Assessment of radioactivity and associated hazards in drinking water in Al-Sadar city, Baghdad

Asia H. Al-Mashhadani, Adel Mehdi Saleh

Department of Physics, College of Science, University of Baghdad, Baghdad. Iraq

Abstract: ***A study of the radioactivity in drinking water from Al-Sader city in Baghdad, Iraq, has been carried out. Thirty water samples were analyzed by γ-ray spectroscopy to determine the ^{226}Ra, ^{232}Th and ^{40}K concentrations. The activity concentration values range were 1.400-55.79BqL^{-1}, ND-11.95BqL^{-1} and 6.3800-253.86 BqL^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively. Radium Equivalent activity was calculated and it was range from 6.8807 BqL^{-1} to 63.521 BqL^{-1}. The absorbed dose rate in air was also calculated for the samples and its range from 3.1524nGyh^{-1} to 29.697nGyh^{-1}. The outdoor annual effective doses ranged from 0.0039mSv to 0.0364mSv with a mean value of 0.0184mSv and the indoor annual effective doses ranged from 0.0186mSv to 0.1716mSv with a mean value 0.0849mSv for one year. The radiation hazard indices of water samples were also calculated, the results showed that the average values of either radionuclides concentration or radiation hazard indices of all water 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 water of Al-Sader city is safe to drink***

Keywords: ^{226}Ra, ^{232}Th and ^{40}K concentrations**,** Al-Sader city**,** annual effective doses**,** radiation hazard indices**.**

1. Introduction

Water is very important compound to life on earth, therefore is one of our most valuable resources. We depend on its quality and quantity for drinking, sanitation, agriculture, industry, urban development, hydropower generation, inland fisheries, transportation, recreation and many other human activities - all related to the economic, mental and physical health of a population. Fresh water makes up only about 2.5% of the total global water resource and the remainder is saltwater [1]. Heavy radionuclides isotopes are in the environment that are not stable, to be stable, these nuclides emit radiations or particles [2]. The radionuclides are present almost everywhere around us; in the earth's crust, air, water, plants and so on. They may be naturally occurring or artificially produced [3]. The increasing interest in radioactivity and its applications has brought about the need for an assessment of human exposure to radiation. It is, therefore, necessary to examine naturally occurring radioactivity in the environment, especially the occurrence of natural radioactivity in groundwater [4]. Concentrations of dissolved radon gas provide one means of detecting the presence of natural radioactivity in groundwater, and, if the radioactivity level of groundwater is beyond acceptable limits, it could result into several health hazards among the populace [5]. Drinking water comes from ground water, which was supplied through public drinking water systems. But many families depend on private, household wells and use groundwater as their source of fresh water. The quality of drinking water is affected by the depth of groundwater from the surface, because there is a chance of being polluted varies from place to place. Human activities can alter the natural composition of groundwater causing undesirable change in groundwater quality in the form of contamination or pollution. Groundwater may contain some natural impurities or contaminants, even with no human activity or pollution. Natural contaminants can come from many conditions in the watershed or in the ground. Water moving through underground rocks and soils may pick up magnesium, calcium and chlorides [6]. Some ground water naturally contains dissolved elements such as arsenic, boron, selenium, or radon, a gas formed by the natural decay of radioactive uranium in soil. Whether these natural contaminants are health problems depends on the amount of the substance present. Radon itself is radioactive because it also decays, losing an alpha particle and forming the element polonium. Some people who are exposed to radon in drinking water may have increased risk of getting cancer over the course of their lifetime, especially lung cancer[7]. Radon accumulates in groundwater due to two different sources, firstly the radioactive decay of dissolved radium (radon's immediate parent in the uranium decay chain), and secondly the direct release of radon from the mineral matrix from minerals (in surrounding rocks) containing members of the uranium decay chain [8]. 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 drinking water from Al-Sader city in Baghdad, Iraq using γ-ray spectrometry.

2. Theory Concepts

2.1 Calculation of Radiation Hazard Indices

It is justifiable to exploit as many as possible of the known 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 [9]. 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) [10].

$Ra_{eq} = C_{Ra} + 1.43\ C_{Th} + 0.077\ C_K$ …… (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 [11].

2.2 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) [12].

$AD = 0.461\ C_{Ra} + 0.623\ C_{Th} + 0.0414 C_K$ …… (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 [13].

