International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Research Article

Natural Radioactivity Concentration and Estimation of Radiation Exposure in Environmental Soil Samples from Al-Sader City/Iraq

Adel Mehdi Saleh[A], Asia H. Al-Mashhadani[A*] and Murtdha Adhab Siyah[B]

[A]Department of Physics, College of Science, University of Baghdad, Iraq
[B]Department of Radioactive Waste Treatment and Management, Ministry of Science and Technology, Baghdad, Iraq

Accepted 16 August 2014, Available online 25 Aug 2014, **Vol.4, No.4 (Aug 2014)**

Abstract

A study of the radioactivity in soil from Al-Sader city in Baghdad, Iraq, has been carried out. Thirty soil samples were collected at 0.5meter below ground level; they were analyzed by γ-ray spectroscopy to determine the ^{226}*Ra,* ^{232}*Th and* ^{40}*K concentrations. The activity concentration values range were 4.120-44.68Bqkg*$^{-1}$*, ND-11.95Bqkg*$^{-1}$ *and 2.820-709.52 Bqkg*$^{-1}$ *for* ^{226}*Ra,* ^{232}*Th and* ^{40}*K respectively. Radium Equivalent activity was calculated and it was range from 30.973Bqkg*$^{-1}$ *to 134.60Bqkg*$^{-1}$*. The absorbed dose rate in air was also calculated for the samples and its range from 15.720nGyh*$^{-1}$ *to 64.065nGyh*$^{-1}$*. The outdoor annual effective doses ranged from 0.0193mSv to 0.0786mSv with an average value of 0.0533mSv and the indoor annual effective doses ranged from 0.0771mSv to 0.3143mSv with an average value 0.2131mSv for one year. The radiation hazard indices of soil samples were also calculated, the results showed that the average values of either radionuclides concentration or radiation hazard indices of all soil samples under study were in the internationally permissible range. The excess lifetime cancer risk was calculated using the risk factors of International Commission on Radiological Protection and Biological Effects of Ionizing Radiation. Thus, the values obtained when compared with their corresponding world permissible values, were found to be below the standard limits. The results from models that have been detected and put them in the calculations refer that the soil of Al-Sader city is safe.*

Keywords: *Excess lifetime cancer risk, Hazard indices, Al-Sader city*

Introduction

Natural radioactivity exists widely in the terrestrial environment. There are many sources of radiation and radioactivity in the environment. Gamma radiation emitted from naturally occurring radionuclides, also called terrestrial background radiation, represent the main external source of irradiation of the human body. It is located in different geological formations such as the surface of the earth, rocks, water, plants and even the air. The concentration of the natural radioactive materials depends on situation of geology and geography and appears at different level in soils of each different geological region (UNSCEAR, 2000). Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radio nuclides are carried to soil by rain and flows (Taskin, H.M *et al*, 2009). Addition to natural sources of radiation, but the soil radioactivity is also affected industrial sources of radiation. The purpose of the study of natural concentrations of radioactive materials is trying to figure out the spatial distribution of these concentrations down the soil profile. The long term exposure to radionuclides such as thorium or radium has very serious health effects such as chronic lung disease and blood diseases (FEPA, 1991). Natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K, and the radionuclides from ^{232}Th- and ^{238}U-series, which occur at trace levels in all ground formations (Tzortzis, M. *et al*, 2004).

The growing worldwide interest in estimating a baseline level of terrestrial gamma radiation is behind the extensive surveys undertaken in many countries. Estimation of the external exposure due to gamma-ray radiation is important because this may contribute significantly to the total annual individual dose. The doses can vary considerably depending on the ^{238}U and ^{232}Th (and their daughter products) and ^{40}K concentrations present in the local geology (Radhakrishna, A.P. *et al*, 1993; Quindos, L. S., *et al*, 1994; Surinder Singh, *et al*, 2005). The aim of present study are assessing the specific activities and examines some of the radiation hazard indices of these naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in 30 samples of soil from Al-Sader city in Baghdad, Iraq using γ-ray spectrometry.

