Determination of Natural Radioactivity and Radon, Thoron Concentrations of Soil in Hilla City- Iraq

Khalid Hussain Hatif [1] **Mohsin Kadhim muttaleb** [2]

[1]*Department of physics, college of Science, University of Babylon*
[2]*Department of physics, college of Science, University of Babylon*
Khalidhsen@yahoo.com mam50_24@yahoo.com

Abstract

Radon and thoron activity concentration levels have been determined in the soil of Hilla city, Iraq. The area of the study included ten districts, they are Hay-Shubbar-Althanya, Hay-Al-Jameaya, Hussein Al-Noor Village, Al-Tohmazya Aloulla, Al-Bakerly Althanya, Wardya Kharij Althanya, Sinjar Aloulla, Hay Al-Jamaan, University of Babylon, and Al-Dollab Village. In this investigation solid state nuclear detector (RAD7) are used. The samples are taken from the surface and the depth 30 cm for each location. Maximum activity of radon activity was (12700 $Bq.m^{-3}$) while the minimum radon activity was (25 $Bq.m^{-3}$) . The maximum thoron activity was (9448 $Bq.m^{-3}$). while the minimum thoron activity (0.00 $Bq.m^{-3}$) .

Analysis of activity concentration of ^{40}K, ^{238}U, ^{232}Th radionuclides in soil samples for different locations at surface. The activity concentration of ^{40}K was 433.122±2.98 $Bq\cdot kg^{-1}$. The range of measured activity of ^{238}U in the soil of Hilla city 14.181±0.49 $Bq\cdot kg^{-1}$. The range of measured activity concentration of ^{232}Th for the soil was 10.807±0.39 $Bq\cdot kg^{-1}$. While the depth 30 cm the an average activity concentration of ^{40}K, ^{238}U, ^{232}Th was 428.783±2.97, 16.984±0.53, 7.710±0.33 respectively and the calculated absorbed dose rate was 31.324 $nGy\cdot h^{-1}$, outdoor and indoor values are 0.0384, 0.1537 $mSv\cdot y^{-1}$, respectively. The external hazard index (H_{ex}) was 0.1701. H_{in} was 0.2084 and less than 1 and the calculated I_γ value are 0.4914.

Keywords: Radon, Thoron, RAD7, Soil , Activity ($Bq\ m^{-3}$).

الخلاصة

تم تحديد مستويات تركيز النشاط الإشعاعي وغازي الرادون والثورون في تربة مدينة الحلة ،العراق.وشملت منطقة الدراسة عشرة مناطق هي: حي شبر، حي الجمعية، قرية حسين نور،الطهمازية الأولى، بكرلي الثانية، وردية خارج، سنجار الأولى، الجامعين، جامعة بابل وقرية الدولاب. في هذا البحث استخدم كاشف الحالة الصلبة النووي(RAD7) . النماذج اخذت من السطح وعمق ٣٠ سم لكل موقع. النشاط الأقصى في نشاط الرادون كان ١٢٧٠٠ بكرل/م^{٣} والأدنى كان ٢٥بكرل/م^{٣} اما الثورون الأقصى ٩٤٤٨ بكرل/م^{٣} والأدنى 0.00 بكرل/م^{٣} .

تحليل تركيز نشاط النويدات المشعة ^{232}Th ^{238}U, ^{40}K, في عينات التربة لمواقع مختلفة على السطح. تركيز ^{40}K 433.122±2.98. بكرل/كغم واليورانيوم ^{238}U 14.181±0.49 بكرل/كغم والثوريوم 10.807±0.39 بكرل/كغم بينما في عمق ٣٠ سم معدلات التراكيز ^{232}Th ^{238}U, ^{40}K كانت 7.710±0.33, 16.984±0.53, 428.783±2.97 على التوالي وحسابات معدل الجرعة الممتصة 31.324 نانوكري/ساعة ،الخارجية والداخلية كانت 0.1537, 0.0384 ملي سفرت/سنة على التوالي .معامل الخطورة الخارجي 0.1701 والداخلي 0.2084 اقل من واحد وحساب I_γ كانت قيمته 0.4914 .

الكلمات المفتاحية: رادون، ثورون، كاشف الحالة الصلبة النووي، تربة، فعالية .($Bq\ m^{-3}$).

1.Introduction

The comprehensive study was conducted to determine thoron, radon activity, radon exhalation rate, uranium, thorium and potassium elemental concentration in surface ,depth soils samples.