2.3 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 [14]. The annual using Eqs.3 and 4:

Outdoor (mSv/y) = AD ($nGyh^{-1}$) × 8760 h × 0.2 × 0.7 $SvGy^{-1}$ × 10^{-6} … (3)

Indoor (mSv/y) = AD ($nGyh^{-1}$) × 8760 h × 0.8 × 0.7 $SvGy^{-1}$ × 10^{-6} … (4)

2.4 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) [15].

$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810$ …… (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) [15]. The internal hazard index (H_{in}) can be calculated by Eq.(6) [15].

$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810$ …… (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.

2.5 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 [16].

ELCR = AEDE x DL x RF …… (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 [16]. This value-free units because it represents the probability of cancer incidence through this we can deduce the equation above.

3. 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 [17].

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 [18]. 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.

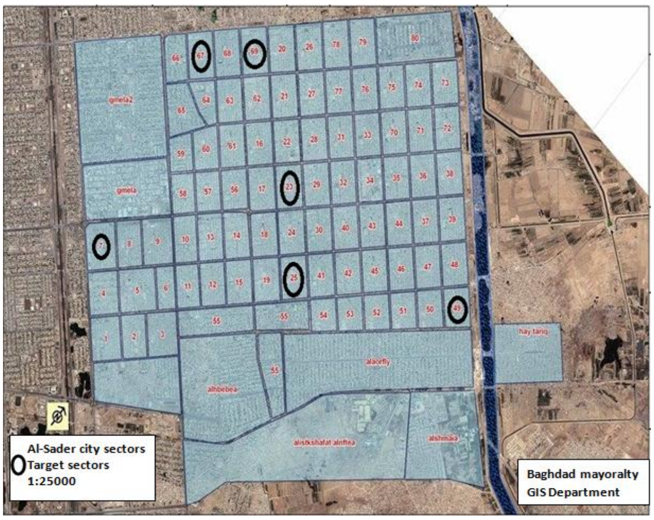

Figure 1: Map of Al-Sader city sectors [19].

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*

4. Materials and Methods

Thirty samples of drinking water were collected from 6 sectors from Al-Sader city in Baghdad, Iraq. Water samples were collected in plastic bottles polyethylene containers. The water samples were acidified with 11 M of H_3O^+, Cl^- at the rate of 10 ml per liter of sample as soon as possible after sampling to avoid absorption of radionuclides on the walls of the containers [20]. Marinelli beakers of 1L capacity rinsed with dilute H_2SO_4 and dried to avoid contamination, were filled with known volumes (1000 mL) of the water sample. 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 [21].

We steamed samples of the water in order to reducing the volume of water from 1000mL to 250mL by using electric heater to raising the concentration of material to be detection, 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 water.

Each sample was identified for the radionuclide that is contaminating the water, 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**.**

5. 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 concentrations values range were 1.400-55.79BqL^{-1}, note detect (ND)-11.95BqL^{-1} and 6.3800-253.86 BqL^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively. The specific activity average values of ^{40}K, ^{226}Ra and ^{232}Th are 129.88BqL^{-1}, 12.883BqL^{-1} and 5.981BqL^{-1} respectively as shown in Fig.2. These radioactivity concentration values obtained in this study are below the world average value of 400BqL^{-1} for ^{40}K, 35BqL^{-1} for ^{226}Ra and 30BqL^{-1} for ^{232}Th [10].

The results obtained for the radium equivalent activity was ranged from 6.8807 BqL^{-1} in sample W_{13} to 63.521 BqL^{-1}in sample W_1 , as shown in Fig.3, all radium equivalent activity are below the permissible values of and 370 BqL^{-1} [10]. Also, the present values of indoor and outdoor annual effective dose equivalent was ranged from 0.0039mSv in sample W_{13} to 0.0364mSv in sample W_1 with a mean value of 0.0184mSv and the indoor annual effective doses ranged from 0.0186mSv in sample W_{13} to 0.1716mSv in sample W_1 with a mean value 0.0849mSv 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) [22]. Furthermore, the external hazard indexes are ranged from 0.0304 in sample W_{13} to 0.3208 in sample W_3 and internal hazard indexes were ranged from 0.0155 in sample W_{13} to 0.1457 in sample W_1 as shown in Figs. 6 and 7. All external and internal indexes values are less than the world permissible value of unity [22].

