https://doi.org/10.26682/hjuod.2022.25.1.22
Journal of University of Duhok.,Vol.25, No.1(Humanities and Social Sciences),P 396-404 , 2022

CONTOUR MAPS DESCRIPTION OF NATURAL RADIATION IN THE SOIL OF NAJAF PROVINCE

EMAAD **K**AZIM **A**BAAS
Education directorate of Al- najaaf (physician)-Iraq

(Accepted for Publication: May 30, 2022)

ABSTRACT

The soil is one of the most important natural sources of ionizing radiation to which humans are exposed. Naturally, radionuclides such as ^{238}U series,^{232}Th series and potassium ^{40}K radioisotope are widespread in the soil and are considered the main sources the terrestrial natural radiation. The study under investigation is regarded as one of the rare studies that deals with the effect of the contents of the radionuclides on levels of natural radiation, besides being helpful in drawing of radiological maps for the area under study. The gamma radiation has been measured to determine ^{238}U, ^{232}Th and ^{40}K natural radioactivity in the soil of selected area in Najaf city, south western part of Iraq. Google Earth program was used to get an upper view picture or photo of the area of study. In addition to this photo, our study involved maps that supported by the center of engineering affairs in the University of Kufa to get a geographical location of area under the study. As soil surface samples, 30 soil samples were obtained in a methodical manner. These samples were investigated using gamma-ray spectrometry, which included a high-counting-efficiency NaI (Tl) detector with a 2"×2" crystal dimension linked to the amplifier via a unit of preamplifier, an analog to digital converter (ADC), and a multichannel analyzer (MCA) with 4096 Cassy type channels. The findings of our research were shown in contoured radiological maps and analyzed using the Gaussian frequency distribution. Finally, all radiation results in the area of study were lower than limits of the global average, and they were also compared to the values recommended by international authorities and ^{40}determined to be within permissible limits.

1: INTRODUCTION

Many unstable nuclides were present in the star material from which the earth was born roughly 4.5 billion years ago [1]. Some of the original primordial nuclides are still present, with half-lives comparable to the age of the earth. Radiation is emitted from outer space (cosmic), the earth (terrestrial), and even within the human body. It's in the air we breathe, the food we eat, the water we drink, and the building materials we use to construct our homes. As a result, radiation is everywhere around us; it is a natural part of our environment and has been since the beginning of time [2]. One of the most common causes of human exposure is radioactivity in the soil environment [3]. The ^{238}U, ^{232}Th, and natural ^{40}K series are the main sources of natural radioactivity in soil [4,5]. Because natural occurring radionuclides materials (NORMs) such as ^{238}U, ^{232}Th, ^{235U}, and ^{40}K have exceptionally long half-lives (up to 1010 years), their presence in soils and rocks can be substantial, and should be treated as permanent. The geological and geographical circumstances, as well as natural environmental radioactivity and the related external gamma radiation exposure, are the key variables. As a result, various quantities of radiation develop in the soil of different parts of the earth [6]. Exposure to natural sources of radiation becomes a significant issue in terms of radiological protection. The National Radiological Protection Board (NRPB) estimated in 1992 that radon accounted for around half of all annual doses of radiation in most of the world [7]. According to the National Council on Radiation Protection and Measurements (NCRP), the average person receives about 3 millisieverts of radiation per year from natural sources, compared to about 0.5 millisieverts from produced material sources of radioactive materials such as medical X-rays, as shown in Figure 1 [8].

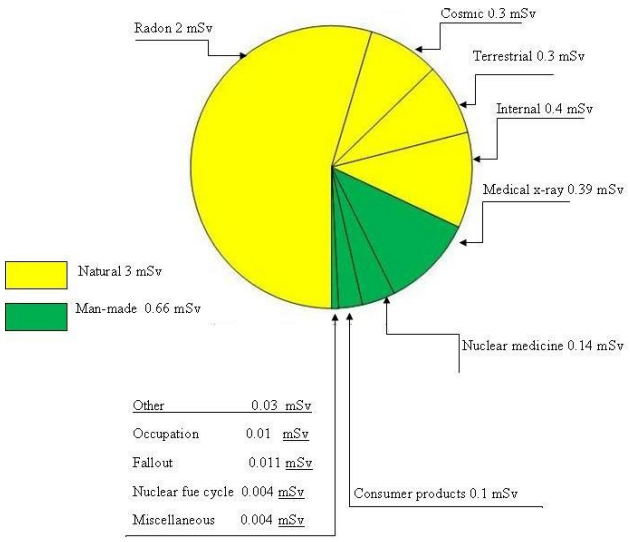

Fig. (1): Annual radiation doses from natural and man-made sources according to (NCRP1987) [8].