Thoron and radon their decay products are alpha, beta and gamma emitting nuclei. Inhalation of these radionuclides represents the main source of exposure to ionizing radiation for population in most countries . Measurements of radon are importance because the radiation dose to human population due to inhalation of Radon and its

daughters contributes more than 50 percent of the total dose from natural sources (Huda *et al.* 2012). Thoron and radon are members of different decay chains, the ratio between thoron and radon or between the decay products of thoron and radon will depend in part on the ratio of uranium to thorium in local soils, rocks or building materials (UNSCEAR 2006).

The radon is a naturally occurring, chemically inert, alpha particle emitting radioactive gas. This colorless, tasteless and odorless gas is produced by natural radioactive decay of uranium, radium and thorium found in trace amounts everywhere in the rocks and soils of the earth's crust . The three naturally occurring isotopes of radon are radon (^{222}Rn) is produced from the decay of ^{238}U having natural abundance of about 99.3 percent of the total uranium within the earth's crust, thoron(^{220}Rn) is produced in nature during the decay of ^{232}Th and action(^{219} Rn) is formed during the decay of ^{235}U . The most stable and abundant isotope of radon is(^{222} Rn) which has a half-life of 3.8 days. It decays by emitting an (α) particle of (5.49 MeV) and creates radioactive daughters (Wasan, 2014).

A distribution of radon in soils has been related to geological controls in terms of its generation and migration; uranium content in bedrocks and soils influence production, and the soil characteristics (including the soil moisture and permeability) control the transportation of radon. The radium and uranium contents of soil generally reflect that of the bedrock from which the soil materials have originated due to weathering processes (Hyun *et al*. 2007).

The radon is present in trace amount, almost every where (indoor and outdoor) on the earth. The concentration of radon in the atmosphere varies, depending on the place, time and the height above the ground and metrological condition. Radon and its decay products may pose a significant health hazards, especially when concentrate in some enclosures such as underground mines, caves, cellars or poor ventilated and badly designed houses. A concern for home owners is the possibility that radon gas would accumulate to dangerous levels (Mamta *et al.* 2011).

Natural environmental radioactivity arises mainly from primordial radionuclides such as ^{40}K and the nuclides from the ^{238}U and abundance series and their decay products which occur at trace levels in all ground formations . Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions and appear at different levels in the soils of each region in the world (UNSCEAR 2006). The knowledge of concentrations and distributions of the radionuclides in these materials of the radionuclides are of interest since it provides useful information in the monitoring of environment radioactivity. Gamma radiation emitted from naturally occuring radioisotopes also called terrestrial background radiation represents the main external source of irradiation of the human body (Mageed *et al.* 2010).

Human beings have always been exposed to ionizing radiations of natural origin namely terrestrial and extraterrestrial radiation .These radionuclides have half lifes comparable to the age of the earth. Gamma radiation from these radionuclides represents the main external source of irradiation of the human body. Natural radioactivity in geological materials mainly rocks and soil comes from ^{232}Th and ^{238}U series and natural ^{40}K (Kinyua *et al.* 2011).

Exposure to natural radiation may be due to external or internal exposure according to the body radiation source geometry. External exposure comes mainly from the γ- emitter in man's surrounding environment which impacts the body and can be harmful to different organs due to the high penetration property of γ- rays. There has been interest in the determination of the average gamma radiation dose to which the population is exposed. The environmental radiation is composed of natural

radiation found in the ground plus the cosmic radiation together with the contribution to background radiation from nuclear weapons tests and accidents which eventually will come down to the ground level. On the other hand internal exposure comes from swallowing or inhaling radioactive materials as in the case of inhaling radon and its daughters (Shafik *et al.* 2013).