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 0.0137×10^{-3} in sample W_{13} to 0.1274×10^{-3} in sample W1 as shown in Fig.8. ELCR for all samples is less than the world average of 0.29×10^{-3} [16]. This implies that the chances of having cancer by the populace in general are insignificant. Therefore, drink water from these areas does not effect on the health and security

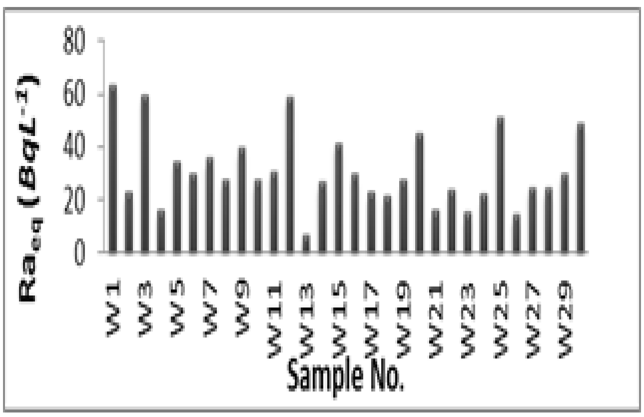

Figure2: The relationship between Radium equivalent and sample number

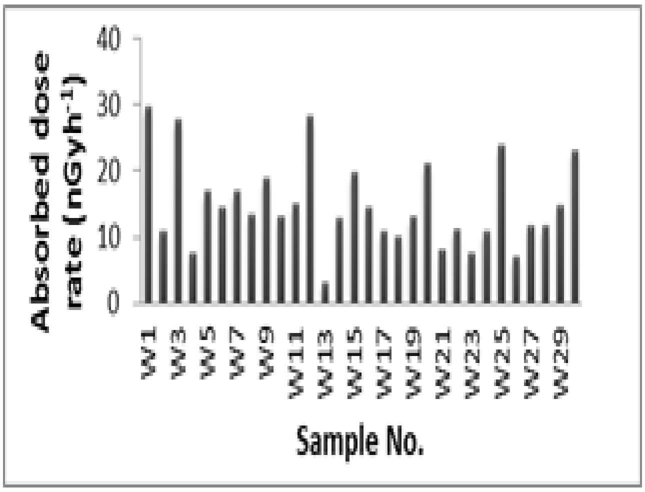

Figure 3: The relationship between the absorbed dose rate in air and sample number.

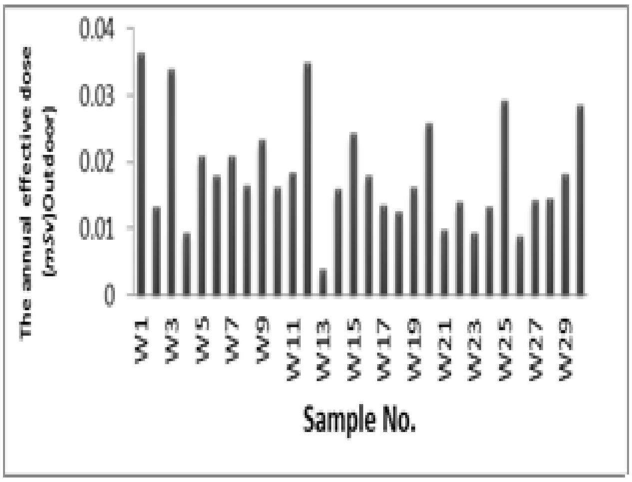

Figure 4: The relationship between the annual effective dose outdoor and sample number

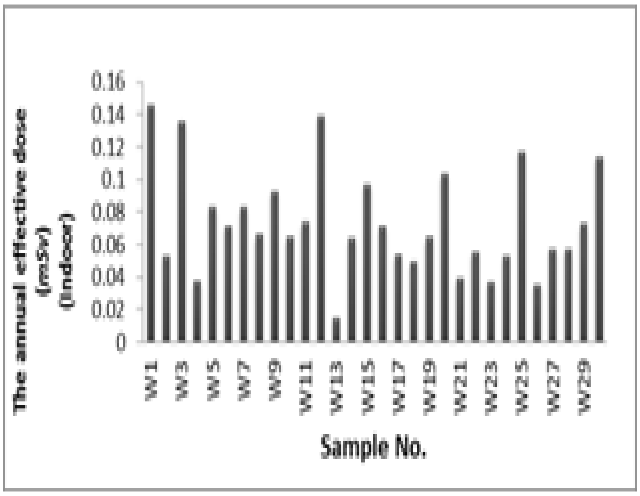

Figure5: The relationship between the annual effective dose indoor and sample number.

