-Rummah Qassim province, Saudi Arabia. Journal of Environmental Biology Vol. 37, 985-991, (2016).

[31] S. Alashrah and A. El-Taher., Gamma Spectroscopic Analysis and Associated Radiation Hazards Parameters of Cement Used in Saudi Arabia. Journal of Environmental Science and Technology 9 (2) 228--245, (2016).

[32] A, El-Taher and Ahmed El-Turki., Radon Activity Measurements in irrigation water from Qassim Province Using RAD7. Journal of Environmental Biology 37, 1299-1302 (2016).

[33] AA Abojassim, HAU Mohammed, LA Najam, A El-Taher., Uranium Isotopes Concentrations in Water Surface Samples for Al-Manathera and Al-Heerra Regions of Al-Najaf, Iraq. Environmental Earth Sciences 78 (5), 132 (2019).

[34] W.M. Badawy, Atef El-Taher, Marina V. Frontasyeva, Hashem A. Madkour and Ashraf E.M. Khater Assessment of anthropogenic and geogenic impacts on marine sediments along the coastal areas of Egyptian Red Sea Applied Radiation and Isotopes 140, 314–326. (2018).

[35] SS Althoyaib, A El-Taher The measurement of radon and radium concentrations in well water from Al-Jawaa, Saudi Arabia Journal of Natural Sciences and Mathematics , Vol. 7, No. 2, PP 179-192 (2015).