Theory Concepts

Calculation of Radiation Hazard Indices

It is justifiable to exploit as many as possible of the known

---

*Corresponding author: **Asia H. Al-Mashhadani** radiation health hazard indices to achieve a safe conclusion on the health status of an exposed person or environment. To represent the activity levels of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with each component, Radium equivalent (Ra_{eq}) is a common index used to compare the specific activities of materials containing ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them (Baratta, E. J., 1990). The activity index provides a useful guideline in regulating the safety standard dwellings.

The radium equivalent activity represents a weighted sum of activities of the above mentioned natural radionuclides and is based on the estimation that 1Bq/kg of ^{226}Ra, 0.7Bq/kg of ^{232}Th, and 13Bq/kg of ^{40}K produce the same radiation dose rates. The Radium Equivalent activity (Ra_{eq}) which is defined mathematically by Eq.(1) (UNSCEAR, 2000).

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_k \quad (1)$$

where C_{Ra}, C_{Th} and C_K are the activity concentration in Bqkg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K, respectively the use of a material whose (Ra_{eq}) concentration exceeds 370Bq/kg is discouraged to avoid radiation hazards (Sam, A.K. and Abbas, N., 2010).

The Absorbed Dose Rate in Air

The absorbed dose rate in air one meter above the ground surface express the received dose in the open air from the radiation emitted from radionuclides concentrations in water. This factor is important quantity to evaluate when considering radiation risk to a biosystem. The absorbed dose rate can be determined by using Eq.(2) (Kocher,D.C. and Sjoreen, A.L., 1985).

$$AD = 0.461C_{Ra} + 0.623C_{Th} + 0.0414C_k \quad (2)$$

where 0.461, 0.623 and 0.0414nGy h^{-1}/Bq kg^{-1} are the conversion factors of ^{226}Ra, ^{232}Th and ^{40}K, respectively (UNSCEAR, 1993).

Annual Effective Doses Equivalent

Annual estimated average effective dose equivalent received by member was calculated using factor of 0.7 SvGy^{-1}, which was used to convert the absorbed dose rate to human effective dose equivalent with an outdoor of 20 % and 80% for indoor (Beretka, J. and Mathew, P.J., 1985). The annual effective doses equivalent outdoor and indoor calculated using Eqs.3 and 4:

$$\text{Outdoor (mSv/y)} = \text{AD (nGyh}^{-1}) \times 8760\text{ h} \times 0.2 \times 0.7\text{ SvGy}^{-1} \times 10^{-6} \quad (3)$$

$$\text{Indoor (mSv/y)} = \text{AD (nGyh}^{-1}) \times 8760\text{ h} \times 0.8 \times 0.7\text{ SvGy}^{-1} \times 10^{-6} \quad (4)$$

Determination of Radiation Hazard Indices

Many of the radioactive materials decay naturally and when these materials decay produces external radiation field which exposed humans. In terms of dose, the principal primordial radionuclides are ^{232}Th, ^{226}Ra and ^{40}K. Thorium and uranium head series of radionuclides that produce significant human exposure. The external hazard index (H_{ex}) is calculated by Eq.(5) (Marr Phebe, 2012).

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \leq 1 \quad (5)$$

where C_{Ra}, C_{Th} and C_K, are the radioactivity concentrations in Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K respectively. The value of this index must be less than unity for the radiation hazard to be negligible; H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370Bq/kg). The internal hazard index (H_{in}) can be calculated by Eq.(6) (Marr Phebe, 2012).

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \leq 1 \quad (6)$$

where C_{Ra}, C_{Th} and C_K, are the radioactivity concentrations in Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K respectively. The value of this index must be less than unity for the radiation hazard to be negligible.

Excess Lifetime Cancer Risk (ELCR)

This gives the probability of developing cancer over a lifetime at a given exposure level, It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose, and we can calculate (ELCR) by Eq (7) if considering 70 years as the average duration of life for human being. (Taskin, H.M *et al*, 2009).

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \quad (7)$$

where AEDE is the Annual Effective Dose Equivalent, DL is the average Duration of Life (estimated to be 70 years) and RF is the risk factor (Sv^{-1}), fatal cancer risk per Sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public exposure (Taskin, H.M *et al*, 2009). This value-free units because it represents the probability of cancer incidence through this we can deduce the equation above.

