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Measuring the Radiation Level of ^{40}K, ^{238}U, ^{232}TH in a Region at Alhindia District in Iraq

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Abstract: The activity and the concentration of natural radionuclides of three elements (^{40}K, ^{238}U and ^{232}TH) were determined in 10 soil samples, collected from the village of Almanfahan in Alhindia District. They were studied and then evaluated. The standard sources of ^{40}K,^{238}U and ^{232}TH are used for calibration of radiation activity by gamma spectrometer NaI (TI). The radioactivity of natural isotopes ^{40}K, ^{238}U and ^{232}TH has been estimated. The results showed the radio activities of element in this study were within the acceptable standard levels. In addition, the radium equivalent activity, average air volume, annual effective dose rate and external risk index were assessed and found to be among the internationally tolerable values. The radioactivity of nuclides of ^{40}K, ^{238}U and ^{232}TH in Al-Manfahan village at Alhindia District were calculated. The radioactivity of ^{238}U ranged from 8.59±44-347.69±616 Bq/kg with an average of 49.68±108 Bq/kg while It was for ^{232}TH ranged from 6.01±167-87.44±41 Bq/kg with an average of 55.06±58.1 Bq/kg and ^{40}K ranged from 95.09±393-357.68±178 Bq/kg with an average of197.91±183.8 Bq/kg with an also, it is found that the average of radiological effects like the Radium equivalent (Ra_{eq}), the absorbed Dose rate (Dr), External Hazard Index (H_{ex}), Internal Hazard Index (H_{in}), representative gamma hazard Index (Iγ), the total Annual Effective Dose Equivalent (AEDE) and Lifetime the Excess Cancer Risk (ELCR) due to natural radioactivity in soil samples for textile plant were 143.65±5.7 Bq/kg and 65.399±2.5 nGy/h and 0.388±0.03 and 0.568±0.04, 1.0137±0.05, 0.320±0.02, 0.080±0.03 mSv/y, 0.401±0.04, 1.403×10^3±0.03, respectively which was attributed to increasing the natural radioactivity in the soil of Al-Manfahan village in the center of the province of Al Hindai.

Key words: Natural radioactivity, specific activity, absorbed, external hazard, annual dose, Iraq

INTRODUCTION

Natural radiation has significantly affected our daily lives. The main sources of natural radioactive amounts are the atmosphere, soil and water (Lee *et al*., 2004). For instance, primary cosmic ray emits from the space and reach to the atmosphere while ground radiation may be emitted from radionuclides in earth's crust including soil and rocks. These types of radiations are emitted from some radioactives which may be transported to human's body through food chains or through inhalation and then accumulated in biological tissues (Namibi *et al*., 1986). Previous studies on radiation levels and the distribution of radionuclides in the environment provide a good radioactive database. This information is necessary to understand human exposure from nature and man-made sources of radiation which are essential in the development of rules and regulations for protection against such radiation (Quindos *et al*., 1994). Natural radioactivity is widespread in various geological formations of the earth (Kathren, 1998). Studies on natural radioactivity are necessary not only for the effect of radiation but because they are of great importance in health physics. Therefore, studies on the measurement of natural radioactivity in a soil are very important to determine the amount of change in a natural background activity over time due to the spread of radioactivity (Damaris, 2014). Radiation is divided into two types and ionizing or non ionizing radiation, ionizing radiation is particles (α and β) while non-ionizing radiation is electromagnetic wave such as microwave, infrared, ultraviolet radiation, radio waves and visible light. The main concept of the process of radioactivity is spontaneous decay of unstable nucleus (Podgorsak, 2005). The aim of this study is to investigate the natural radioactivity of ^{238}U, ^{232}Th and ^{40}K in soil samples which was collected from differentlocations in the village of Almanfahanat Alhindia Province in Karbala City in Iraq as shown in Fig. 1.

