Original Research Article

Computation of radiation risk parameters due to gamma radiation doses from some rivers within oil producing communities of Abia State, Nigeria

ABSTRACT

Oil production involves the extraction of petroleum, gas and produced water, with some associated natural radionuclides from the sub-surface which could enhance background ionization radiation. This study presents the radiological analyses and computation of radiation risk parameters due to gamma radiation doses from some water samples collected from some oil producing communities in Abia State, Nigeria. The measurement was carried out using Sodium Iodide detector that is activated by thallium, and the radiological risk parameters computed were the annual effective dose of radiation due to ingested water (EDIW), the Annual Gonadal Dose Equivalent (AGDE) and the Excess Lifetime Cancer Risk (ELCR). The computed radiological risk parameters show that the annual effective dose of radiation due to ingested water by an individual ranged from 1.89 mSv y^{-1} to 3.52 mSv y^{-1} and exceeded the 0.1 mSv/yr permissible limit recommended by the International Commission on Radiological Protection (ICRP). The Annual Gonadal Dose Equivalent ranged from 0.041 mSv y^{-1} to 0.075 mSv y^{-1} and is below the World average value of 0.3 mSv y^{-1}. The Excess Lifetime Cancer Risk ranged between 5.30 x 10^{-3} and 9.87 x 10^{-3} and is above the World permissible limit of 0.29 x 10^{-3}. The elevation of most of the radiological risk parameters may be attributed to oil production activities within these environments and may likely have negative impacts on the inhabitants who consume the water and also use it for other economic activities.

Keywords: Radiation risk parameters, gamma radiation, oil communities, Abia State

1. INTRODUCTION

The presence of natural radioactivity in crude oil has been known since the beginning of the 20th century. There are data available in the literature indicating that ^{226}Ra and ^{228}Ra have activity concentrations in radioactive scales in the order of 1.0 × 10^3 kBq/kg [1]. Oil and gas production processing operations have been known to involve naturally occurring radioactive materials that lead to internal and external radiation hazards and thus act as a significant source of radiation dose to the workers [2]. This is because oil production involves the extraction of a combination of petroleum, gas and produced water together with the associated natural radionuclides from the sub-surface and these radionuclides contribute to enhancement of natural background ionization radiation. Units in oil equipment where NORM (Naturally Occuring Radioactive Materials) accumulates during oil production include; separators, oil shipment system, produced water dump, dehydrators, etc. Oil production associated radionuclides find their route into environmental components such as air, soil and water mostly in the course of oil spillages, oil disposal and gas flaring hence, personnel working near closed systems where NORM accumulations occur could be exposed to gamma rays and be subjected to their attendant consequences [3].

Researchers in the areas of Radiation and Medical Physics have been working hard to understudy the health impacts of exposure to ionisation radiation- both nuclear radiations and low level non-nuclear radiations. A detailed evaluation of excessive lifetime cancer risk due to natural radioactivity in sediments collected from rivers in Northern Pakistan revealed that they created a huge radiological threat when used as a building material due to the high value of their hazard indices [4].

Measurements of indoor and outdoor ambient gamma dose rates in and around granite regions of Shimoga District were carried out using environmental radiation Dosimeter ER-709. The calculated indoor and outdoor annual effective dose rate ranged between 0.559 to 1.631 mSv/yr with an average value of 0.872 mSv/yr and 0.106 to 0.339 mSv/yr with an average value of 0.235 mSv/yr, respectively. These results were found to be higher than the world average [5].

In an environment, one of the primary external sources that can affect the level of background radiation is a river. For this reason, studies on the radioactivity content of some rivers close to some oil mineral producing sites in Abia State, Nigeria, was carried out in this research.

