Poll Res. 40 (1) : 53-57 (2021)

ISSN 0257–8050

CALCULATION OF RADIOACTIVITY LEVELS FOR VARIOUS SOIL SAMPLES OF NEIGHBORHOOD AL RAHMAH (IRAQ)

[*1] SHATHA F. ALHOUS, [2] LUBNA A. ALASADI, [3]SHAYMAA AWAD KADHIM, [4] HAYDER H.HUSSAIN AND [5] RUSUL MOHAMMED ALKHAFAJI

[1,5] Department of Physics, Faculty of Education for Girls, University of Kufa, Iraq.
[2,3,4]Department of Physics, Faculty Science, University of Kufa, Iraq.

(Received 7 July, 2020; accepted 22 August, 2020)

ABSTRACT

The study of radioactive nuclei concentrations in soils is a very important topic due to the contribution of some factors in increasing these concentrations. Where the nucleus transition to food and then the human and endanger their life. Where taken 15 samples of soils from Al Rahmah district, where a gamma-ray spectrometer system connected with the NaI(TI) detector was used to measure the specific activity of the ^{226}Ra, ^{232}Th and ^{40}K nuclei, the specific activity values were varied from (0.526 -5.385) $Bq.kg^{-1}$ with mean (2.193 $Bq.kg^{-1}$) for ^{226}Ra,(0.56 -5.29) $Bq.kg^{-1}$ with average (2.95 $Bq.kg^{-1}$) for ^{232}Th and (209.239-990.387) $Bq.kg^{-1}$ with mean (598.714 $Bq.kg^{-1}$) for ^{40}K, respectively. Specific activity values showed that there was only a significant increase in ^{40}K concentrations, while that the difference between the rate of Thorium and Radium concentrations was little. External and internal hazard indices, outdoor and indoor absorbed doses and Radium equivalent activity and total annual effective dose which were below the internationally recommended limits. The excess life-time cancer risk (ELCR) was ($0.717*10^{-3}$) which compares with the worldwide value ($1.45*10^{-3}$), this is the first study in this region and can be considered as a baseline for future studies in this area.

KEY WORD : Soil, Gamma spectroscopy, Specific activity, ELCR, Al Rahmah, Iraq.

INTRODUCTION

U-238, Th-232 and K-40 are three long-lived natural radionuclides present in the earth's crust. In general, there are two sources of environmental, natural radionuclides (mainly from the ^{238}U series, ^{232}Th) and artificial sources (^{137}Cs). These radionuclides can be released into the environment as a result of human activities, including energy production and military operations such as nuclear weapons testing or nuclear accidents (Chernobyl disaster in 1986 and Fukushima earthquake in 2011) (Kapdan *et al.,* 2011). It is important to study the distribution, properties of radionuclides and their effect on the environment. Uranium, Thorium, and decay products are radionuclides that pose a potential risk to human health due to the emission of ionizing radiation (Barescut *et al.,* 2011). It is very important to measure natural radioactivity in rocks and soil to determine and control the amount of natural background activity change with time to protect the environment (Iqbal *et al*., 2000) .The level of radiation is not the same in different parts of the world and depends on the concentration of radionuclides in the earth's crust. Natural concentrations of radionuclides in the soil are usually associated with the radionuclide concentration in the substratum. The concentrations of radionuclides (Ultra-Microelement) in plants are linearly linked to the concentration of radionuclides in soil (Al-Hamarneh and Awadallah, 2009).