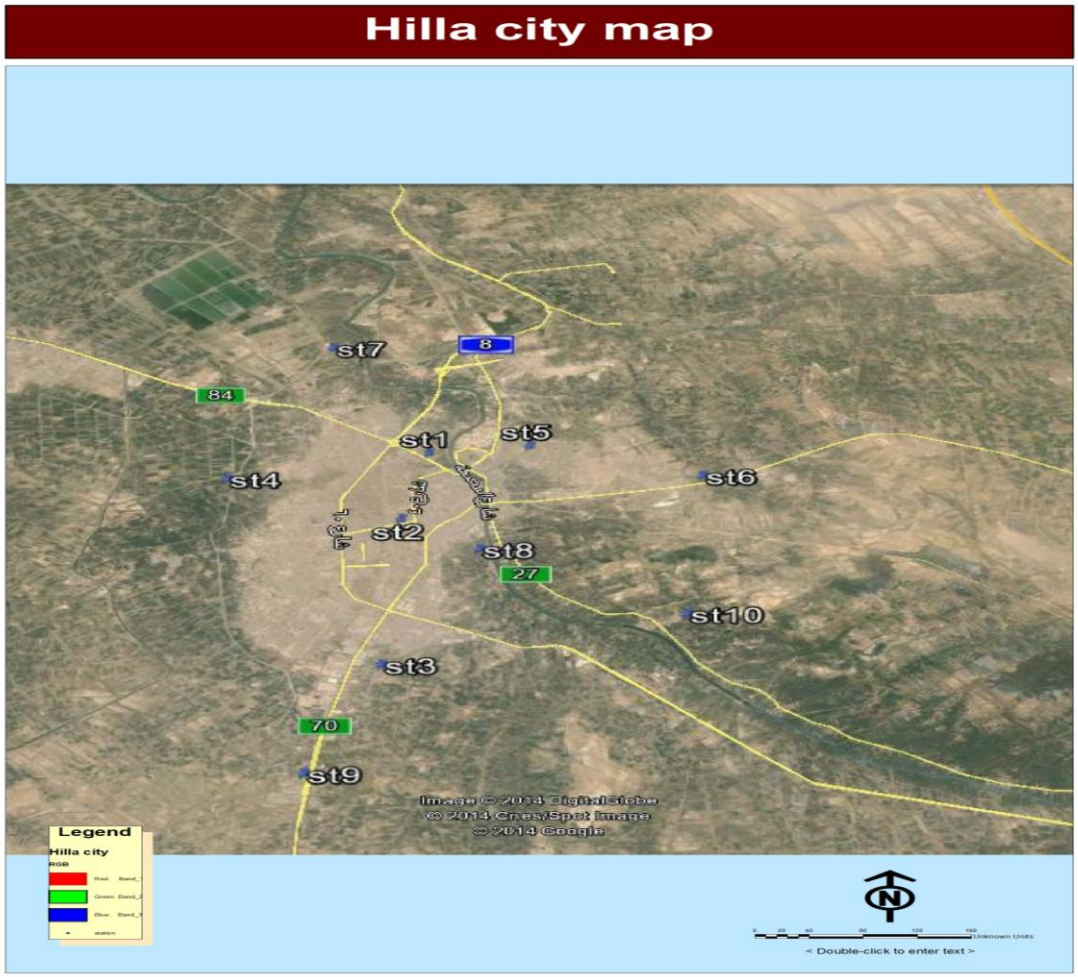
2. Location of the Study Area

Study area is located in the province of Babylon (100 Km) south of the capital Baghdad where the city of Hilla which has an area of (49.816) km^2 on both sides of the River Hilla (a branch of the Euphrates River) at Latitude(32˚ 29′) north, longitude (44˚26′) east as shown in fig. (1). Geographical location (of the River Hilla) is located in the center of the province of Babylon approximately between longitudes (44˚15′) and (44˚ 50′) east and the constituencies of latitude (32˚ 15′) and (32˚ 44′) north (Money, Robert I. 2007).

The present study (10) regions were chosen as fair distribution in Hilla City. The regions were determined using (GIS) as shown in fig.(1) which was obtained the map sites of the city drawn by using (GPS) technical. Table (1) shows the sites studied in city.

Table(1): Samples measurements of sites in Hilla city .