2. **MATERIALS AND METHODS**

2.1 Study Area

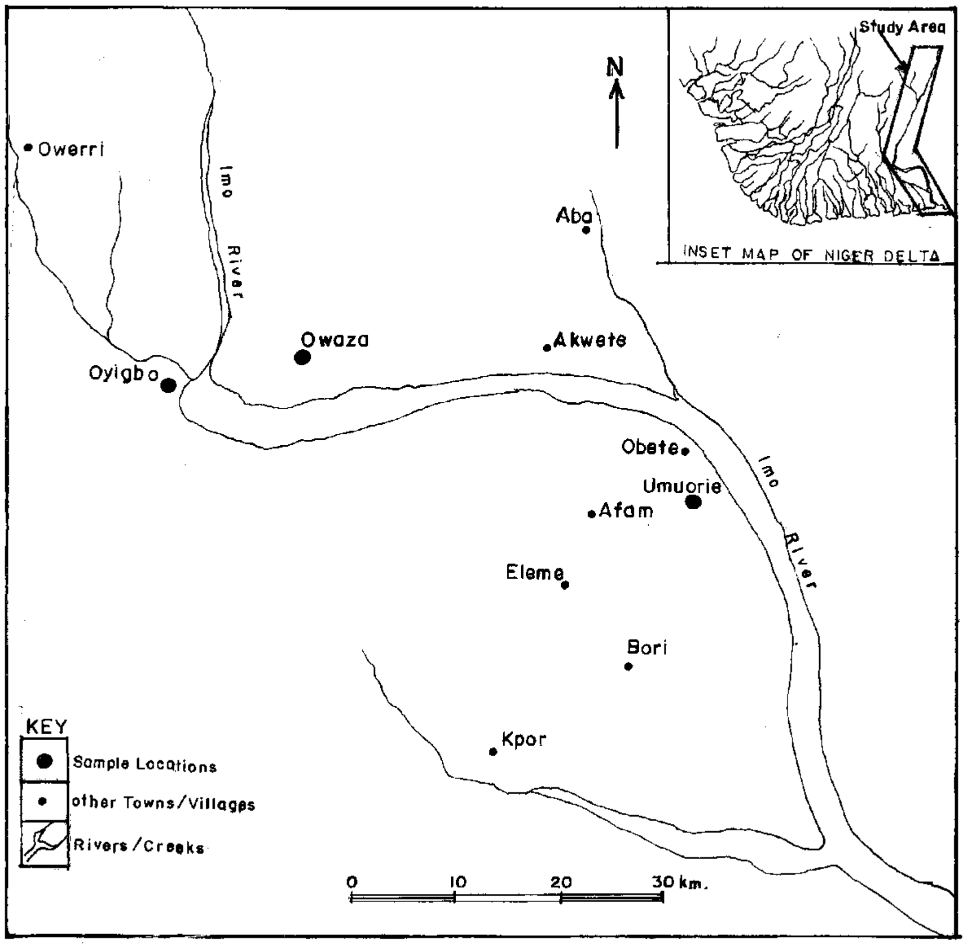
Radiological studies were conducted in 2009 on water samples collected from three rivers (Owaza river, Imo river and Umorie river) around three selected oil mineral producing fields in Abia state. The surveyed oil communities are Owaza, Imo river area and Umorie; all located in Ukwa West Local Government Area of Abia State, Nigeria. These oil fields belong to the Eastern division of Shell Petroleum Development Company and contribute about five percent of the total barrels of oil per day produced in the division [6]. A map showing the study area is shown in Figure 1.

2.1 Sample Collection and Analyses

Twenty one water samples (seven from each river) were collected from surface water bodies within the three selected oil producing fields. The samples were carefully prepared according to International Atomic Energy Agency specifications for gamma radiation analyses [7]**.** The activity concentrations of gamma rays from the samples were computed after the count rates were obtained using a Sodium Iodide detector that is activated by thallium [NaI (Tl)]. The mean activity concentrations of the samples in Bq/l for the Identified Radionuclides (K-40, Ra-226 and Ra-228) were calculated using the formula given in equation 1;

$$A_i = \frac{N_c}{\mathcal{E}_d . S_v . P_\gamma . t_c} \qquad (1)$$

Where $N_c = C_T - C_b$ (the net count rate of the samples), C_T = total measured count rate, C_b = background count rate, $\mathcal{E}_d$ = efficiency of the detector for the radionuclide of interest, S_v = sample volume (in Litre), P_γ = gamma emission probability (branch ratio), t_c = total counting time. The following gamma-emitting radionuclides were identified by the detector [NaI (Tl)]; ^{226}Ra, ^{228}Ra and ^{40}K.