The general populace is unlikely to be exposed to radiation from any source. The European Commission has released a draft proposal for revising the minimum safety requirements for worker and public protection against the hazards of ionizing radiation [9]. The United Nations Scientific Committee on the Effects of Atomic Radiation estimates that the global mean dosage from natural radiation sources of normal area is 2.4 mSv/y, while the global mean dose from all man-made sources, including exposure, is roughly 0.8 mSv/y [10,11]. As a result, natural sources of radiation account for 75% of the radiation dose absorbed by humans. The largest component to the world population's external dosage is undoubtedly gamma radiation dose from natural sources [12]. This information ensures radiological control because the higher soil layer holds the majority of the environmental radiation. ^{238}U, ^{232}Th, and ^{40}K have significant radioactivity [11,13]. The significant radioactivity of ^{226}Ra and ^{228}Ra, as well as the pressure they exert on soil, need extra caution. It is well established that even little amounts of radiation can cause biological harm, and that radiation that is eaten or breathed poses a serious health risk [14].

Natural radionuclides have a radiological impact because they expose the body to gamma rays and irradiate lung tissue through inhalation of radon and its daughters. In general, human exposure to ionizing radiation occurs via medical diagnosis and therapeutic tools or instruments, as well as radiated food, air, and environmental sources. Because the last one's radiation cannot be turned off, environmental radioactivity surveillance becomes a need. In general, scientific data on the radioactivity contents of naturally occurring radioactive compounds in soil in Iraq is scarce, particularly in terms of environmental radiological examinations. Based on these facts, it is reasonable to conclude that knowledge of (NORMs) such as ^{238}U, ^{232}Th, and ^{40}K is a necessary pre-requisite for assessing the rate of exposure and absorbed dose by the population in order to assess radiological implications and establish a baseline. Data repository that can be used as a reference by radiation observers in the studied area [15].

2: NATURAL RADIATIONS

The environmental radioactivity can be classified into two types based on the source of radiation: natural and artificial. The natural radioactivity is obtained from natural sources of Uranium, Thorium, and Actinium radioactive series, as well as rare non- radioisotopes series such as Potassium-40 [16]. Radioisotopes with short half-lives, such as Platinum-190, Rhenium-187, Lutetium-176, Hafnium-174, Gadolinium-152, Samarian-147, Neobynium-144, Lanthanum-138, Indium-115, Rubidium-87, and Vanadium-50 were not studied. Artificial activity, on the other hand, is primarily derived from abandoned sources, radioactive waste, and radioactive fallout in nature. As shown in Table 1; four unique natural series: Uranium, Actinium, Thorium, and Neptunium were found.

Table (1) : The Natural series of Uranium ,Actinum , Thoriom and Neptunium

Series	*First Isotope*	*Half-life(years)*	*Last Isotope*
Uranium	^{238}U	4.5×10^{9}	^{206}Pb
Actinium	^{235}U	7.10×10^{8}	^{207}Pb
Thorium	^{232}Th	1.39×10^{10}	^{208}Pb
Neptunium	^{237}Np	2.14×10^{6}	^{209}Bi

In nature, the uranium, actinium, and thorium series only are found. Because the ^{237}Np isotope has a significantly shorter half-life (about 5 billions years) than the earth's lifetime, hence, all neptunium perished during the first fifty million years beyond the planet originated.

3: STUDY OBJECTIVES

This research intends to conduct continuous soil contaminants aiming to monitor the health and safety control measurers from radiations caused by NORM radioactivity in soil. Create a radiological contour map to depict the amounts of radioactivity in the soil. Qualify and quantify the occurrence of natural radionuclides in the soil of Najaf city, such as (U ^{238}, Th ^{232}, and K ^{40}).

4: EXPERIMENTAL PART

4-1: Gamma-Ray Spectrometer

Gamma rays are utilized in nuclear spectroscopy because of their deep penetrating power. A set-up was used to measure the number of gamma rays, as seen in the image below. The spectrometer is made up of a scintillation counter NaI (Tl) with a crystal diameter of (2″×2″), a scalar, shielding, and a specially designed sample container that allows the sample to completely surround the scintillation detector on all sides.