No.	Location name	Location Symbol	Coordinates
1	Hay-Shubbar-Althanya	St.1	$44^0\ 25'\ 44.7''$ E , $32^0\ 29'\ 23.7''$ N
2	Hay-Al-Jameaya	St.2	$44^0\ 25'\ 17.2''$ E , $32^0\ 28'\ 21.3''$ N
3	Hussein Al-Noor Village	St.3	$44^0\ 25'\ 00.7''$ E , $32^0\ 25'\ 41.8''$ N
4	Al-Tohmazya Aloulla	St.4	$44^0\ 23'\ 07.7''$ E , $32^0\ 29'\ 10.6''$ N
5	Al-Bakerly Althanya	St.5	$44^0\ 26'\ 56.4''$ E , $32^0\ 29'\ 43.1''$ N
6	Wardya Karij Althanya	St.6	$44^0\ 29'\ 05.1''$ E , $32^0\ 29'\ 30.9''$ N
7	Sinjar Aloulla	St.7	$44^0\ 24'\ 29.0''$ E , $32^0\ 31'\ 43.5''$ N
8	Hay Al-Jamaan	St.8	$44^0\ 26'\ 15.2''$ E , $32^0\ 27'\ 46.0''$ N
9	University of Babylon	St.9	$44^0\ 24'\ 04.5''$ E , $32^0\ 23'\ 49.5''$ N
10	Al-Dollab Village	St.10	$44^0\ 28'\ 44.6''$ E , $32^0\ 26'\ 30.9''$ N



Fig(1). Map of showing sampling locations where St. refers to the sample

3. Experimental Method

3.1. Radon Measurement Instrument RAD7

The interior of the measurement instrument RAD7 from Durridge Company we find a hemisphere with a silicon solid-state detector a representation of the measurement chamber with the detector is shown in figure (2)**.** Through the filter the sample air is sucked in by the pump and reaches the detector chamber. There is a high voltage of 2000 to 2500 V between the detector and the hemisphere accelerates the positively ionized particles towards the detector. If a radon nucleus decays in the chamber into a positively ionized Polonium-218, this particle will be accelerated towards the detector. On the surface of the detector the short lived ^{218}Po decays and the α radiation with a characteristic energy is emitted to the detector. The detector produces a signal with 50 per cent probability. This signal is intensified electronically and transformed into a digital signal. The microprocessor stores the energy level of the signal and produces the spectrum.

After the preparations of the measurement we can pump radon which containing air into the RAD7 after a short time we can see some counts in the energy interval A which is the energy interval of the α decay of ^{218}Po. Usually the counting rate increases in the first five minutes because in this period of time the amount of positive ionized ^{218}Po nuclei increases until it reaches a constant level on the detector. After 20

minutes the secular equilibrium state between ^{218}Po and ^{222}Rn is reached the activity of the daughter nucleus is similar to the activity of the mother nucleus. At this time almost all counts can be found in the energy level A which you can see in figure(3). After a period of time we find that the counts per time in A are constant but the overall counting rate increase. These new counts occur at the energy level C of the spectrum. They originate from the decay of ^{214}Po which reaches its equilibrium state after 3 hours. In the full equilibrium state the height of both peaks is almost equal as shown in figure(3) (Mohammed *et al.* 2014).

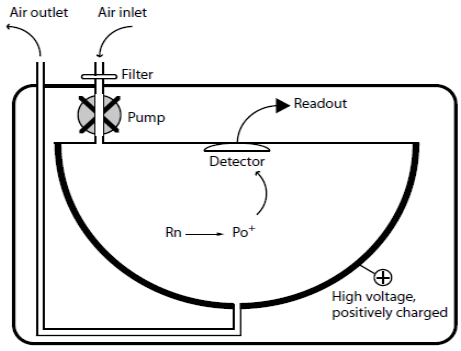


Figure 2. Measurement chamber of the RAD7.

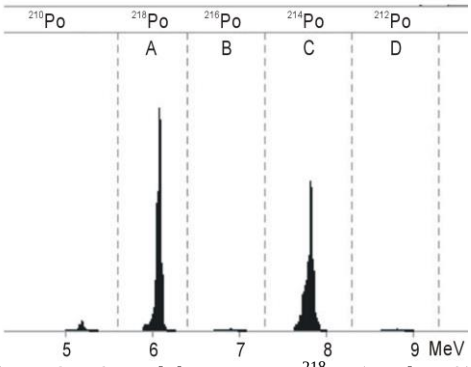


Figure 3. RAD7 alpha spectrum-^{218}Po (window A) and ^{214}Po (window C).

3.2.NaI(Tl) Scintillation Detector

The gamma ray interacting with a scintillator produces a pulse of light that is converted to an electric pulse by a photomultiplier tube (PMT). The PMT consists of a photocathode, a focusing electrode, and 10 or more dynodes that multiply the number of electrons striking at each dynode. A chain of resistors typically located in a plug-in tube base assembly biases the anode and dynodes. Complete assemblies including the scintillator and PMT are available**.**

Properties of a scintillation material required to produce a good detector are transparency, availability in large size and large light output proportional to gamma-ray energy. Few materials have good properties for detectors. Thallium activated sodium iodide [NaI(Tl)] and cesium iodide [CsI(Tl)] crystals are commonly used as well as a wide variety of plastics. CsI(Tl) and plastics have much faster light decay times than NaI(Tl) and are primarily used for timing applications (Slawomir Osuch 1994).