Natural background levels of the agro-ecosystem can be increased if phosphoric fertilizers are applied. The concentrations of Naturally Occurring Radioactive Materials (NORMs) in phosphorus fertilizers can be similar to the mean concentrations in soil or ten times higher. The production, transport, storage and use of these fertilizers cause an additional dose of exposure to humans (Snyder *et al.*, 2009). It is, therefore, necessary to limit values (NORMs) concentrations in fertilizers. Terrestrial isotopes, Thorium, Uranium, and Potassium enter the human body through the food chain, mostly by eating. Plants absorb these radionuclides through their roots and accumulate in eaten parts of plants. When these plants are processed and consumed, the accumulating radionuclides produce an internal radiation dose for humans (Koranda and Robison, 1978). There is a plentiful study on the effect of radionuclides in soil under laboratory conditions (Vig *et al*., 2003). Since the soil is contaminated with radionuclides and heavy metals, there is a proclivity for crops to absorb the toxic material and ultimately transport them to the human body. In addition, the low quality and productivity of crops caused by contaminated foods, grains and vegetables will ultimately affect human health (Prasad, 2003). The aim of this study is to measure the natural radioactivity contents, Radium equivalent activity, external and internal radiation hazard indices, representative level index (Iγ), effective dose rate (D_{eff}) and the risk cancer in the surface soils of Al Rahma neighborhood. The data provided in this study will be baseline.

ANALYTICAL TECHNIQUE

Study area

Najaf is one of the cities of central Iraq which is located to southwest of the capital, Baghdad. It has an area of 864 km and is about 60 m above sea level. it's one of the important cities in Iraq due to the Najaf sea is the most important geographical phenomenon in the city also, the presence of religious shrines, Imam Ali shrine is the most important one which located in the city center. Al Rahmah neighborhood, about (3 km) from Imam Ali shrine, was chosen for this study due to appearance of many cases of cancer in this region. Moreover , it's a popular area with high population and its streets are not paved, so the residents are in direct exposure to soil.

SAMPLE COLLECTION AND MEASURING METHODS

In 2013, soil samples were collected from fifteen different sites and randomly from various lands located within the administrative boundaries of Al Rahmah. Where the Figure 1 represented the map of Iraq is where the Najaf Province is located and that samples location are indicated in Al-Rahma neighborhood where the radiation level was measured.

One kg of soil samples were taken by manually using a small shovel from (5-10) cm depth and kept in plastic bags and transferred to the laboratory of the physics department of the Faculty of Science, University of Kufa. The samples were prepared for measurement after removal of impurities such as

Fig. 1. Map showing the locations of sampling for *Al Rahmah*, Najaf, Iraq.

rocks, roots of plants and leaves, and then dried with air and using the oven at (80 °C) until the moisture was completely removed and fixed weight. Dried samples were grinding and passed through a (2 mm) mesh sieve. Then, the samples were packed into (1-liter) polyethylene marinelli beaker and sealed tightly. In order to reach the state of the secular equilibrium between the radium (^{226}Ra and ^{228}Ra) nuclei and their daughters, the samples were stored for two months. Soil samples were analyzed to measure the radioactivity of natural radioactive nuclei by using an Ortec-digiBASE gamma-ray spectrometer based on the 3″ × 3″ NaI detector with 6.8% energy resolution at 662 keV for ^{137}Cs. The Scinti Vision™-32 software was installed in the computer for data analysis, and the energy and efficiency of the system were calibrated. The measurement time was (28800 second). An empty marinelli was used in the same time period above to measure the average background radiation. The values of energies 1460 keV for ^{40}K, 1764 keV for ^{214}Bi and 2614 keV for ^{208}Tl were adopted to measure the radioactivity for the ^{40}K, ^{226}Ra and ^{232}Th nuclei respectively.

CALCULATIONS

For each individual isotope, the specific activity in (Bq.kg^{-1}) units was calculated by using the equation (1) (Hussain and Hussain, 2011).

$$\mathcal{A}_n = \frac{(\mathcal{C}_n - \mathcal{C}_b)}{t \varepsilon_\gamma I_\gamma m_s} \quad ..(1)$$