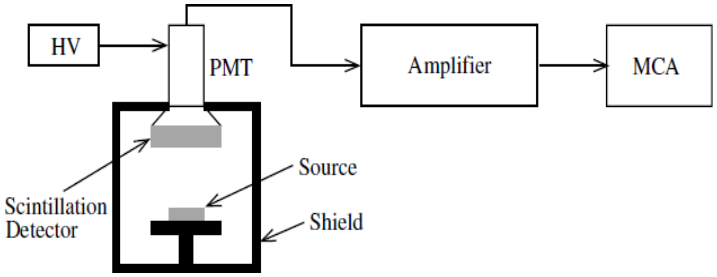

Fig. (2): A spectrometer system is depicted as a block diagram [23]

4-2: Study Subject

The soil samples were taken from the study area, which includes biologically significant sites such as the University of Kufa in Najaf, Iraq.

4-3: Obtaining and Preparing Samples

To quantify NORMs in the soil surface, thirty soil samples were collected in a systematical selection as matrix distribution. Drilling a hole at a depth of 35 cm before the earth surface yielded an average from each point. The gathered samples were packed in labeled closed polyethylene bags and transferred to the radiation detection and measurement laboratory of the university of Kufa's college of science's physics department. Soil samples were roasted for 24 hours at 100°C to eliminate moisture. A 1.4 L polyethylene marinelli beaker was utilized as a sampling and measuring container in this experiment.

4-4: Specific activity measurements:

The spectra of soil samples were analyzed. The specific activities and radium equivalent activities of ^{232}Th, ^{238}U, as well as ^{40}K radionuclides were measured and listed in Table 2. These values were discussed as follows:

4-5: Energy calibration

The calibration of the instrument is the first step in every spectroscopic measurement. Calibration is the link between the number of channels and the energy absorbed in the detector. The quantity of energy absorbed in the detector is proportional to the responsiveness of a good

multi-channel analyzer across its entire MCA [23]. The detector's reaction is proportional to the quantity of energy absorbed in the detector and has a linear response across its entire MCA [23]. The slope is determined in some MCAs using a simple two-point energy, as indicated in the equation below.

E = A×ch +B

The energy is E, the channel number is ch, while A and B are constants. As a result, the energy as a function of channel number can be read directly, allowing the user to choose between first-order (linear) and second-order (quadratic) equations using least square fit to data points [17]. The spectrometer's energy was calibrated by obtaining a spectrum from radioactive reference sources with known energies such as ^{60}Co ($E_{\square 1}$= 1332 keV, $E_{\square 2}$= 1773 keV) and ^{137}Cs ($E_{\square}$ = 662 keV).

The first order equation was used in this study. The energy calibration can be done with a variety of radioactive sources with established peaks. The spectrometer was calibrated in the investigation using six standard gamma radiation sources provided by Spectrum Techniques LLC. Table 2 shows the sources: ^{22}Na, ^{57}Co, ^{60}Co, ^{109}Cd, ^{133}Ba, and ^{137}Cs.

Table (2): Standard source energies and transition probability [23]

Isotope	E_γ (keV)	I_γ %	Isotope	E_γ (keV)	I_γ %
^{22}Na	511 1274	100 99.94	^{109}Cd	88	3.6
^{57}Co	122 136	85.6 10.9	^{133}Ba	302.8 356 383.8	18.3 62 8.9
^{60}Co	1173 1333	99.97 99.98	^{137}Cs	662	85.1

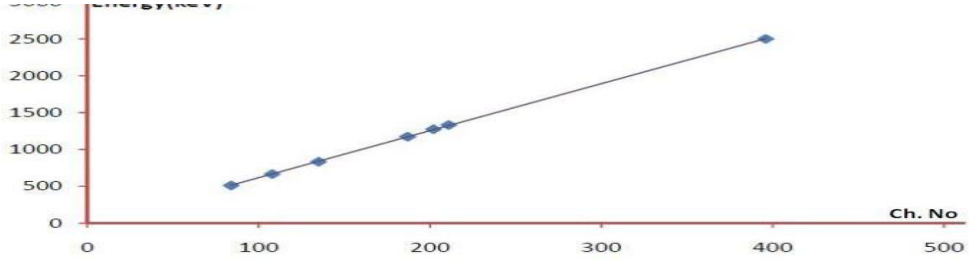

Fig. (3): Calibration curve of channel-energy of NaI (Tℓ) detector.