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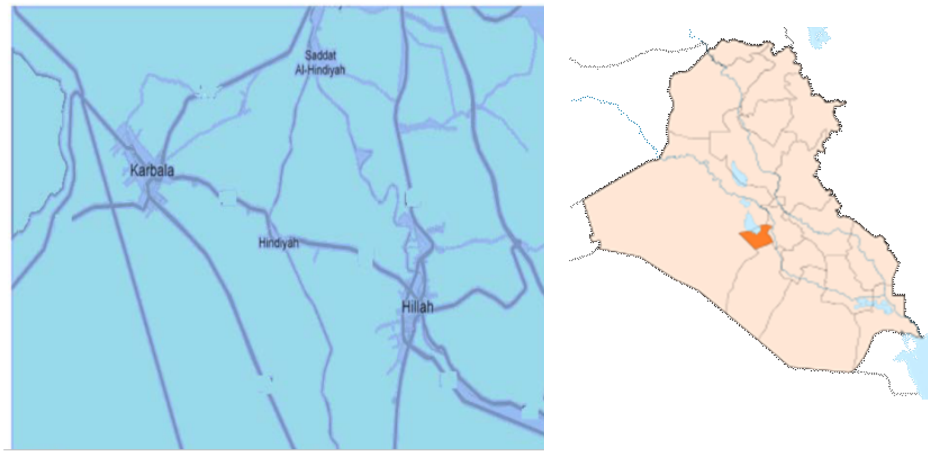

Fig. 1: Geographical map of Alhindia District location, Karbala, Iraq

MATERIALS AND METHODS

Experimental procedure: Ten soil samples were collected at a depth of 15 cm from a soil in an elected area of 3 km^2 from rural region (Almanfahan village) of Alhindia District in Holy Province of Karbala. This group has been guided by the standards recommended by the International Atomic Energy Agency (IAEA). First, the samples were cleaned to remove undesirable materials. Next, the samples were placed in a preheated oven (Ueto-91src) at 273 K to remove the moisture. After that the samples were analyzed for the selective homogeneous particle size by a sieve then 300 μm producing net weights of 0.75 kg. A sample was then filled in a single cubic in marinellicup of fixed size to ensure the engineering homogeneity around the detector. The plastic cup was then sealed with tape and stored for a one month. The multivariate analyzer (4096 channel range) combined with the analogue to digital unit through interface and desperation energy (FWHM) in the peak 1.33 keV for ^{60}Co is 7.9%. A shield was set to prevent emitting a radiation. To the surrounding using ORTEC cylindrical chamber (diameter 22 cm) consists of two parts, one of the stainless steel of 20 cm and the second part of the lead with a width of 5 cm. The was calibrated for an energy acquisition by using a set of radioactive standard sources spectrometer of known energies and gamma-ray 1 μCi such as ^{137} Cs.

^{60}Co and ^{22} Na. Energy efficiency was performed in a gamma spectrometer using the same calibration sources in a one cup of marinelli to cover power from 500-2500 kV. then a standard source was placed over the detector with an exact geometrical match between geometric sample and sample detector. A sample was placed in the middle of the chamber inside the shield with a period of about 4 h according to its radioactivity. The energy with secular equilibrium was and determined at 1764.49 kV from gamma power transition of 214 Bi (probability of 15.96%) at 2614 keV from gamma transfer energy of 208 Tl, (probability 99%), respectively while activity is 40 K balance with them, respectively while activity is ^{40}K. It is determined using a 1400 kV a gamma ray line (Probability of 11%).

Theoretical calculations

Specific Activity (A): It is possible to calculate the radioactivity of any element of this series in terms of the radioactivity of another element. Specifically, in the thorium (^{232}Th) series, the specific effectiveness of the uranium series ^{238}U was measured by measuring the specific efficiency of the Bismuth ^{214}Bi with a card of 1764 keV. The specific efficiency of the Thalum ^{208}Tl radionuclide with the 2614 keV card. While the specific activity of thorium ^{232}Th was measured by determining the specific efficiency of the radioactive ^{40}K potassium receptor with 1460 keV. The qualitative efficacy (A) can be measured by the following Eq. 1 (Muayed, 2015):

$$A = \frac{C}{I_{\gamma} \times \varepsilon \times M \times t} \quad (1)$$

Where:

C = Net gamma counting rate (counts/sec)
ε = Efficiency of the detector
$I_{ã}$ = Intensity of the gamma-line in a radionuclide
M = Mass of the sample (kg)
t = The live time for collecting the spectrum sec (Harb *et al*., 2008)

External Hazard Index (H_{ex}): Measurment of hazard indices depending on the specific efficacy of uranium, thorium and potassium, several risk factors were measured including:

Radium equivalent: The Radium equivalent (Ra_{eq}) can be measured from the following Eq. 2 (Al-Aamer, 2008; Diab *et al*., 2008):

$$Ra_{eq}\left(Bq/kg\right) = A_U + 1.43A_{Th} + 0.077A_K \tag{2}$$

A_{th}, A_u and A_K are the specific efficiency of the uranium chain and the thorium and potassium series, respectively. In Eq. 2, it is assumed that 10 Bq/kg of uranium, 7 Bq/kg of thorium and 130 Bq/kg of potassium produces an equal dose of radiation (Al-Aamer, 2008). The highest value of Ra_{eq} should be less than the global limit (370 Bq\kg) (Jassim *et al*., 2016).