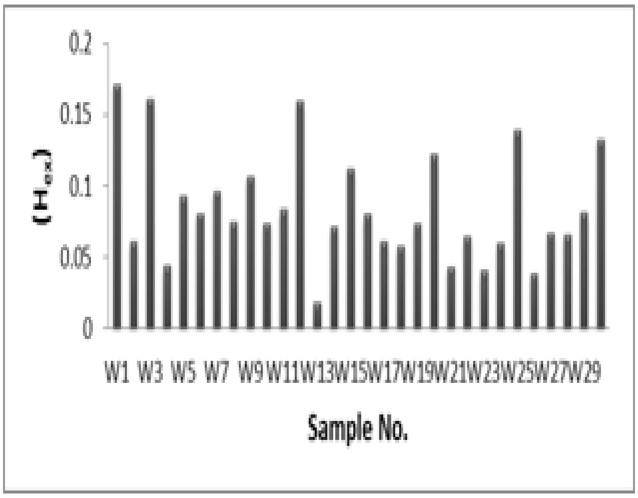

Figure 6: The relationship between the external hazard index and sample number.

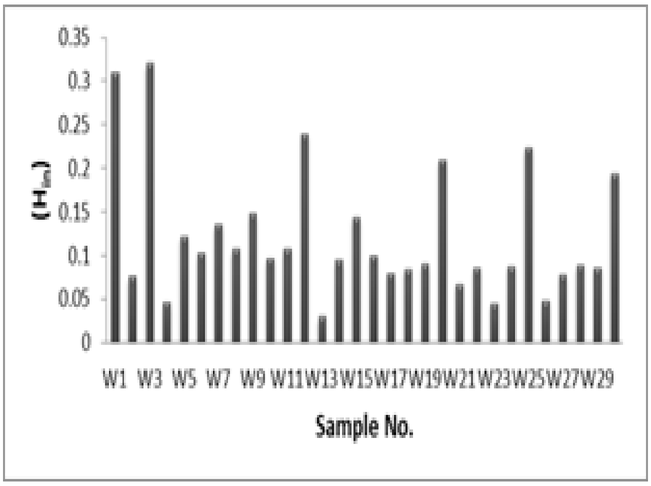

Figure7: The relationship between the internal hazard index and sample number.

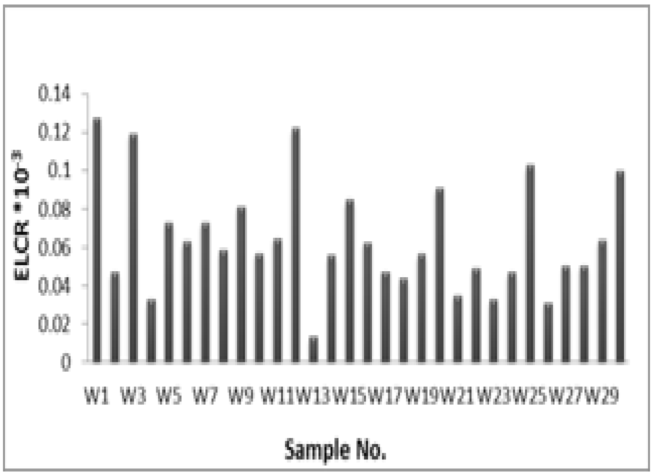

Figure 8: The relationship between Excess Lifetime Cancer Risk and sample number.

6. **Conclusions**

The evaluation of radiation hazard indices and excess lifetime cancer risk of water in Al-Sader city in Baghdad, Iraq have been conducted. The values obtained when compared with the various world permissible values were found to be below the standards for such environment and drink water from this area will pose no significant health threat to human lives and the environment is said to be radiologically hazard safe.

Table (2): Concentration of radionuclide, the hazard indices and excess lifetime cancer risk**.**