Map of Imo River showing sample locations.

Figure 1: Map Showing Sample Locations

2.2 Methods of Computation of Radiological Risk Parameters

The gamma radiological risk parameters computed in this work and the formulae used for the computations are given in equations 2, 3, 4 and 5. These parameters are used to quantify the health impacts of environmental exposure to gamma radiation on humans.

(i) Effective Dose of Radiation due to Ingested Water

The annual effective dose of radiation due to ingested water by an individual (in mSv/yr) was calculated using the expression in equation 2 [8];

EDIW = $\sum_{i=1}^{3} A_i \times C_i \times D_i$ (2),

where A_i = Specific Activity of Identified Radionuclides (K-40, Ra-226 and Ra-228), C_i= Annual Consumption Rate of Water (Approximately 730 L/yr) [7], D_i= Activity to Dose Conversion Factors for the Identified Radionuclides (D_k = 6.2 x 10^{-6} mSv/Bq, D_{Ra-226} = 2.8 x 10^{-4} mSv/Bq and D_{Ra-228} = 2.2 x 10^{-4} mSv/Bq) [9].

(ii) **Annual Gonadal Dose Equivalent (AGDE)**

The AGDE due to specific activities of Ra-226, Ra-228 and K-40 was calculated using the formula in equation 3 [10];

$AGDE_{\gamma}$ (µSv y^{-1}) = $3.09_{Ra-226} + 4.18A_{Ra-228} + 0.314A_{K-40}$ (3)

(iii) Excess Lifetime Cancer Risk (ELCR)

In this work, the total ELCR from gamma radiation was calculated using the formula in equation 4 [11];
ELCR = EDIW x DL x RF (4)

where DL is the average duration of life (estimated to be 70 years), and RF is Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert given as 0.04 Sv^{-1} for public [12], which we converted to 4 x 10^{-5} $(mSv)^{-1}$ to facilitate our computation.

The percentage deviation of the computed radiological risk parameters from standard limits was computed to show the extent of deviation of the present results from the international limits and world average limits. We used the formula in equation 5;

% Dev. = $\frac{X-S}{S}$ x 100 (5)

Where X stands for the computed radiological risk parameters and S stands for international and world average limits.

3. RESULTS AND DISCUSSION

The results of the specific activity of the identified gamma radionuclides (K-40, Ra-226 and Ra-228) and their associated Radiological Risk Parameters from the three surveyed rivers (Owaza, Imo and Umorie rivers) are presented in Table 1. The results of the percentage deviation of the computed radiological risk parameters from standard limits are presented in Table 2. Bar charts comparing the maximum and minimum values of EDIW, AGDE and ELCR with permissible standards for the three surveyed rivers are presented in Figures 2 to 4.

Table 1. Specific activity of the identified gamma radionuclides and their radiological risk parameters

Sample I.D	^{40}K (Bq/l)	^{226}Ra (Bq/l)	^{228}Ra (Bq/l)	EDIW (mSv/yr)	AGDE(mSv/yr)	ELCR x 10^{-3}
OWR1	33.31±7.03	8.18±1.23	7.6±2.43	3.04	0.068	8.52
OWR2	28.51±5.99	10.25±1.54	8.1±2.59	3.52	0.074	9.87