4-6: Efficiency Calibration

Using the six standard gamma ray sources stated above, the photo-peaks relative intensities corresponding to respective gamma ray lines were calculated. To measure the photo-peak relative efficiency, divide the relative intensity of the photo-peaks with energy (E) by the reference relative intensity of the identical photo-peak [26]. To rectify the activity of each standard source, the following relationship was used:

$A = A_{oe}^{-\lambda\Delta t}$

Where Ao is each source's beginning activity (Bq) at time t_o, A is the source's activity (Bq) at time t, λ is the decay constant, and $\Delta t = t - t_o$. The following relationship was used to compute the detector measuring system's efficiency (ε) for a specific energy:

$$\varepsilon = \frac{C}{A \cdot I_\gamma \cdot t} \times 100\%$$

After background subtraction, C was the count (area) under the prescribed energy peak, for spectrum collection t was the time (sec), and Iγ was the emitted gamma ray transition probability.

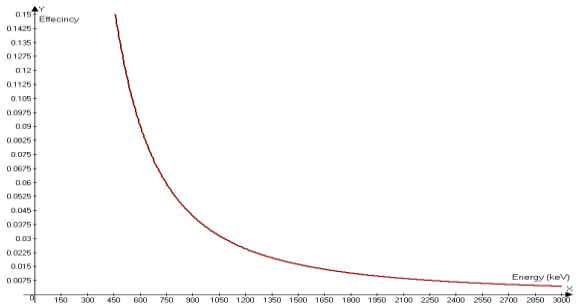

Fig. (4): The efficiency calibration curve of NaI (Tl) detector

5: RESULTS AND DISCUSSION

5-1: Specific activity measurements: The spectra of soil samples were analyzed. The specific activities and radium equivalent activities of ^{238}U, ^{232}Th and ^{40}K radionuclides were measured and listed as values in Table 3.

Table (3): Specific activities of natural radionuclides and Radium equivalent in (Bq/kg) with their total uncertainties of soil samples.

Sample code	Specific activity (Bq/kg)			Raeq(Bq/kg)
	238_U	232_{Th}	40_K	
S1	14.87±0.84	4.90±0.28	83.56±2.02	28.31±1.39
S2	3.63±0.42	3.37±0.23	110.98±2.32	16.99±0.92
S3	10.15±0.71	3.31±0.23	125.34±2.53	24.53±1.24
S4	11.72±0.80	3.67±0.26	159.10±2.98	29.22±1.40
S5	5.18±0.49	4.16±0.25	96.09±2.12	18.52±1.01
S6	6.99±0.58	1.40±0.15	80.49±1.98	15.19±0.94
S7	8.48±0.62	4.22±0.25	156.52±2.70	26.56±1.19
S8	19.25±1.03	5.33±0.31	93.97±2.29	34.10±1.65
S9	4.20±0.46	1.69±0.17	96.98±2.22	14.08±0.87
S10	8.25±0.64	7.02±0.34	106.86±2.33	26.52±0.58
S11	10.17±0.71	4.64±0.27	90.10±2.12	23.74±0.64
S12	8.69±0.63	7.09±0.33	107.53±2.25	27.11±0.56
S13	**10.90±0.74**	**8.48±0.37**	**148.30±2.75**	**34.44±1.6148**
S14	3.06±0.38	3.80±0.24	64.62±1.77	13.48±0.87
S15	9.55±0.70	3.89±0.26	116.42±2.47	24.08±1.26
S16	14.22±0.81	5.03±0.28	132.69±2.51	31.63±1.40
S17	10.57±0.69	3.72±0.23	68.69±1.78	21.18±1.16
S18	15.73±0.93	7.92±0.38	130.82±2.71	37.13±1.68
S19	11.70±0.76	4.04±0.26	161.38±2.87	29.91±1.35
S20	9.11±0.64	2.02±0.17	86.21±1.99	18.63±1.04
S21	10.73±0.70	5.25±0.28	132.33±2.46	28.43±1.28
S22	7.78±0.57	3.42±0.22	84.65±1.91	19.19±1.03
S23	11.03±0.73	2.64±0.20	87.37±2.07	21.54±1.18
S24	18.65±0.94	4.10±0.25	83.95±2.02	30.98±1.46
S25	10.69±0.70	4.73±0.27	95.58±2.12	24.82±1.25
S26	8.58±0.61	4.12±0.24	138.07±2.49	25.10±1.15
S27	13.19±0.75	7.41±0.32	83.63±1.90	30.22±1.35
S28	2.94±0.35	1.40±0.14	73.93±1.79	10.63±0.69
S29	8.76±0.62	3.40±0.22	103.03±2.14	21.56±1.10
S30	5.61±0.49	3.67±0.23	85.04±1.94	17.41±0.97