Sample No.	Ra-226 (BqL^{-1})	Th-232 (BqL^{-1})	K-40 (BqL^{-1})	Ra_{eq} (BqL^{-1})	Absorbed dose rate ($nGyh^{-1}$)	The annual effective dose (mSv/y)		(H_{ex})	(H_{in})	ELCR $*10^{-3}$
						(Outdoor)	(Indoor)			
W_1	48.37	5.130	101.50	63.521	29.697	0.0364	0.1716	0.3096	0.1457	0.1274
W_2	4.930	6.590	109.16	22.759	10.898	0.0134	0.0615	0.0755	0.0535	0.0469
W_3	55.79	0.590	41.220	59.808	27.793	0.0341	0.1616	0.3208	0.1363	0.1194
W_4	0.620	7.900	59.210	16.476	7.6588	0.0094	0.0445	0.0463	0.0376	0.0329
W_5	10.04	5.580	215.30	34.598	17.018	0.0209	0.0934	0.1221	0.0835	0.0732
W_6	7.440	5.860	183.75	29.969	14.688	0.0180	0.0809	0.1022	0.0721	0.0630
W_7	13.44	8.650	131.49	35.934	17.029	0.0209	0.0971	0.1354	0.0836	0.0732
W_8	11.23	3.380	151.74	27.747	13.565	0.0167	0.0750	0.1070	0.0666	0.0585
W_9	14.52	8.150	174.24	39.591	18.985	0.0233	0.1069	0.1484	0.0931	0.0816
W_{10}	8.120	5.580	147.34	27.445	13.320	0.0163	0.0741	0.0973	0.0653	0.0571
W_{11}	8.190	6.460	176.20	30.995	15.095	0.0185	0.0837	0.1071	0.0740	0.0648
W_{12}	28.20	7.890	253.86	59.030	28.426	0.0349	0.1595	0.2399	0.1394	0.1222
W_{13}	4.130	1.580	6.3800	6.8807	3.1524	0.0039	0.0186	0.0304	0.0155	0.0137
W_{14}	7.890	4.900	152.61	26.648	13.008	0.0160	0.0720	0.0945	0.0639	0.0560
W_{15}	10.96	11.95	177.60	41.724	19.850	0.0243	0.1127	0.1440	0.0974	0.0851
W_{16}	6.880	6.100	184.32	29.796	14.603	0.0179	0.0805	0.1001	0.0717	0.0627
W_{17}	6.300	5.570	112.63	22.938	11.037	0.0135	0.0620	0.0799	0.0541	0.0473
W_{18}	9.240	4.300	79.260	21.492	10.220	0.0125	0.0581	0.0844	0.0501	0.0438
W_{19}	5.320	8.480	131.16	27.546	13.166	0.0162	0.0744	0.0896	0.0646	0.0567
W_{20}	30.56	6.250	76.380	45.379	21.144	0.0259	0.1226	0.2098	0.1038	0.0907
W_{21}	8.150	0.000	105.08	16.241	8.1075	0.0099	0.0439	0.0671	0.0398	0.0347
W_{22}	7.610	6.270	95.860	23.957	11.383	0.0140	0.0647	0.0864	0.0558	0.0490
W_{23}	1.400	2.920	124.84	15.188	7.6329	0.0094	0.0410	0.0450	0.0374	0.0329
W_{24}	9.770	2.080	123.29	22.238	10.904	0.0134	0.0601	0.0880	0.0535	0.0469
W_{25}	29.68	10.51	89.640	51.612	23.941	0.0294	0.1394	0.2241	0.1174	0.1029
W_{26}	3.020	2.150	109.28	14.509	7.2559	0.0089	0.0392	0.0478	0.0356	0.0312
W_{27}	3.780	9.450	99.050	24.920	11.731	0.0144	0.0673	0.0781	0.0575	0.0504
W_{28}	7.950	5.480	113.37	24.516	11.773	0.0144	0.0662	0.0889	0.0578	0.0504
W_{29}	1.460	8.580	214.82	30.271	14.912	0.0183	0.0817	0.0859	0.0732	0.0641
W_{30}	21.51	11.10	155.80	49.380	23.282	0.0286	0.1334	0.1946	0.1142	0.1001
Av.	12.883	5.981	129.88	31.437	15.042	0.0184	0.0849	0.1217	0.0738	0.0644

References

[1] S. P.Ranjan, S.Kazama, M.Sawamoto, "Effects of climate and land use changes on groundwater resources in coastal aquifers" Journal of Environmental Management, 80(1), pp. 25-35, 2006.

[2] M. S Baxter, "Environment Radioactivity: A perspective on industrial contributions" International Atomic Energy Agency Bulletin, 2, pp. 33-38, 1993.

[3] J.Beretka, P.Matthew, "Natural radioactivity of Australian building materials, industrial wastes and by-products". Health Phys, 48, pp. 87-95, 1985.

[4] B. M Smith., W. N. Grune, F. B.Higgind, J. G.Terill, "Natural radioactivity in ground water supplies in Maine and New Hampshire", J. Am. Wat. Wks Ass., 53(1), pp.75–88, 1961.