Where $\mathcal{A}_n$ is the specific activity of each radionuclide in Bq.kg^{-1}, $_n\mathcal{C}_n$ the count rate in cps for a sample, $\mathcal{C}_b$ the count rate in cps for background, ε_γ and I_γ are detection efficiency and emission probability of γ-ray, t is the counting time and m_s is the mass of the sample in kg. The distribution of ^{40}K, ^{226}Ra and ^{232}Th nuclei in rocks and soil are not uniform, so a common factor was used to compare its combined radiological effects, this factor is called the Radium equivalent activity (Ra_{eq}) as proposed by the Organization of Economic Cooperation and Development (Ahmad *et al.*, 2015). And so will we calculate, representative level index (Iγ), effective dose rate (D_{eff}, D_{eff1}), internal hazard index (H_{in}), internal hazard index (H_{ex}) and absorbed dose rate (D_{in}, D_{out}) in soil samples. Likewise, we considered the Excess Life-time Cancer Risk (ELCR) account for them as important to human life.this risk due to radiation effects can be calculated from the following equation (Avwiri *et al.*, 2014).

$$ELCR = AEDA*LS*RF \quad .. (2)$$

AEDE: The Annual Effective Dose Equivalent.
LS: is a mean life span for adult (66 years).

By offsetting these variables we will get the (ELCR) of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples .The value of risk factor (RF) for stochastic effects in the population is 0.05 per Sievert as recommended by ICRP (James and Birchall, 1995).

RESULTS AND DESCUSSION

The specific activity values calculated for the 15 soil samples were listed in Table 1 in addition to their ratios.

From Table 1 we can see that the values of ^{226}Ra and ^{232}Th specific activity for the soil samples in this study with maximum values in sample S_9. While the minimum value of them were recorded in sample S_6 in this study, and these values were significantly lower than the worldwide average recommended by UNSCAER [12]. The measurements of the specific activity of the ^{40}K with maximum value in sample S_2 and a minimum value in sample S_{15}, only (from s_1 to s_8) samples with average out of fifteen samples have specific activity values of ^{40}K higher than the worldwide average value (420 Bq.kg^{-1}) recommended by the UNSCAER, the observed increase in the values of the specific activity of potassium in many soil samples may be due to the fact that a war in this region in 2004 between Iraq and US forces or due to the soil Geology. The ratios were used to provide a clear idea of the relationship between these concentrations, from Table 1 we can show that the concentrations of Thorium are greater slightly than the concentrations of Radium , but both less than the concentrations of Potassium because of the significant increase in Potassium concentrations, the ratio between concentrations of Th/K and Ra/K are close together while the ratio of Th/Ra is higher than the global limits the maximum values of Rdium equivalent activity, representative level index, external hazard index, outdoor absorbed dose, internal hazard index, indoor absorbed dose, annual effective dose equvilent and cancer risk in sample S_2, the reason could be the high Potassium concentration activity in this sample, while the minimum values in sample S_{14} as shown from Table 2, all values of the indicators are less than the permissible limits except for the annual effective

Table 1. The specific activity of ^{226}Ra, ^{232}Th and ^{40}K and their ratios in soil samples collected from Al Rahmah.

Sample code	Specific Activity ($Bq.kg^{-1}$)			Ratios		
	^{226}Ra	^{232}Th	^{40}K	Ra/K	Th/K	Th/Ra
S_1	2.629±0.55	2.56± 0.23	856.61± 2.11	0.0031	0.0030	0.98
S_2	1.606±0.64	2.01± 0.25	990.38±2.08	0.0016	0.0020	1.25
S_3	2.018±0.81	1.01±0.19	982.05± 2.09	0.0021	0.0010	0.50
S_4	1.165±0.55	1.54±0.22	975.89± 2.16	0.0012	0.0016	1.32
S_5	3.708±0.72	1.28±0.19	916.92± 2.03	0.0040	0.0014	0.35
S_6	0.526±0.48	0.56±0.15	866.77±2.16	0.0006	0.0007	1.07
S_7	0.796±0.47	0.98±0.21	879.10± 2.04	0.0009	0.0011	1.24
S_8	1.733±0.45	2.00±0.19	842.28± 1.99	0.0021	0.0024	1.15
S_9	5.385±1.07	5.29±0.40	223.44± 3.39	0.0241	0.0237	0.98
S_{10}	1.080±0.24	4.22±0.15	258.48± 2.29	0.0042	0.0163	3.91
S_{11}	1.051±0.21	4.41±0.16	262.39± 2.23	0.0040	0.0168	4.19
S_{12}	1.989±0.20	3.69±0.15	254.23± 2.18	0.0078	0.0145	1.85
S_{13}	4.731±0.99	5.28±0.39	240.09± 3.43	0.0197	0.0220	1.12
S_{14}	1.051±0.26	4.21±0.16	220.58± 2.28	0.0048	0.0191	4.00
S_{15}	1.904±0.51	5.28±0.40	209.23± 2.09	0.0091	0.0252	2.77
Max	5.385	5.29	990.3877	0.0241	0.0252	4.19
Min	0.526	0.56	209.2392	0.0006	0.0007	0.35
Mean	2.193	2.95	598.7149	0.0067	0.0104	1.84
Worldewide (Charles, 2010; Rangaswamy, Srinivasa Srilatha) Sannappa, 2015)	35	30	420	0.087	0.075	0.86