4.Theory Concepts

4.1. Work Principle of RAD7

An internal cell of RAD7 is a hemisphere with volume 0.7 liter, an ion-implanted, planar and silicon alpha detector is at the center of the hemisphere. The high voltage power circuit charges the inside conductor to a potential of 2000 - 2500 V relative to the detector creating an electric field throughout the volume of the cell. When the radon and thoron daughters deposited on the surface of the detector, decay, they emit alpha particles of characteristic energy directly into the solid state detector. The radon concentration in the internal cell of RAD7 is determined by the following differential equation:

$$\frac{dC(t)}{dt} = -\lambda C(t) \text{ ----------(1)}$$

$$\frac{dC_{p_0}(t)}{dC} = \lambda_{p_o} C(t) - \lambda_{p_o} C_{p_o}(t) - - - - - (2)$$

where $C(t)$ is the Radon concentration in the internal cell of RAD7, λ is the decay constant of Radon, $C_{po}(t)$ is ^{218}Po concentration, and λ_{Po} is ^{218}Po decay constant and equals to 0.0037 s^{-1}. After a certain time of pumping, the Radon concentration in internal cell of RAD7 equals to that of the environment C_0. Equation (2) can be rewritten :

$$dC_{p_o}(t)dt = \lambda_{p_o} C_o - \lambda_{p_o} C_{p_o}(t) - - - - - - (3)$$

The initial condition : $C_{p_o}(0) = 0 - - - - (4)$

The solution of Equation (3) :

$$C_{p_o}(t) = C_o(1 - e^{-\lambda p_o t}) - - - - - - - - - - - (5)$$

If the time is much longer than the half-life of ^{218}Po, Equation (5) can be rewritten :

$$C_{p_o}(t) = C_o - - - - - - - - - - - - - - - - - (6)$$

Radon concentration can be obtained from Equation (6) and this is the measurement principle of RAD7 (Tan et al. 2014).

4.2. ^{40}K, ^{238}U and ^{232}Th Analyses in Soil

Samples were collected from the soil surface and transported to laboratory, the soil samples were air dried for 2–4 day, pulverized, homogenized and sieved through 2 mm mesh, about 100 g of the meshed soil samples were filled in 100 ml beakers. The beakers were then sealed and stored for at least 40 days to allow radioactive equilibrium between radon and its decay products, measurements of natural radionuclides, namely ^{40}K, ^{238}U, and ^{232}Th in soil samples were undertaken by using a NaI(Tl) gamma scintillation detector (D. 3"×3"), the detector was enclosed in a 7.5 cm thin lead shield to protect the measurement from the background gamma radiation. The activity determination was based on 1.76 MeV gamma rays from ^{214}Bi for ^{238}U, 2.62 MeV gamma rays from ^{208}Tl for ^{232}Th, the activity of ^{40}K was determined through its 1.46 MeV gamma rays .

4.3. The Activity Concentration

The activity concentrations of the radionuclides in the measured samples were computed using the following relation (K. M. Dabayneh et al. 2008):

$$C(Bq/kg) = \frac{C_a}{I \times \varepsilon_{ff} \times M_s} - - - - - - - - - - (7)$$

where C_a is the net gamma counting rate (counts per second) ε_{ff} the detector efficiency of the specific γ-ray, I is the intensity of the γ -line in a radionuclide and M_s is the mass of the sample (kg).

4.4. The Radium Equivalent Activity (Ra_{eq})

The Ra_{eq} index represents a weighted sum of activities of the above mentioned natural radionuclides and is based on the estimation that 1 Bq·kg^{-1} of ^{226}Ra, 0.7 Bq·kg^{-1} of ^{232}Th, and 13 Bq·kg^{-1} of ^{40}K produces the same gamma radiation dose rates. The index is given :

$$Ra_{eq} = C_{Ra} + (1.43C_{Th}) + (0.077C_k) - - - - - (8)$$

where C_{Ra}, C_{Th} and C_K are the average activity concentration in the sample in Bq·kg^{-1} of ^{226}Ra, ^{232}Th, and ^{40}K respectively (K. M. Dabayneh et al. 2008).