Absorbed Dose rate in air (AD): The total rate of the absorbed Air Dose (AD) can be measured in terms of concentrations of terrestrial nuclei by the following Eq. 2 (EC, 1999):

$$AD\left(nGy/h\right) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \tag{3}$$

Effective annual dose: The annual effective dose was measured using the following Eq. 4 and 5 (UNSCEAR, 2000):

$$\text{AEDE indoor}\left(mSv\backslash y\right) = AD\left(nGy/h\right)\times 8760\ h\times 0.8\times 0.7Sv/Gy\times 10^{-6} \tag{4}$$

$$\text{AEDE outdoor}\left(mSv\backslash y\right) = AD\left(nGy/h\right)\times 8760\ h\times 0.2\times 0.7Sv/Gy\times 10^{-6} \tag{5}$$

The coefficient (0.7 Sv/Gy) was used as a factor of conversion from the air-absorbed dose to the effective annual dose received by adults and (0.8) the time spent inside and 0.2 was the proportion of time spent abroad (8760) refers to the number of hours of the year and the global average effective annual dose is 0.48 (mSv) (EL-Taher and Makhluf, 2010):

External Hazard Index (H_{ex}): The external risk guide is an assessment of the risk of natural gamma radiation, calculated from the following Eq. 6 (Mahur *et al*., 2010):

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{6}$$

It should be less than one, if it is equal to or greater than one indicates a radiological hazard. Hussain *et al*. (2010) internal risk index (H_{in}). The internal exposure is the result of the inhalation of radon and its fluids which can be expressed in terms of internal risk factor and is calculated by the following Eq. 7 (Singh *et al*., 2009):

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \tag{7}$$

This factor must be less than one to be within the internationally permissible limits (UNSCEAR., 2000a, b).

Activity concentration Index (Iγ): It is a parameter used to measure the risk of Kama radiation associated with natural radionuclides (^{238}U, ^{232}Th and ^{40}K) in the studied substance and the (Iγ) coefficient is defined by Eq. 8 (Harb *et al*., 2008):

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \tag{8}$$

Excess lifetime cancer risk: The value of excess lifetime cancer risk can be calculated by Eq. 9 (UNSCEAR., 2000):

$$ELCR = AEDE.DL.RF \tag{9}$$

Where:

ELCR = Excess Lifetime Cancer Risk
DL = Average Duration of human life
RF = Risk Factor, Sv^{-1}
DL = Average Duration of Life (estimated to be 70 years
RF = Risk Factor

Sv, i.e., fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

RESULTS AND DISCUSSION

Al-Manfhan area the district of Hindia District

Activity specified: The results of specific activity for ^{238}U, ^{232}Th and ^{40}K radionuclides in a sample from the center of the Hindia District in Al Manfahan village is displayed in Table 1, a set of activity defined for ^{238}U, it ranged from 3.86 Bq/kg in S4 as a minimum value to 156.46 Bq/kg

Table 1: Results of Natural Radioactivity Center of the Hindia District of Al-Manfahan

	Specific activity (Bq/kg)		
Sample codes	^{238}U	^{232}Th	^{40}K
S1	24.77±72	6.01±167	180.71±179
S2	26.82±76	78.03±60	100.96±316
S3	10.91±44	71.14±55	221.57±133
S4	8.59±44	66.15±40	188.92±128
S5	20.95±32	24.02±38	357.68±178
S6	14.56±51	55.50±48	210.02±124
S7	8.93±54	87.44±41	225.31±136
S8	15.69±44	26.85±45	182.73±122
S9	17.85±50	52.21±47	216.12±129
S10	347.69±616	83.23±40	095.09±393
Max	347.69±616	87.44±41	357.68±178
Min	8.59±44	6.01±167	95.09±393
Average±SD	49.68±108	55.06±58.1	197.91±183.8