The Study Area

Al-Sader city was built in Iraq in 1959 with geographical location corresponds to 33°23′20″N 44°27′30″E by Prime Minister Abdul Karim Qassim in response to grave housing shortages in Baghdad. At the time named Revolution City (Al-Thawra), it provided housing for Baghdad's urban poor, many of whom had come from the countryside and who had until then lived in appalling conditions (The Iraqi Ministry of Planning, 2009).

Al-Sader city was divided to the sectors of space sector one of about 25010 square meters and includes 79 sectors spaces equal and designed differently in some parts as in both the 23 and 34, and each containing a sector on a mosque and at least one. However, the sector may be another after the invasion of Iraq in 2003 called the sector zero. Hence the number of sectors of the city became eighty sectors and the zero sector is between neighborhood Al-Amanaa and the sector one (Baghdad Mayoralty GIS Department). The number of the city's population according to the census site of the Baghdad Provincial 2.995750 million people. And through this information shows us clearly the importance of Al-Sader city for the purpose of search. The map of Al-Sader city Fig.1 shows the sectors that targeted in the research as represented in Table 1.

Table 1: The samples taken from Al-Sader city sectors

Group no.	Target sectors	No. of samples
1	Sector (7)	1,2,3,4and 5
2	Sector (49)	6,7,8,9 and 10
3	Sector (25)	11,12,13,14 and 15
4	Sector (67)	16,17,18,19 and 20
5	Sectors (69)	21,22,23,24 and 25
6	Sectors (23)	26,27,28,29 and 30

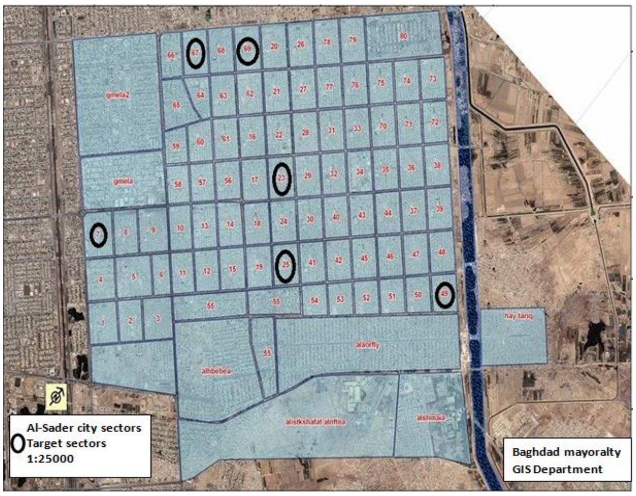

Figure1: Map of Al-Sader city sectors

Materials and Methods

Thirty samples of soil were collected from 6 sectors from Al-Sader city in Baghdad, Iraq. Sample preparation was carried out by placing each soil sample in an oven for drying at a temperature of 100°C until a constant weight was reached to ensuring complete removal of any residual moisture. The dried samples were pulverized into a fine powder and passed through a standard 1 mm mesh size. The homogenized samples were filled into 1L Marinelli beakers. All samples were weighed (about 500gm) by using a high sensitive digital weighing balance with a percent of ±0.01%. The beakers were subsequently firmly sealed for at least four weeks to ensure a state of secular equilibrium between radium isotopes and their respective daughters (Onoja R. A., 2010). Each sample was then counted by using Hyper Pure germanium Detector (HPGe).

Gamma spectrometer and relevant accessories were supplied by Canberra, USA used to measure the activity concentrations for each radionuclide in the soil. Each sample was identified for the radionuclide that is contaminating the soil, it has been used a very sophisticated, well advanced piece of equipment produced by ORTEC is hand held HPGe detector with an overall efficiency better than 42%. The resolution of this detector is 1.32MeV for Co-60 energy. The energy calibration of HPGe gamma-ray spectrometer is performed by Co-60 radioactive source**.**