4.5.The Annual Effective Dose Equivalent

The annual effective dose equivalent to the population can be calculated using the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv·Gy^{-1}) the

indoor to outdoor ratio (1.4), the outdoor occupancy factor 0.2 and the indoor occupancy factor 0.8. Therefore, the annual effective doses outdoors and indoors equivalent are calculated by using the relations (N. Huy et al. 2005) as:

$$D_{outdoor}(mSv/yr) = [D_r(mGy/hr) \times 24hr \times 365.25d \times 0.2 \times 0.7Sv/Gy] \times 10^{-6} \quad ---(9)$$

$$D_{indoor}(mSv/yr) = [D_r(mGy/hr) \times 24hr \times 365.25d \times 1.4 \times 0.8 \times 0.7Sv/Gy] \times 10^{-6} \ldots(10)$$

The corresponding worldwide values of D_{out} and D_{in} and D_{tot} are 0.08, 0.42 and 0.50 $mSv \cdot y^{-1}$ respectively .

4.6.The External and Internal Hazard Index

The external (H_{ex}) and internal (H_{in}) hazard index due to the emitted γ-rays of the soil samples were calculated and examined according to the following criterion as:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_k}{8410} \leq 1 \quad ----------(11)$$

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_k}{8410} \quad ----------(12)$$

The value of H_{ex} must be lower than unity in order to keep the radiation hazard insignificant. This is the radiation exposure due to the radioactivity from a construction material, limited to 1.5 $mGy \cdot y^{-1}$. The maximum values of H_{ex} equal to unity correspond to the upper limit of Ra_{eq} (370 $Bq \cdot kg^{-1}$) .

An additional hazard index so called representative (radioactivity) level index was calculated by using the formula as:

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_k}{1500} \quad ----------(13)$$

The value of Iγ must be less than unity in order to keep the radiation hazard in significant (Kaleel et al. 2012).

5. Results and Discussion

5.1. Radon and Toron in soil

The average value of radon activity in Bq/m3 was calculated for each sampling point. The results were listed in tables(2), (3), (4) and the average radon concentrations as a function of sample point number are shown in figures(4),(5),(6). The radioactive level of ^{222}Rn for soil samples, as shown in table(2), range from 4940±2170 Bq/m3 for sample St.5 at in Al-Bakerly Althanya district at depth 15cm under ground surface, to 25±32 Bq/m3 at Wardya Karij Althanya district with the same depth , in table(3) for depth 30 the concentration varied from 8600±1865 Bq/m3 at St.5 to 110±93 Bq/m3 at St.6 . While in the depth 45cm in table(4) the maximum radon concentration is 12700±2210 Bq/m3 at St.5 to 271±292 at St.8 the radioactive level of ^{220}Rn for soil samples, as shown in table(2), range from 7588±1483 Bq/m3 for sample St.2 at in Hay-Al-Jameaya district at depth 15cm under ground surface, to 0.00±240 Bq/m3 at Wardya Karij Althanya district with the same depth in table(3) for depth 30 the concentration varied from 7317±1463 Bq/m3 at St.2 to 0.00±241 Bq/m3 at St.8 . While in the depth 45cm in table(4) the maximum thoron concentration is 9448±1638 Bq/m3 at St.6 to 0.00±267 Bq/m3 at St.3 . When looking for the whole data in the tables, one can see that in the majority of locations, there is variation between the radon and thoron concentrations and the depth for the same sample point as shown in the samples of data in figures(4,5,6) . However large variation of radon concentration in soil gas over a small depth is well known . Also it is worth to notice

the sample point St.5 has the maximum radon concentration for all the three depths compared with other locations.

Table(2) Radon(Rn^{222}) and thoron (Rn^{220}) concentration in soil gas at depth (15cm) in Hilla city

No.	Location Sample	Radon Concentration ($Bq.m^{-3}$)				Mean of radon concentration ($Bq.m^{-3}$)	Mean of thoron concentration ($Bq.m^{-3}$)
		1	2	3	4		
1	St.1	1880	4300	4400	5740	4080 ± 1610	5665 ± 1313
2	St.2	1780	3800	4810	3830	3550 ± 1270	7588 ± 1483
3	St.3	952	3010	3350	4170	2870 ± 1370	5133 ± 1243
4	St.4	102	578	374	442	374 ± 201	5153 ± 1235
5	St.5	1770	5290	6260	6430	4940 ± 2170	3193 ± 1016
6	St.6	0.00	68	0.00	34	25 ± 32	0.00 ± 240
7	St.7	203	408	476	544	408 ± 147	2845 ± 956
8	St.8	918	1600	1840	1560	1480 ± 393	3060 ± 987
9	St.9	271	3230	6150	7970	4410 ± 3380	1438 ± 706
10	St.10	1440	1640	2230	2060	1840 ± 369	4683 ± 1203