Table 2: Results Ra_{eq}, D_r, H_{ex}, H_{in} and Iγ in textile plant

Sample codes	Ra_{eq}(Bq/kg)	D_r(nGy/h)	H_{ex}	H_{in}	Iγ
S1	47.29±13.97	22.717±6.13	0.127±0.03	0.217±0.04	0.345±0.09
S2	146.19±6.37	65.065±2.85	0.394±0.01	0.492±0.02	1.026±0.04
S3	129.70±5.11	129.70±2.26	0.350±0.01	0.389±0.01	0.931±0.035
S4	117.73±3.95	52.928±1.75	0.317±0.01	0.349±0.013	0.844±0.02
S5	82.85±3.61	39.516±1.60	0.223±0.009	0.299±0.012	0.618±0.025
S6	110.10±4.79	49.955±2.13	0.297±0.012	0.350±0.016	0.792±0.033
S7	151.33±4.27	67.829±1.90	0.408±0.011	0.441±0.015	1.084±0.029
S8	68.16±4.38	31.546±1.94	0.184±0.011	0.240±0.01	0.494±0.030
S9	109.15±4.63	49.684±2.05	0.294±0.012	0.359±0.016	0.785±0.032
S10	474.03±15.5	216.287±7.11	1.280±0.041	2.541±0.08	3.213±0.104
Max	474.03±15.5	216.287±7.11	1.280±0.041	2.541±0.08	3.213±0.104
Min	47.29±13.97	22.717±6.13	0.127±0.03	0.217±0.04	0.345±0.09
Average±SD 143.65±5.7	143.65±5.7	65.399±2.5	0.388±0.03	0.568±0.04	1.0137±0.05

Table 3: Results of $AEDE_{indoor}$, $AEDE_{outdoor}$, AEDE and ELCR in textile plant

Sample codes	$AEDE_{indoor}$ (mSv/y)	$AEDE_{outdoor}$ (mSv/y)	AEDE (mSv/y)	ELCRX10^{-3}
S1	0.111±0.03	0.027±0.007	0.139±0.03	0.487±0.13
S2	0.319±0.01	0.079±0.003	0.398±0.013	1.396±0.06
S3	0.286±0.011	0.071±0.002	0.358±0.012	1.254±0.04
S4	0.259±0.008	0.064±0.002	0.324±0.01	1.135±0.03
S5	0.193±0.007	0.0484±0.001	0.242±0.008	0.848±0.034
S6	0.245±0.010	0.061±0.002	0.306±0.012	1.072±0.04
S7	0.332±0.009	0.083±0.0023	0.415±0.011	1.455±0.040
S8	0.154±0.009	0.038±0.002	0.193±0.01	0.677±0.041
S9	0.243±0.010	0.060±0.0025	0.304±0.012	1.066±0.044
S10	1.061±0.03	0.265±0.008	1.326±0.03	4.641±0.15
Max	1.061±0.03	0.265±0.008	1.326±0.03	4.641±0.15
Min	0.111±0.03	0.027±0.007	0.139±0.03	0.487±0.13
Average±SD	0.320±0.02	0.080±0.03	0.401±0.04	1.403±0.03
World wide average	0.42	0.08	0.50	-

in S10 as a maximum. In ^{232}Th certain activity ranged from 3 in S5 to 10.9 Bq/kg in S7. While the activity was specified at ^{40}K Ranged from 67.97 in S10 to 255.49 Bq/kg in S5. Geochemical composition of the soil was sandy clay. It seems the uranium Activity Higher than thorium activity in some samples. It is obviously seen that, the radioactivity of uranium is several times higher than that of thorium in the same sites. Also, it is noted that radioactivity of ^{40}K exceeds significantly much higher than both of ^{238}U and ^{232}Th. Moreover, this can be due to the abundance of ^{40}K in the soil because a lot of potassium containing fertilizers was used in the vicinity of sampling locations. The results of an average particular radioactivity of collected soil samples in this study were below the global average levels according to UNSCEAR (2000) which is 35, 30 and 400 Bq/kg for ^{232}Th and ^{40}K, respectively.