OWR3	35.23±7.39	9.18±1.38	8.5±2.72	3.40	0.075	9.52
OWR4	23.31±4.92	6.18±0.97	5.66±1.84	2.28	0.050	6.38
OWR5	25.25±5.30	7.12±1.07	5.89±1.88	2.52	0.055	7.04
OWR6	22.35±4.69	5.57±0.84	6.02±1.93	2.21	0.049	6.18
OWR7	20.75±4.36	6.55±0.98	5.25±1.68	2.28	0.049	6.37
IMR1	28.28±4.24	9.20±2.94	6.50±2.08	3.05	0.064	8.55
IMR2	30.35±4.55	8.75±2.80	5.75±1.84	2.85	0.061	7.98
IMR3	29.75±4.46	9.80±3.14	6.20±1.98	3.13	0.066	8.77
IMR4	24.97±3.64	6.22±2.08	3.37±1.07	1.93	0.041	5.39
IMR5	23.55±3.53	6.52±2.08	4.22±1.35	2.12	0.045	5.93
IMR6	20.65±3.09	6.05±1.94	3.50±1.12	1.89	0.040	5.30
IMR7	22.57±3.39	7.25±2.32	2.85±0.91	2.04	0.041	5.72
UMR1	28.75±3.16	8.25±2.64	7.57±2.42	3.03	0.066	8.49
UMR2	30.25±3.33	7.85±2.51	6.85±2.19	2.84	0.062	7.96
UMR3	25.05±2.76	9.25±2.96	7.35±2.35	3.18	0.067	8.91
UMR4	19.06±2.09	5.94±2.26	5.20±1.80	2.14	0.046	5.98
UMR5	21.02±2.31	6.12±1.96	5.15±1.65	2.17	0.047	6.08
UMR6	20.55±2.26	5.30±1.69	4.75±1.52	1.94	0.043	5.43
UMR7	22.35±2.46	5.75±1.84	5.03±1.61	2.08	0.046	5.84

N/b: Water Samples collected from; Owaza River (OWR 1 to OWR 7), Imo River (IMR 1 to IMR 7) and Umorie River (UMR 1 to UMR 7)

Table 2: Percentage deviation of the computed radiological risk parameters from standard limits

Sample I.D	EDIW(mSv/yr)	% deviation*	AGDE(mSv/yr)	% deviation**	ELCR x 10^{-3}	% deviation***
OWR1	3.04	2940	0.068	-77.33	8.52	2838
OWR2	3.52	3420	0.074	-75.33	9.87	3303
OWR3	3.40	3300	0.075	-75.00	9.52	3182
OWR4	2.28	2180	0.050	-83.33	6.38	2100
OWR5	2.52	2420	0.055	-81.67	7.04	2328
OWR6	2.21	2110	0.049	-83.67	6.18	2031
OWR7	2.28	2180	0.049	-83.67	6.37	2097
IMR1	3.05	2950	0.064	-78.67	8.55	2848
IMR2	2.85	2750	0.061	-79.67	7.98	2652
IMR3	3.13	3030	0.066	-78.00	8.77	2924
IMR4	1.93	1830	0.041	-86.33	5.39	1759
IMR5	2.12	2020	0.045	-85.00	5.93	1945
IMR6	1.89	1790	0.040	-86.67	5.30	1728
IMR7	2.04	1940	0.041	-86.33	5.72	5430
UMR1	3.03	2930	0.066	-78.00	8.49	2828
UMR2	2.84	2740	0.062	-79.33	7.96	2645
UMR3	3.18	3080	0.067	-77.67	8.91	2972
UMR4	2.14	2040	0.046	-84.67	5.98	1962
UMR5	2.17	2070	0.047	-84.33	6.08	1997
UMR6	1.94	1840	0.043	-85.67	5.43	1772
UMR7	2.08	1980	0.046	-84.67	5.84	1914

* deviation of EDIW (mSv/yr) from 0.1 mSv [13]; ** deviation of AGDE (mSv/yr) from the world average value of 0.3 (mSv/yr) [14] ; *** deviation of ELCR from the world average value of 0.29 x 10^{-3} [15].