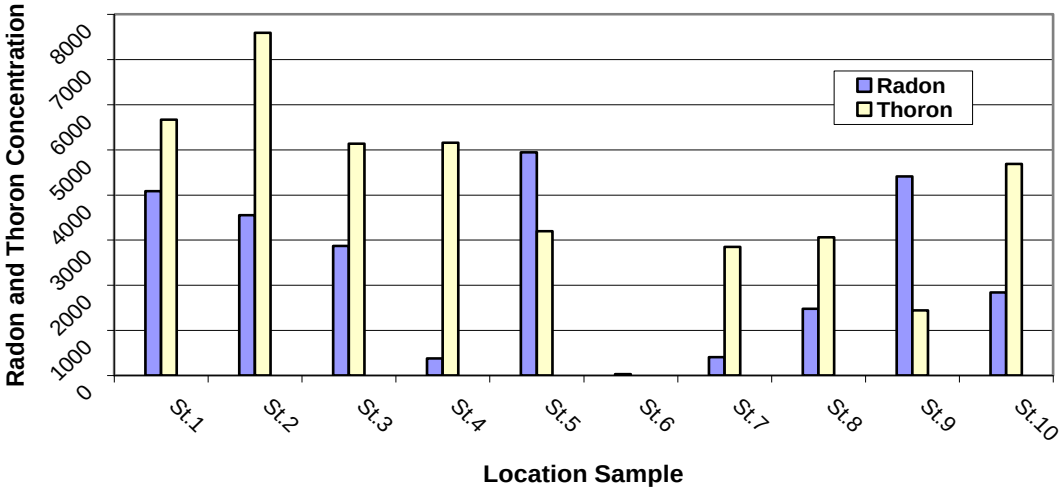


Fig.(4): Radon and thoron concentration of soil at depth 15 cm in Hilla city

Table(3) Radon(Rn^{222}) and toron (Rn^{220}) concentration in soil gas at depth (30cm) in Hilla city.

No.	Location Sample	Radon Concentration ($Bq.m^{-3}$)				Mean of radon concentration ($Bq.m^{-3}$)	Mean of thoron concentration ($Bq.m^{-3}$)
		1	2	3	4		
1	St.1	1640	4230	5360	6260	4370 ± 2000	4308 ± 1165
2	St.2	3560	6360	5880	6640	5610 ± 1400	7317 ± 1463
3	St.3	2480	4060	3450	4160	3540 ± 769	5435 ± 1278
4	St.4	338	541	1159	1050	772 ± 395	1083 ± 638
5	St.5	5880	9570	9920	9020	8600 ± 1850	3668 ± 1071
6	St.6	0.00	169	68	203	110 ± 93	0.00 ± 240
7	St.7	544	578	850	1050	757 ± 241	3015 ± 980
8	St.8	714	1020	1160	1290	1050 ± 247	0.00 ± 241
9	St.9	6630	5780	5610	5950	5990 ± 450	486 ± 494
10	St.10	2330	5120	6120	6190	4940 ± 1810	6815 ± 1415