Radiation effects: Table 2 shows the radiological effects (Ra_{eq}, Dr, H_{ex}, H_{in}, Iγ, AEDE and ELCR) from the soil samples collected from the district of Al-Hindi district of Al-Manfahan village above the equation, look for Radium equivalent activity in the soil samples shown in Table 2. The equivalent radium activity calculated for the same soil sample ranges from 474.03±15.5-47.29±13.96 Bq/kg mean 143.65±6.55 Bq/kg. That the analysis of all soil samples from radium is equivalent to the activity value well and the minimum permissible 370 Bq/kg (Anonymous, 1979). The absorbed dose rate ranges from 216.287±7.11-22.717±6.13 ng an average of 65.399 nGy/h, the world's outdoor exposure due to gamma rays (nG/h), based on UNSCEAR. (2000) and Singh *et al*. (2009). The recorded value in the study area for most samples is important for health and does not show any serious effects on people living there. In the end, the use of a specific activity measured in the soil is the detection of radioactive dose which is delivered externally in the form of gamma dose. External the risk index was calculated from 1.280±0.041-0.127±0.03 at an average of 0.388 and the mean values were lower than the unit according to the radiation protection report (Anonymous, 1979). These radionuclides are some sources. The internal exposure ranged from 2.541±0.08-0.217±0.04 with an average of 0.568, so, the values calculated for the values were lower than the unit according to the radiation protection report (EC., 1999). I The values of calculated values for samples from this site are shown in Table 2. F values range from 3.213-0.345 at 1.0137. This calculated code is lower than the international values (Anonymous, 1979). The internal, external and total values of the AEDE are listed in Table 3. These mean values were 0.320±0.03 and 0.265±0.03 mSv/y, respectively, noting that these values

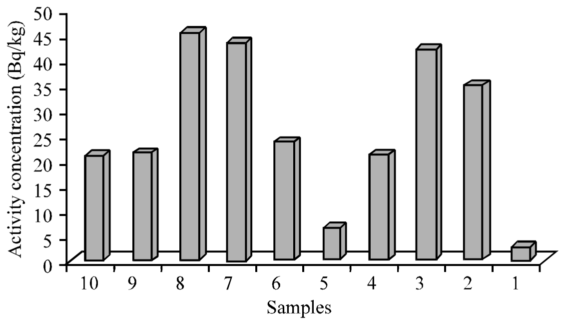

Fig. 2: The specific activity U238 of all samples at depth 0-15 cm

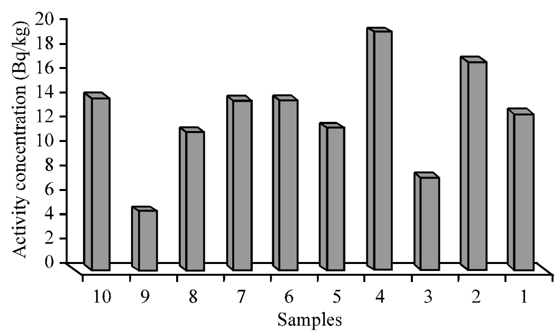

Fig. 3: The specific activity TH232 of all samples at depth 0-15 cm

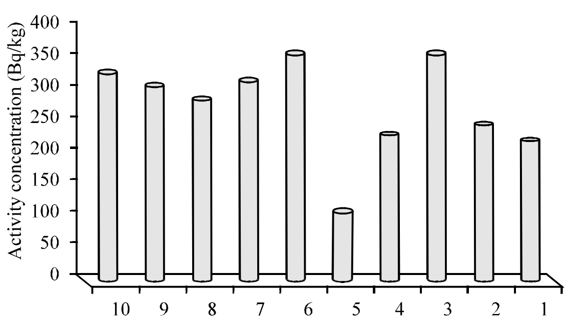

Fig. 4: The specific activity K 40 of all samples at depth (0-15)cm

are than the corresponding global values of 0.42, 0.08 and 0.50 mSv/y, respectively (EC, 1999). Calculated increase The lifetime risk of cancer from this site is shown in Table 3. These values vary from 4.641±0.15-0.487±0.13 10-3L 0.583 10 10^{-3} with an average of 1.403$10^{-3}$. According to these results (Fig. 2-4).

CONCLUSION

The measurement level of natural radioactivity of the studied soil sample in the present study shows, normal levels of radioactivity concentration, All the obtained ^{40}K values show levels within the natural permissible values. Preliminary, values for Radium equivalent, (Ra_{eq}), radiation Hazard Index (H_{ex}) and annual effective dose equivalent indicate that the areas monitored can be regarded as having normal levels of natural radioactivity.

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