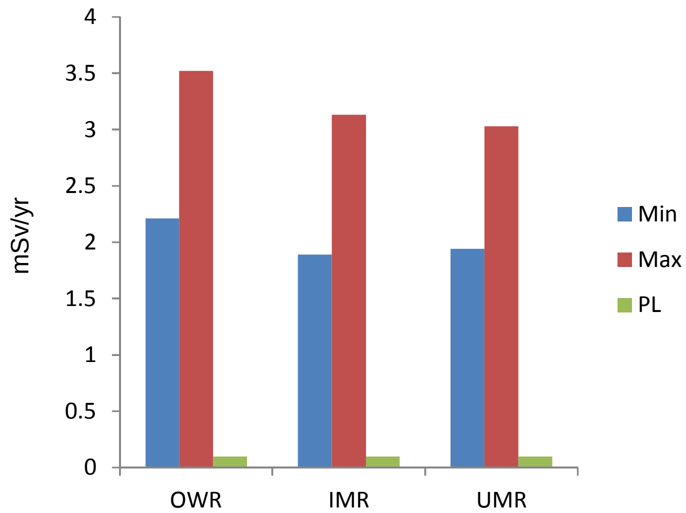


Figure 2. Bar chart comparing the maximum (Max) and minimum (Min) values of EDIW with permissible limit (PL) for the three surveyed rivers

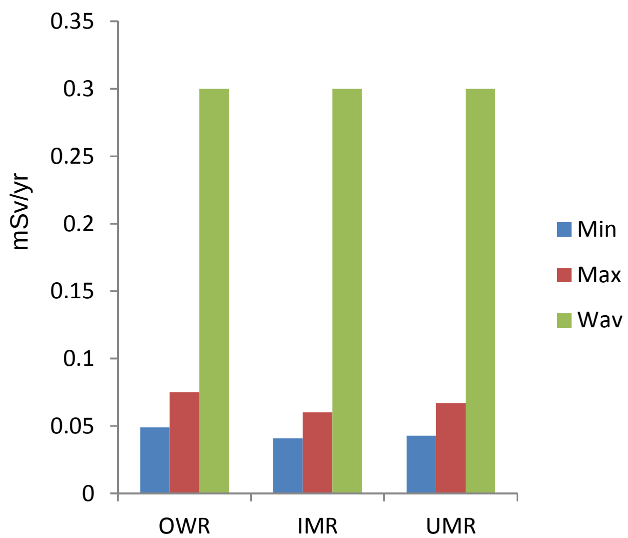


Figure 3. Bar chart comparing the maximum (Max) and minimum (Min) values of AGDE with world average value (Wav) for the three surveyed rivers

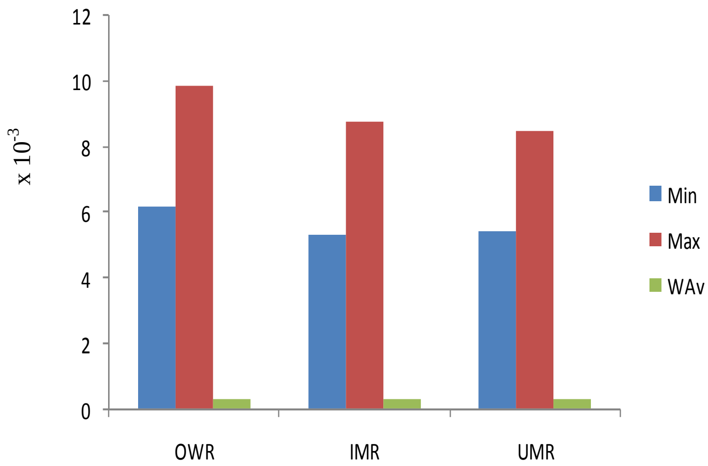


Figure 4. Bar chart comparing the maximum (Max) and minimum (Min) values of ELCR with world average value (Wav) for the three surveyed rivers

The results of annual effective dose of radiation due to ingested water (E.D.I.W.) show that for OW. River, E.D.I.W. ranged from 2.21 to 3.52 mSv/yr; for IM. River, E.D.I.W. ranged from 1.89 to 3.13 mSv/yr and for UM. River, E.D.I.W. ranged from 1.94 to 3.18 mSv/yr. The results of the annual effective dose of radiation due to ingested water (E.D.I.W.) for the three surveyed rivers exceeded 0.1 *mSv* per year which is the permissible limit set by International Commission on Radiological Protection (ICRP) for the total dose of radiation (artificial and natural) that should be received from the consumption of drinking water [13]. The comparison of the maximum (Max) and minimum (Min) values of EDIW with permissible limit (PL) for the three surveyed rivers is illustrated in the bar chart of Figure 2. These results are also greater than the permissible dose limit for radiation exposure which has been set at 1 *mSv* per year which is applicable to the total dose received from all internal and external sources excluding the natural background radiation [16].The results of Table 2 show that the deviations of the computed annual effective dose of radiation due to ingested water (E.D.I.W.) from the standard permissible limit of 0.1 *mSv* per year range from 1790% to3420%. These levels of deviation are so high and indicate that water collected from these sources and ingested, or used for other economic purposes may have been negatively affected radiologically due to oil production activities going on around these areas.