5-2: Uranium activity concentrations:

The specific activity concentrations of ^{238}U were measured for soil samples. As shown in Table 3, the values of specific activities in detected samples with their total uncertainties were ranged from 2.94±0.35Bq/kg to 19.25±1.03Bq/kg. Figure 5 depicts a map of the ^{238}U radionuclide activity concentration distribution in the research area. These findings are owing to the relatively low levels of ^{238}U in the virgin soil of the research area, which is dominated by sand-claying soil. lastly, the low ^{238}U level in the investigated area poses no concern to residents or the general public in terms of radiation protection.

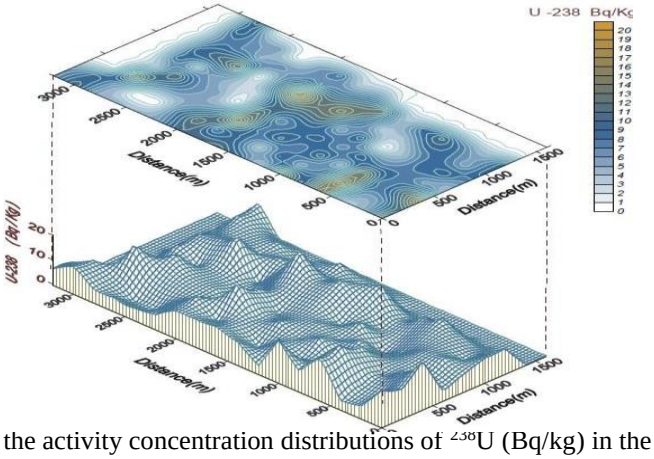

Fig. (5): A map of the activity concentration distributions of ^{238}U (Bq/kg) in the studied area

5-3: Thorium activity concentrations:

Table 3 shows the results for ^{232}Th and the particular activity concentrations radionuclide radioactivity on centration in soil samples, while Figure 5 shows the concentrations radionuclide in the research region. The activity concentrations ranged from 1.40±0.14Bq/kg to 8.48±0.37 Bq/kg as a maximum value. The research area's activity concentrations of ^{232}Th were below the allowed limits.

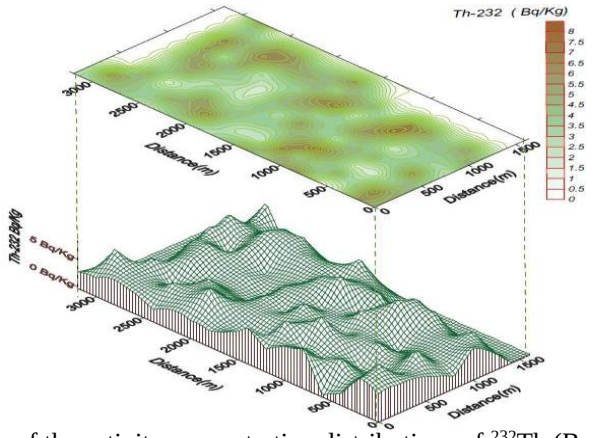

Fig. (6): A map of the activity concentration distributions of ^{232}Th (Bq/kg) in the studied area

5-4: Potassium activity concentrations:

Table 3 was revealing the results of the ^{40}K radionuclide activity concentrations in soil samples, as well as their average values. The map of specific activities is shown in Figure 7. The values with their total uncertainties were found to be in a range from 64.62±1.77 Bq/kg to 161.38±2.87Bq/kg. The average activity concentration collected in this work is lower than the permissible.