Table 2. Calculated values of hazard indices for soil samples collected from Al Rahmah.

ID	Ra_{eq} ($Bq.Kg^{-1}$)	I_g ($Bq.kg^{-1}$)	H_{ex}	D_{out} ($Bq.Kg^{-1}$)	H_{in} ($nGy.h^{-1}$)	D_{in} ($nGy.h^{″1}$)	D_{eff} ($mSv.y^{″1}$)	D_{eff1} ($mSv.y^{-1}$)	Cancer risk Risk*10^{-3}
S_1	72.256	0.614	0.195	39.655	0.202	51.551	0.048	0.252	0.995
S_2	80.742	0.691	0.218	44.604	0.222	57.985	0.054	0.284	1.119
S_3	79.082	0.678	0.214	43.760	0.219	56.887	0.053	0.279	1.098
S_4	78.515	0.674	0.212	43.482	0.215	56.527	0.053	0.277	1.091
S_5	76.145	0.649	0.206	41.860	0.216	54.418	0.051	0.267	1.050
S_6	68.075	0.587	0.184	37.870	0.185	49.231	0.046	0.241	0.950
S_7	69.892	0.601	0.189	38.792	0.191	50.430	0.047	0.247	0.973
S_8	69.450	0.593	0.188	38.283	0.192	49.767	0.046	0.244	0.960
S_9	30.153	0.238	0.081	15.408	0.096	20.031	0.018	0.098	0.386
S_{10}	27.018	0.222	0.073	14.370	0.076	18.681	0.017	0.091	0.360
S_{11}	27.558	0.226	0.074	14.649	0.077	19.044	0.018	0.093	0.367
S_{12}	26.841	0.22	0.072	14.224	0.078	18.491	0.017	0.090	0.356
S_{13}	30.764	0.244	0.083	15.838	0.096	20.589	0.019	0.101	0.397
S_{14}	24.055	0.196	0.065	12.720	0.068	16.537	0.015	0.081	0.319
S_{15}	25.561	0.205	0.069	13.304	0.074	17.295	0.016	0.084	0.333
Max	80.742	0.691	0.218	44.604	0.222	57.985	0.054	0.284	1.119
Min	24.055	0.196	0.065	12.720	0.068	16.537	0.015	0.081	0.319
Mean	52.406	0.442	0.142	28.597	0.147	37.176	0.035	0.182	0.717
Worldewide (Charles, 2001, 2010)	370	?1	?1	59	?1	84	0.07	0.41	1.45

doses equvilent, they are greater than the limits of worldwide [12]. It is important to focus on the risk of cancer by using the equation (2) which gives a risk factor of ($0.717*10^{-3}$), the estimated values are significantly less than the ICRP cancer risk of (1.45×10^{-3}). This indicates that the soil in this region is safe and has no negative effects on human health (Mohammed and Ahmed, 2017).