The results of the Annual Gonadal Dose Equivalent (AGDE) due to gamma radiation are presented in Table 1. The values obtained ranged from 0.049 to 0.075 mSv/yr for OW. River; 0.040 to 0.066 mSv/yr for IM. River and 0.043 to 0.067 mSv/yr for UM. River. The AGDE values for all the samples collected are below the world average value of 0.3 mSv/yr [14]. These results are also within the range of AGDE, between 0.0013 and 4.46 mSv/yr (estimated from activity concentration) reported for naturally occurring radionuclides from produced waters in the oil and gas industry [17]. Comparison of the maximum (Max) and minimum (Min) values of AGDE with world average value for the three surveyed rivers is illustrated in the bar chart of Figure 3. Consumption of water from the surveyed sources may not impact negatively on the gonads.

The Excess Lifetime Cancer Risk (ELCR) for gamma radiation as presented in Table 1 shows that the values range from 6.18 x 10^{-3} to 9.87 x 10^{-3} for OW. River; 5.30 x 10^{-3} to 8.77 x 10^{-3} for IM. River and 5.43 x 10^{-3} to 8.91 x 10^{-3} for UM. River. Comparison of the maximum (Max) and minimum (Min) values of ELCR with world average value for the three surveyed rivers is illustrated in the bar chart of Figure 4. These values are above the world average of 0.29 x 10^{-3} [15]. These results are also higher than the range of ELCR, between 0.17 x 10^{-3} and 0.39 x 10^{-3} reported for the terrestrial environment of Western Ghats, India [18].This implies that people who use water from these surveyed rivers may have enhanced their probability of developing cancer over their life time.

4. CONCLUSION

Radiological risk parameters due to gamma radiation have been computed for water samples collected from three rivers (Owaza, Imo and Umorie rivers in Ukwa West LGA) around the surveyed oil producing areas. The results of annual effective dose of radiation due to ingested water (EDIW) ranged from 1.89 to 3.52 mSv/yr for the surveyed areas. These results show very high percentage deviation (1790 % to 3420 %) from the standard permissible limit of 0.1 mSv/yr [13]. Results obtained for the Annual Gonadal Dose Equivalent (AGDE) were below the World average value of 0.3 mSv/yr, as measured values were within the range of 0.040 to 0.075 mSv/yr. These results show negative percentage deviation (-75.00 % to -3420 %) from the world average limit. For the Excess Lifetime Cancer Risk (ELCR), the measured values were within the range of 5.30×10^{-3} to 9.87×10^{-3}, which exceeded the world average value of 0.29×10^{-3}. These results also show very high percentage deviation (1728 % to 3303 %) from the world average limit.

Despite the fact that the measured values of the Annual Gonadal Dose Equivalent (AGDE) were below the World average value, the continuous usage of water from these rivers both for consumption and other economic activities may still likely have adverse impacts on the inhabitants of the surveyed environments who frequently make use of the water. This is because measured values of the annual effective dose of radiation due to ingested water (EDIW) and Excess Lifetime Cancer Risk (ELCR) exceeded the standard permissible limit and the recommended world average value respectively. The observed elevation of some of the radiological risk parameters obtained in this work relative to the permissible standard and World recommended values, may be attributed to oil production activities within these environments.