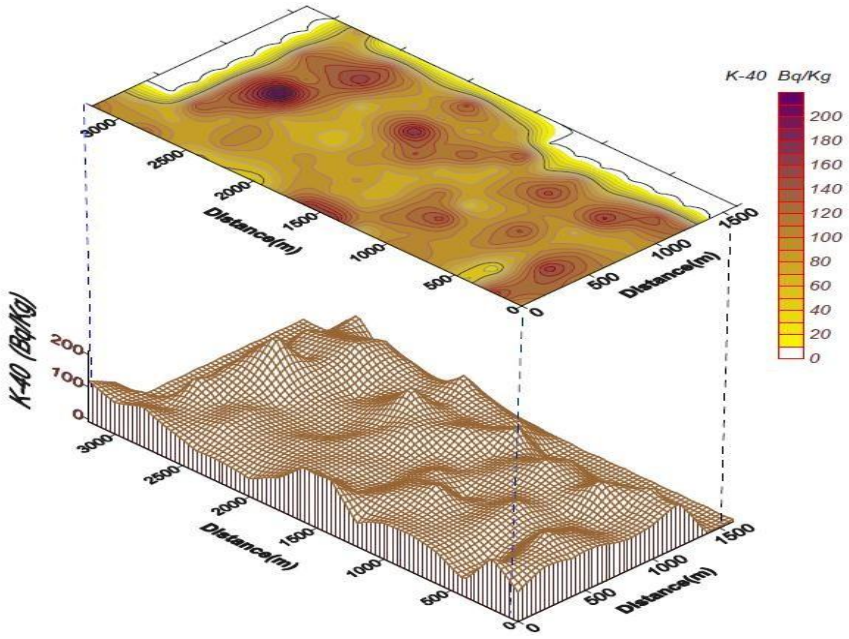

Fig. (7): A map of the activity concentration distributions of ^{40}K (Bq/kg) in the studied area

6: CONCLUSIONS

1- Contour maps can be used for the description of the natural radiation in the soil.

2- The radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K are generally very safe and have consistent values with those reported by many other countries in the world for soil samples.

3- The natural radiation level using sodium Iodide detector revealed that the distribution was not uniform.

4- Artificial radionuclides were not detected in any of the measured soil samples.

7: REFERENCES

Scholten, L. C. and Timmermans, C. W. M. (2005). "Natural radioactivity in phosphate fertilizers". J. Fertilizer Research, vol. 43: 103-107.

El-Ghossain, M. O. and Abu Saleh, R. M. (2007). "Radiation measurement in soil in the middle of Gaza-Strip using different type of detector". J. Islamic University, vol.15: 23-27.

Abusini, M.; Al-ayareh, K. and Al-jundi, J. (2007). "Determination of Uranium, Thorium and Potassium activity concentrations in soil cores in Araba valley, Jordan". J. Rad Prot Dosim, vol. 128: 3-4.

Yasir, M. S.; Ab Majid, A. and Yahaya, R. (2007). "Study of natural radionuclides and its radiation hazard index in Malaysian building materials". Journal of Radioanalytical and Nuclear Chemistry, vol. 273 (3): 539 – 541.

Vosniakos, F.; Zavalaris, K.; Papaliagas, T.; Aladjadjiyan, A. and Ivanova, D. (2002). " Measurements of natural radioactivity concentration of building material in Greece", Journal of Environmental protection Ecology. p: 324-29.

UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation. (2000) "Sources, effects and risks of ionizing radiation". Report to the General assembly with annexes, New York.

Ibrahim, N. (1999). "Natural activities of 238U, 232Th and 40K in building materials". J. Environ. Radio act, 43: 255-258.

NCRP, National Council on Radiation Protection and Measurements. (1987). "Exposure of the population in the United States and Canada from natural background radiation". No. 94.

Maduar, M. F. and Junior, P. M. (2007). "Gamma Spectrometry in the Determination of Radionuclides Comprised in Radioactivity Series". International Nuclear Atlantic Conference-INC, Santos SP, Brazil, September 30 to October 5, 2007. ISPAN

UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation. (1993) "Sources, effects and risks of ionizing radiation". Report to the General Assembly with Annexes, New York.

José, A.; Jorge, J.; Cleomacio, M.; Suêldo, V. and Romilton dos, S. (2005). "Analysis of the 40K Levels in Soil using Gamma Spectrometry". Brazilian Archives of Biology and Technology, Vol.48: 221-228.

UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation. (1988). "Sources effects and risks of ionizing radiation". Report to the General Assembly, with annexes, New York. 16

WHO, (1993). "Guidelines for Drinking–Water Quality". Recommendations World Health Organization, Geneva.

Rowland, R. E. (1993)"Low-level Radium retention by the human body; a modification of the ICRP publication 20 retention equation". J. Health Phys, vol. 65(5): 507-513.