CONCLUSION

Soils in Al rahmah neighborhood has a significant increase in potassium activity concentrations may be due to geology of the soil or have been in the sea of Najaf. Where should be noted that the studyarea was previously agricultural land, which led to a high concentration of Potassium. While Radium and Thorium, their concentrations are low in this region compared with other countries in the world. Finally the ELCR is lower than average world. UNSCEAR2000B, all values of hazard indices are less than the permissible limits.

ACKNOWLEDGEMENT

Sincere thanks to Dr. Murtadha Sh. Asoowd in department of Physics, college of education, university of Al- Qadisiyah, Iraq for clarifying several points in this research.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Ahmad, N., Jaafar, M. and Alsaffar, M. 2015. Natural radioactivity in virgin and agricultural soil and its environmental implications in Sungai Petani, Kedah, Malaysia. *Pollution.* 1(3) : 305-313.

Al-Hamarneh, I. F. and Awadallah, M. I. 2009. Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan. *Radiation Measurements.* 44 (1) : 102-110.

Avwiri, G., Ononugbo, C. and Nwokeoji, I. 2014. Radiation Hazard Indices and Excess Lifetime cancer risk in soil, sediment and water around mini-okoro/ oginigba creek, Port Harcourt, Rivers State, Nigeria. *Comprehensive Journal of Environment and Earth Sciences.* 3 (1) : 38-50.

Barescut, J., Lariviere, D., Stocki, T., Pandit, G., Sahu, S., and Puranik, V. 2011. Natural radionuclides from coal fired thermal power plants-estimation of atmospheric release and inhalation risk. *Radioprotection.* 46 (6) : S173-S179.

Charles, M. 2001. UNSCEAR Report 2000: sources and effects of ionizing radiation. *Journal of Radiological Protection.* 21 (1) : 83.

Charles, M. 2010. Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2006 Report, Volume 1–Report to the General Assembly, with Scientific Annexes A and B: Oxford University Press.

Hussain, R. O. and Hussain, H. H. 2011. Investigation the natural radioactivity in local and imported chemical fertilizers. *Brazilian Archives of Biology and Technology.* 54 (4) : 777-782.

Iqbal, M., Tufail, M. and Mirza, S. M. 2000. Measurement of natural radioactivity in marble found in Pakistan using a NaI (Tl) gamma-ray spectrometer. *Journal of Environmental Radioactivity.* 51(2) : 255-265.

James, A. and Birchall, A. 1995. New ICRP lung dosimetry and its risk implications for alpha emitters. *Radiation Protection Dosimetr.* 60 (4) : 321-326.

Kapdan, E., Varinlioglu, A. and Karahan, G. 2011. Radioactivity levels and health risks due to radionuclides in the soil of Yalova, Northwestern Turkey. *International Journal of Environmental Research.* 5 (4) : 837-846.

Koranda, J. J. and Robison, W. L. 1978. Accumulation of radionuclides by plants as a monitor system. *Environmental Health Perspectives.* 27 : 165-179.

Mohammed, R. and Ahmed, R. 2017. Estimation of excess lifetime cancer risk and radiation hazard indices in southern Iraq. *Environmental Earth Sciences.* 76 (7) : 303.

Prasad, M. 2003. Phytoremediation of metal-polluted ecosystems: hype for commercialization. *Russian Journal of Plant Physiology.* 50 (5) : 686-701.

Rangaswamy, D., Srinivasa, E., Srilatha, M. and Sannappa, J. 2015. Measurement of terrestrial gamma radiation dose and evaluation of annual effective dose in Shimoga District of Karnataka State, India. *Radiation Protection and Environment.* 38(4) : 154.

Snyder, C., Bruulsema, T., Jensen, T. and Fixen, P. 2009. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. *Agriculture, Ecosystems & Environment,* 133(3-4) : 247-266.

Vig, K., Megharaj, M., Sethunathan, N. and Naidu, R. 2003. Bioavailability and toxicity of cadmium to microorganisms and their activities in soil: a review. *Advances in Environmental Research.* 8 (1) : 121-135.