[5] A. M.Arogunjo, I. P. Farai, I. A. Fuwape, "Dose rate assessment of terrestrial gamma radiation in the delta region of Nigeria", Radia. Prot. Dos.,108, pp. 73–77, 2004.

[6] K. Almahallawi, "Modeling Interaction of land Use, Urbanization and Hydrological Factors for the analysis of Groundwater Quality in Mediterranean Zone" Ph.D.Thesis. University of Lille, France. 2004

[7] United Nation Scientific Committee on Atomic Radiation, UNSCEAR, "Sources and Effects of Ionizing Radiation", A/AC-82/r, 441, pp. 113-120, 1986

[8] J.K.Otton, "The geology of Radon: U.S. Geological Survey", General Interest Publications of the U.S. Geological Survey, 1992.

[9] E. J. Baratta, "Radon, Radium and Uranium in drinking water". Lewis Publisher, Washington DC, pp. 203-213, 1990.

[10] United Nation Scientific Committee on Atomic Radiation (UNSCEAR), "Sources and Effects of Ionizing Radiation"

(Report to the General Assembly). United Nation, New York, 2000.
[11] A.K Sam, N. Abbas, "Assessment of radioactivity and associated hazards in local and imported cement types used in Sudan". Radiation Protection Dosimetory, 88, pp. 225-260, 2010.
[12] D.C. Kocher, A.L. Sjoreen, "Dose-rate conversion factors for external exposure to photon emitters in soil", Healthy Phys.48, pp.193-205, 1985.
[13] S.Joga, S.Harmanjit, S.Surinder, B.S. Bajwa R.G. Sonkawade, "Comparative study of natural radioactivity levels in soil samples from the Upper Siwaliks and Punjab, India using gamma-ray spectrometry" Journal of Environmental Radioactivity, 100 (2), pp. 94–98, 2009.
[14] United Nation Scientific Committee on Atomic Radiation, (UNSCEAR), United Nations Scientific Committee on the Effects of Atomic Radiation. "Exposure from natural sources of radiation", UN, New York, 1993.
[15] J.Beretka, P.J. Mathew, "Natural radioactivity of Australia Building materials industrial wastes and by-products", Health Phy., 48, pp. 87-95, 1985.
[16] H.M.Taskin, P.Karavus, A.Ay, S.Touzogh, Hindiroglu, G.Karaham),"Radionuclide concentration in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey", Journal of Environmental Radioactivity, 100, pp. 49-53, 2009.
[17] Marr Phebe, "The Modern History of Iraq", Westview Press, 2012, page 172.
[18] The Iraqi Ministry of Planning "Summary results of the census of buildings and installations and families", the Central Bureau of Statistics, 2009.
[19] Baghdad mayoralty GIS Department,
[20] International Atomic Energy Agency, "Summary Report on the post accident review meeting on the Chernobyl accident". Safety Ser. 75- INSAG-1, IAEA,Vienna, 1986.
[21] R. A. Onoja, "Total radioactivity count in taps and well water around Zaria area, Kaduna State, Nigeria". Ph.D. Thesis, ABU, Zaria. Nigeria, 2010.
[22] Y.Orgun, N. Altinsoy, S.Y. Sahin, Y. Gungor, A.H. Gultekin, G. Karaham and Z. Karaak, "Natural and anthropogenic radionuclide in rocks and beach sands from Ezine region, Western Anatolia", Turkey. Applied Radiation and Isotopes, 65, pp. 739-747, 2007.

Asia Hameed Hamad

Date of Birth: Baghdad 5/2/1966

- Religion: Muslim
- Martial statues: Married
- No. of children: 2
- Specialization: Arabic
- Scientific Degree: Assistant Professor
- Work Address: Department of Physics, College of Science, University of Baghdad
- Work Phone: 009647787525
- E-mail:assia19662006@yahoo.com

- B.Sc. in 1987 from Baghdad University
- M.Sc. in 1993 from Baghdad University
- Ph.D in 1999 from Baghdad University

- I publish more than 30 Papers
- Courses Which I Teach

1- Medical physics
2- Radiation physics
3- Nuclear Physics
4- Modern Physics
5- General Physics
6- Environmental Physics

- There are 14 Thesis which was I supervised.
- There are more than 20 Conferences which I participated.
- Member in editorial board of Iraqi Journal of Physics

Second Author **Adel Mehdi Saleh,** M.Sc. student in Department of Physics, College of Science, University of Baghdad, Baghdad. Iraq