Ahmed, N. K. (2004). "Natural radioactivity of ground and drinking water in some areas of upper Egypt". Turkish J. Eng .Env. Sci. vol. 28: 345-354.

Vosniakos, F.; Zavalaris, K.; Papaligas, T. (2003). "Indoor concentration of natural radioactivity and the impact to human health". J. Environ. Protect. Ecol. Vol. 4 (3): 733-737.

Semat, H. and Albright, J. (1972). "Introduction to atomic and nuclear physics". 5th edition, Holt Rinhart and Winston, INC, USA.

Littlefield, T. A. and Thorley, N. (1974). "Atomic and nuclear physics". 3rd edition. Van Nostrand Reinhold Company LTD, London.

AL Saif, A. S., (2009). "Radioecological aspects of Hail region: behavior of some radionuclides in soil". MSc thesis, King Saud University.

Harb, S. (2004). "On the human radiation exposure as derived from the analysis of natural and man-made radionuclide's in soil". PhD Thesis, Hannover University.

NCRP, National Council on Radiation Protection and Measurements. (1992). "Exposure of the Population in the United States and Canada from Natural Background Radiation". No. 94.

Podgorsak, E. B. (2006). " Radiation physics for medical physicists". Springer -Verlag Berlin Heidelberg.

Ahmed, S. N. (2007). "Physics and Engineering of Radiation Detection". Academic Press Inc. Published by Elsevier, Printed and bound in Great Britain.

Jevremovic, T. (2005). "Nuclear principles in Engineering". Springer Science, Business Media, Inc. USA.

Knoll, G. F. (1979). "Radiation detection and measurement". John Wiley & Sons, New York.

Tsoulfanidis, N. (1995. " Measurement and detection of radiation ". 2nd edition. Taylor & Francis publisher, Washington, USA.

Kataoka, T.; IKebe, Y.; Minato, S. and Shida, K. (1982). "Detailed evaluation of natural gamma radiation field due to Uranium-238 series ". J. Nucl. Sci. vol. 19 (6): 482-490.

وصف الخرائط الكنتورية للنشاط الاشعاعي الطبيعي لتربة مدينة النجف

الخلاصة

تعد التربة واحدة من أهم مصادر الطبيعة للإشعاع المؤين الذي يتعرض له البشر حيث إن العوامل الرئيسية التي تمثل مصادرا أرضية للإشعاع هي ألنويدات المشعة العائدة لسلسلة أليورانيوم 238 وكذلك سلسلة ألثوريوم232 بالإضافة إلى النظير المشع للبوتاسيوم 40. وتعتبر هذه الدراسة من الدراسات النادرة التي تتعلق بقياس أثر النشاط الإشعاعي الطبيعي للنويدات المشعة المذكورة آنفا والتي تساهم في رسم خريطة إشعاعية لمنطقة الدراسة بواسطة قياس أشعة كاما لنماذج تربة سطحية في منطقة تم اختيارها في وسط مدينة النجف الاشرف التي تقع في الجزء الجنوبي الغربي من جمهورية العراق. ولقد تم استخدام برنامج Google earth للحصول على صورة جوية لمنطقة الدراسة بالإضافة إلى الاستعانة بخرائط لمنطقة الدراسة من قسم الشؤون الهندسية في جامعة الكوفة للمساهمة في وضع خريطة جغرافية لمستويات النشاط الإشعاعي لمنطقة الدراسة ثم قسمت المنطقة بنظام Systematic إلى 30 عينة تربة. وتم استخدام مطياف أشعة كاما كاشف يوديد الصوديوم الوميضي المطعم بالثاليوم (بلورة الكاشف ذات أبعاد 2*2 انج(الموصول بشكل مباشر بمضخم اولي والذي يرتبط هو الاخر بقناة المحول الخطي إلى المحلل متعدد القنوات الذي يحوي على4096 قناة من نوع كاس Cassy و برنامج عددي, وتم استخدام الخرائط الكنتورية كوسيلة لتوضيح النشاط الاشعاعي الطبيعي للتربة في مدينة النجف وبالاعتماد على المستويات العالمية المسموح بها من قبل منظمة المجلس العلمي للأمم المتحدة 2000والوكالة الدولية للطاقة ,UNSCEAR فقد أشارت النتائج إلى إن مستويات الاشعاع ضمن الحدود المسموح بها عالميا.