Results and Discussion

Table (2) presents the three natural radionuclide isotopes (^{40}K, ^{226}Ra and ^{232}Th) which are found in the study samples. The activity concentration values range were 4.120-44.68Bqkg^{-1}, ND-11.95Bqkg^{-1} and 2.820-709.52 Bqkg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively. The specific activity average values of ^{226}Ra, ^{232}Th and ^{40}K are 25.81Bqkg^{-1} 21.74 Bqkg^{-1} and 434.67 Bqkg^{-1} respectively as shown in Table.2. These radioactivity concentration values obtained in this study are below the world average value of 35Bqkg^{-1} for ^{226}Ra and 30Bqkg^{-1} for ^{232}Th except the activity concentration of ^{40}K found to be higher than the world wide average which is 400Bqkg^{-1} (UNSCEAR, 2000). This can be explained by what Al-Sader city ails the presence of a large underground water and sewage water underneath the soil. The results obtained for the radium equivalent activity was ranged from 30.973Bqkg^{-1} in sample S_{29} to 134.60Bqkg^{-1}in sample S_{19} , as shown in Fig.3, all radium equivalent activity are below the permissible values of and 370 BqL^{-1} (UNSCEAR, 2000).

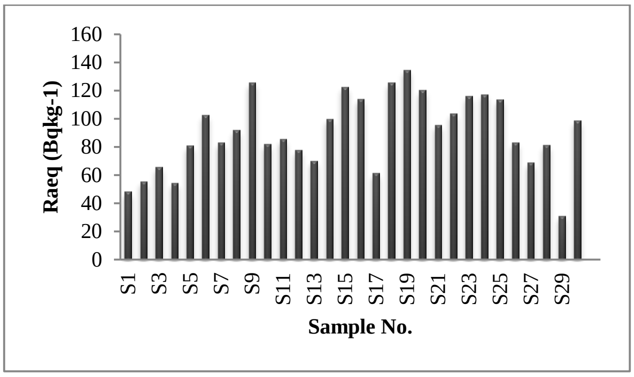

Figure 2: The relationship between Radium equivalent and sample number

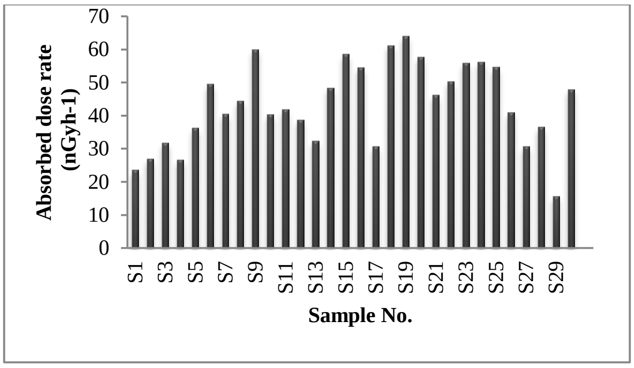

Figure 3: The relationship between the absorbed dose rate in air and sample number

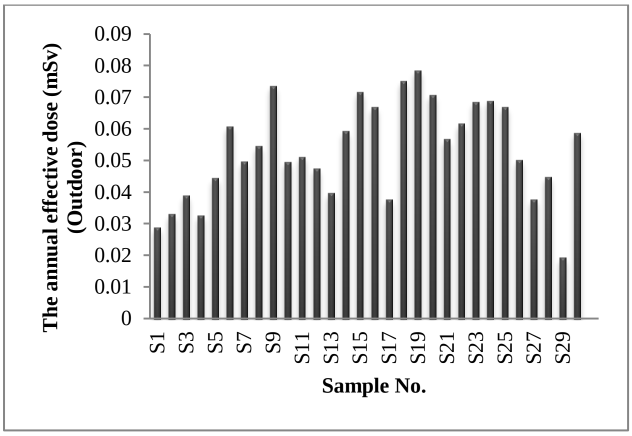

Figure 4: The relationship between the annual effective dose outdoor and sample number

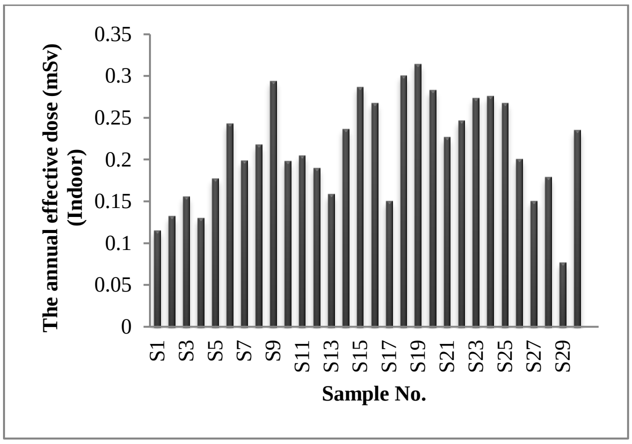

Figure5: The relationship between the annual effective dose indoor and sample number