References

[1] Paschoa, A.M., (1997). Naturally occurring radioactive materials (NORM) and petroleum origin, Applied Radiation and Isotopes; 48, (10–12), Pages 1391–1396

[2] Ahmed, H. And Ghany, A., (2011). Low natural terrestrial radioactivity in oil-derived lubricants, International Journal of Low Radiation; Volume 8, Issue 3,pgs 232- 240 DOI: 10.1504/IJLR.2011.046167 www.inderscienceonline.com/loi/ijlr

[3] Reed G., Holland B., McArthur A. Evaluating the real risks of radioactive scale in oil and gas production. Proceedings of the SPE Health, safety and environment in oil and gas exploration and production conference. 1991 Nov 11-14; The Hague, Netherlands. p. 549-558.

[4] Qureshi, A.A., Tariq, S., Din, K.U., Manzoor, S., Calligaris, C., and Waheed,A. Evaluation of Excessive Lifetime Cancer Risk due to Natural Radioactivity in the Rivers Sediments of Northern Pakistan. Journal of Radiation Research and Applied Sciences 2014; 7:438-447.

[5] Rangaswamy D.R, Srinivasa, E, Srilatha, M. C, and Sannappa J. Measurement of terrestrial gamma radiation dose and evaluation of annual effective dose in Shimoga District of Karnataka State, India. Radiat Prot Environ 2015; 38:154-9.

[6] Shell Free online Library, 1999. The Free Library Gale Group, Thompson Coorporation Company, Nigeria. Retrieved on 05/01/2011 from; www.thefreelibrary.com

[7] IAEA, Technical Report 309, 1989. Construction and Use of Calibration Facilities for Radiometric Field Equipment.

[8] Abojassim, A. A., Al-Gazaly, H. H. and Kadhim, S. H, 2014. Estimated the radiation hazard indices and ingestion effective dose in wheat flour samples of Iraq markets, International Journal of Food Contamination, Springer, **DOI:** 10.1186/s40550-014-0006-7

[9] ICIRP, 2012. Compendium of Dose Coefficient Based on ICRP Publication 60. ICRP Publication 119 Ann. ICRP 41 Suppl.

[10] Mamont-Ciesla, K., Gwiazdowski, B., Biernacka, M., and Zak, A. (1982). Radioactivity of Building Materials in Poland, Natural Radiation Environment. *Halsted Press, New York.*

[11] Qureshi, A.A., Tariq, S., Din, K.U., Manzoor, S., Calligaris, C., andWaheed,A. Evaluation of Excessive Lifetime Cancer Risk due to Natural Radioactivity in the Rivers Sediments of NorthernPakistan. Journal of Radiation Research and Applied Sciences 2014; 7:438-447.

[12] Organisation for Economic Cooperation and Development, 2011. Evolution of ICRP Recommendations 1977, 1990 and 2007, Nuclear Energy Agency No. 6920. Retrieved on 13/05/2016 from www.oecd.org/publishing/corrigenda

[13] Canadian Nuclear Safety Commission, 2008. Standards and Guidelines for Tritium in Drinking Water. Catalogue number INFO-0766, ISBN 978-0-662-47497-5. Retrieved on 17/05/2016 from www.nuclearsafety.gc.ca

[14] Emelue, H.U., Nwaka, B., Amanze, K., and Nwosu, C.O. Radiological Health Hazard Indices and Excess Life Time Cancer Risk of Oil Producing Communities in Nigeria. British Journal of Medicine and Medical Research 2014; 4(36), 5853-5865.

[15] Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hindiroglu, S., and Karahan, G. Radionuclide Concentration in Soil and Lifetime Cancer Risk due to the Gamma Radioactivity in Kirklareli, Turkey Journal of Environmental Radioactivity 2009; 100, 49-53

[16] ICRP Publication 103, the 2007 Recommendations of the International Commission on Radiological Protection. www.icrp.org/ docs/ICRP_Publication_103-Annals_of_the_ICRP_37(2-4)-Free_extract.pdf (retrieved on 26/04/16)

[17] International Association of Oil and Gas Producers, Managing Naturally Occurring Radioactive Material in the Oil and Gas Industry, Report 412 (version 2), March, 2016. London, UK.

[18] Maniganadan, P.K. and Shekar, B.C., Evaluation of Radionuclides in the Terrestrial Environment of Western Ghats, Journal of Radiation Research and Applied Sciences 2014; 7 (3), 310 – 316.