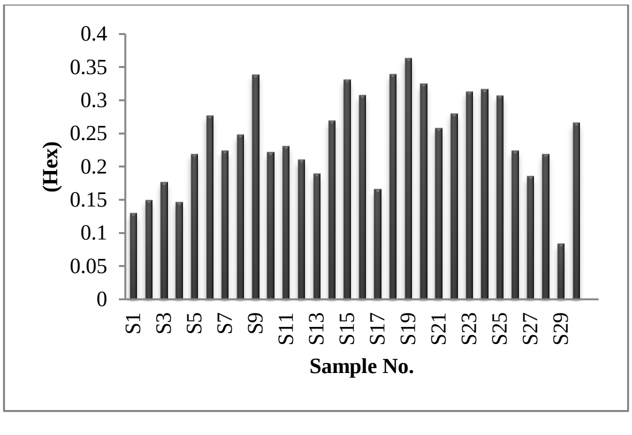

Figure 6: The relationship between the external hazard index and sample number

Also, the present values of indoor and outdoor annual effective dose equivalent was ranged from 0.0193mSv in sample S_{29} to 0.0786mSv in sample S_{19} with an average value of 0.0533mSv for outdoor and the indoor annual effective doses ranged from 0.0771mSv in sample S_{29} to 0.3143mSv in sample S_{19} with an average value 0.2131mSv for one year as shown in Figs.4 and 5. All values of indoor and outdoor annual effective dose equivalent lower than the world average values (0.07mSv/y for outdoor and 0.45mSv/y for indoor) (Orgun, Y., 2007).

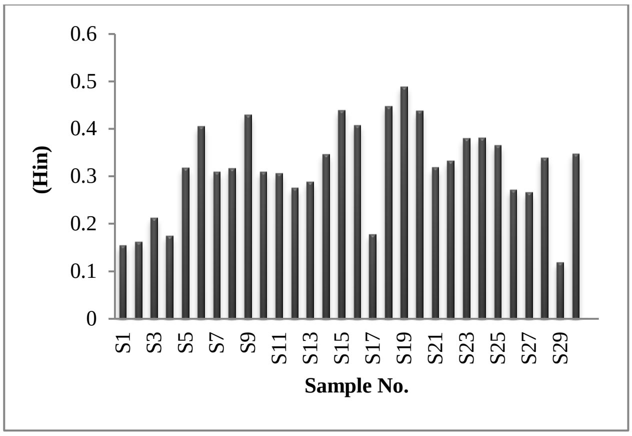

Figure7: The relationship between the internal hazard index and sample number

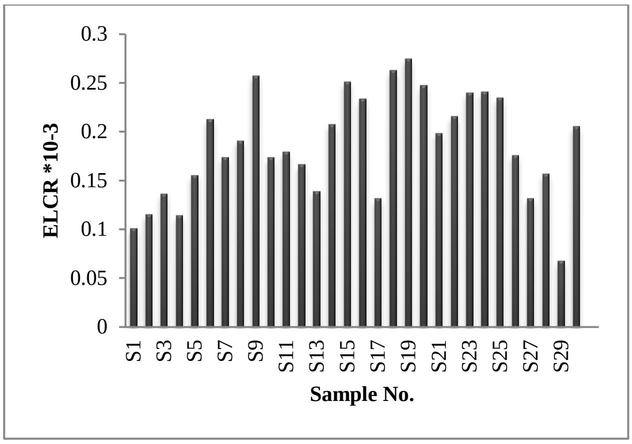

Figure 8: The relationship between Excess Lifetime Cancer Risk and sample

Furthermore, the external hazard indexes are ranged from 0.0837 in sample S_{29} to 0.3635 in sample S_{19} and internal hazard indexes were ranged from 0.1184 in sample S_{29} to 0.4887 in sample S_{19} as shown in Figs. 6 and 7. All external and internal indexes values are less than the world permissible value of unity (Orgun, Y., 2007). This indicates that the values will not lead to respiratory diseases such as asthma and cancer and external diseases such as skin cancer and cataracts. Average excess lifetime cancer risk (ELCR) ranged from 0.0675×10^{-3} in sample S_{29} to 0.2750×10^{-3} in sample S_{19} as shown in Fig.8. ELCR for all samples is less than the world average of 0.29×10^{-3} (Taskin, H.M *et al*, 2009). This implies that the chances of having cancer by the populace in general are insignificant. Therefore, soil from these areas does not effect on the health and safe.

Conclusions

The evaluation of radiation hazard indices and excess lifetime cancer risk of soil in Al-Sader city in Baghdad,

Table 2: Concentration of radionuclide, the hazard indices and excess lifetime cancer risk for soil in Al-Sader city

Sample No.	Ra-226 (*Bqkg^{-1}*)	Th-232 (*Bqkg^{-1}*)	K-40 (*Bqkg^{-1}*)	Ra_{eq} (*Bqkg^{-1}*)	Absorbed dose rate (nGyh^{-1})	The annual effective dose (*mSv/y*)		(H_{ex})	(H_{in})	ELCR *10^{-3}
						(Outdoor)	(Indoor)			
S_1	8.600	11.60	298.24	48.152	23.539	0.0289	0.1155	0.1300	0.1546	0.1010
S_2	4.440	16.98	345.66	55.337	26.940	0.0330	0.1321	0.1494	0.1621	0.1156
S_3	12.50	17.22	368.68	65.513	31.754	0.0390	0.1558	0.1769	0.2126	0.1363
S_4	9.800	12.94	338.78	54.390	26.605	0.0326	0.1305	0.1469	0.1748	0.1142
S_5	34.80	32.16	2.8200	81.006	36.195	0.0444	0.1776	0.2188	0.3181	0.1554
S_6	44.68	15.22	469.62	102.61	49.522	0.0607	0.2429	0.2772	0.4046	0.2126
S_7	29.68	13.32	447.68	83.199	40.515	0.0497	0.1987	0.2247	0.3094	0.1739
S_8	23.92	21.88	477.66	91.989	44.433	0.0545	0.2180	0.2484	0.3167	0.1907
S_9	31.60	34.58	577.00	125.48	59.999	0.0736	0.2943	0.3389	0.4290	0.2575
S_{10}	31.00	8.880	497.60	82.014	40.424	0.0496	0.1983	0.2215	0.3100	0.1735
S_{11}	26.48	14.76	492.34	85.497	41.786	0.0512	0.2050	0.2309	0.3065	0.1794
S_{12}	22.88	9.440	539.30	77.905	38.756	0.0475	0.1901	0.2104	0.2757	0.1664
S_{13}	34.68	18.30	119.80	70.074	32.350	0.0397	0.1587	0.1893	0.2882	0.1389
S_{14}	27.06	22.24	530.98	99.749	48.313	0.0593	0.2370	0.2694	0.3466	0.2074
S_{15}	38.00	30.94	524.06	122.60	58.490	0.0717	0.2869	0.3311	0.4395	0.2510
S_{16}	35.10	27.78	508.36	113.97	54.534	0.0669	0.2675	0.3078	0.4079	0.2340
S_{17}	4.120	13.86	487.18	61.453	30.703	0.0377	0.1506	0.1660	0.1777	0.1318
S_{18}	38.12	23.00	709.52	125.64	61.276	0.0751	0.3006	0.3393	0.4481	0.2630
S_{19}	43.88	33.88	549.02	134.60	64.065	0.0786	0.3143	0.3635	0.4887	0.2750
S_{20}	39.64	27.08	544.56	120.30	57.690	0.0708	0.2830	0.3249	0.4380	0.2476
S_{21}	21.10	24.34	515.88	95.629	46.249	0.0567	0.2269	0.2583	0.3185	0.1985
S_{22}	18.40	27.88	590.48	103.74	50.298	0.0617	0.2467	0.2801	0.3326	0.2159
S_{23}	23.60	31.94	606.24	115.95	55.877	0.0685	0.2741	0.3131	0.3805	0.2398
S_{24}	22.42	35.70	571.02	117.44	56.217	0.0689	0.2758	0.3171	0.3811	0.2413
S_{25}	20.30	34.10	580.50	113.76	54.635	0.0670	0.2680	0.3072	0.3651	0.2345
S_{26}	16.42	17.30	546.22	83.218	40.961	0.0502	0.2009	0.2247	0.2716	0.1758
S_{27}	28.54	27.30	14.160	68.670	30.751	0.0377	0.1509	0.1855	0.2669	0.1320
S_{28}	41.92	27.16	6.1780	81.235	36.502	0.0448	0.1791	0.2194	0.3390	0.1567
S_{29}	12.17	0.000	244.19	30.973	15.720	0.0193	0.0771	0.0837	0.1184	0.0675
S_{30}	28.38	20.34	536.24	98.757	47.955	0.0588	0.2353	0.2667	0.3477	0.2058
Av	25.81	21.74	434.67	90.361	43.435	0.0533	0.2131	0.2440	0.3177	0.1864

Iraq has been conducted. The values obtained when compared with the various world permissible values were found to be below the standards for such environment and soil from this area will pose no significant health threat to human lives and the environment is said to be radiologically hazard safe.

References

Baghdad Mayoralty GIS Department**.**

Baratta, E. J. (1990), Radon, Radium and Uranium in drinking water. Lewis Publisher, Washington DC, pp. 203-213.

Beretka, J. and Mathew, P.J. (1985) Natural radioactivity of Australia Building materials industrial wastes and by-products, *Health Phys*. 48, pp.87-95.

FEPA, (1991), National Interim Guidelines and Standards for Industrial effluents, Gaseous Emissions and Hazardous wastes management in Nigeria.

Kocher,D.C, Sjoreen,A.L, (1985), Dose-rate conversion factors for external exposure to photon emitters in soil. *Healthy Phys*.48, pp.193-205.

Quindos, L. S., Fernandez, P.I., Soto, J., Rodeanas, C., Gomez, J. 1994, Natural radioactivity in Spanish soils. *Health Phys*., 66, pp. 194-200.

Marr Phebe, (2012) The Modern History of Iraq, Westview Press, page 172.

Onoja R. A. (2010), Total radioactivity count in taps and well water around Zaria area, Kaduna State, Nigeria. Ph.D. Thesis, ABU, Zaria. Nigeria.

Orgun, Y., N. Altinsoy, S.Y. Sahin, Y. Gungor, A.H. Gultekin, G. Karaham and Z. Karaak, (2007). Natural and anthropogenic radionuclide in rocks and beach sands from Ezine region, Western Anatolia, Turkey.*Applied Radiation and Isotopes*, 65,pp. 739-747.

Radhakrishna, A.P., Somashekarappa, H.M., Narayana, Y., Siddappa, K. 1993, A new natural background radiation area on the southwest coast of India. *Health Phys*,. 65, pp.390-395.

Sam, A.K and Abbas, N. (2010), Assessment of radioactivity and associated hazards in local and imported cement types used in Sudan. *Radiation protection Dosimetory*, 88, pp.225-260.

Surinder Singh, Asha Rani, Rakesh Kumar Mahajan, (2005), ^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry, *Radiation Measurements*, 39(4), pp. 431-439.

Taskin, H.M, Karavus, P., Ay, A., Touzogh, S., Hindiroglu and Karaham, G., (2009), Radionuclide concentration in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. *Journal of environmental radioactivity*, 100, pp.49-53.

The Iraqi Ministry of Planning, (2009), Summary results of the census of buildings and installations and families, The Central Bureau of Statistics.

Tzortzis, M., Svoukis, E. And Tsertos, H., (2004),A Comprehensive Study of Natural Gamma Radioactivity Levels and Associated Dose Rates From Surface Soils in Cyprus, *Radiat. Prot. Dosimetry*, 109, pp.217-224.

UNSCEAR, (2000), Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly, New York.

United Nation Scientific Committee on Atomic Radiation, (UNSCEAR), (1993), United Nations Scientific Committee on the Effects of Atomic Radiation. Exposure from natural sources of radiation, UN, New York.