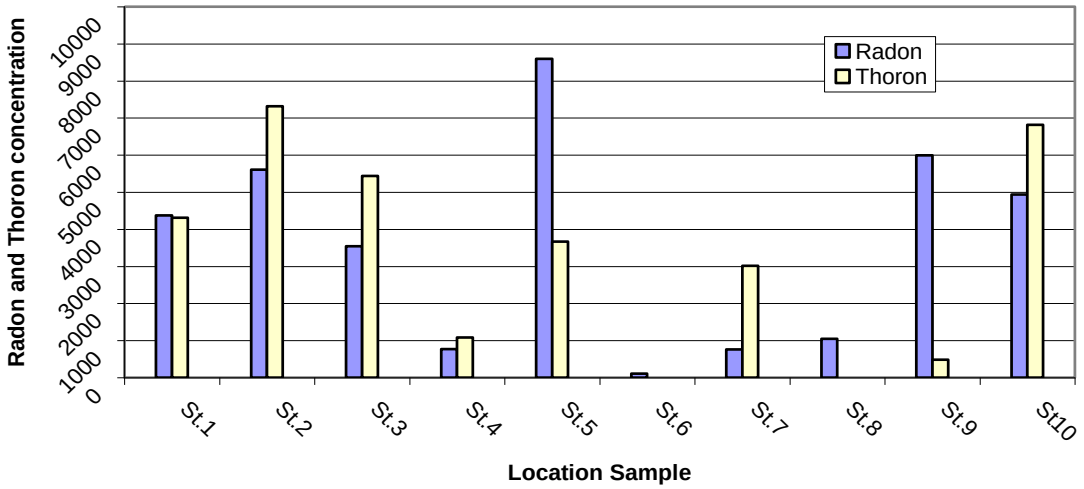


Fig.(5): Radon and thoron concentration of soil at depth 30 cm in Hilla city

Table (4) Radon(Rn^{222}) and thoron (Rn^{220}) concentration in soil gas at depth (45cm) in Hilla city

No.	Location Sample	Radon Concentration ($Bq.m^{-3}$)				Mean of radon concentration ($Bq.m^{-3}$)	Mean of thoron concentration ($Bq.m^{-3}$)
		1	2	3	4		
1	St.1	4370	8330	9770	10300	8180 ± 2670	5930 ± 1327
2	St.2	3850	9540	11100	10100	8640 ± 3250	7165 ± 1460
3	St.3	2280	4340	3830	4860	3830 ± 1110	0.00 ± 267
4	St.4	879	1390	1180	1050	1130 ± 215	15 ± 253
5	St.5	9440	13900	13600	14100	12700 ± 2210	3423 ± 1062
6	St.6	2010	7810	9510	9370	7170 ± 3530	9448 ± 1638
7	St.7	1020	1190	1730	1800	1440 ± 390	3075 ± 987
8	St.8	677	271	135	0.00	271 ± 292	60 ± 208
9	St.9	7220	12200	11400	11700	10600 ± 2300	5775 ± 1330
10	St.10	5950	7880	7920	7430	7290 ± 924	6903 ± 1433

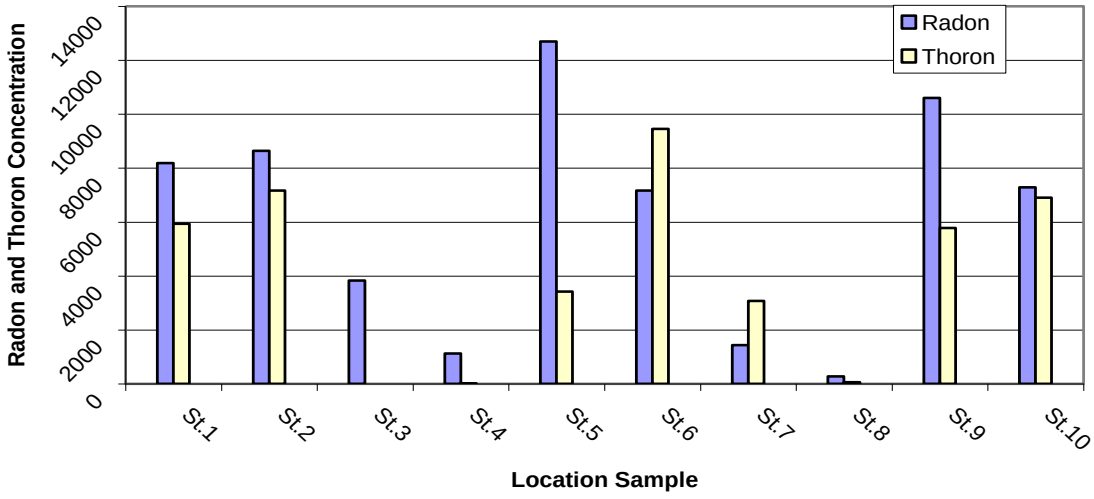


Fig.(6): Radon and thoron concentration of soil at depth 45 cm in Hilla city

5.2.The Specific activity Concentration

Analysis of activity concentration of ^{40}K, ^{238}U, ^{232}Th radionuclides in soil samples for different locations at surface (0-5cm) in table (5). The activity concentration of ^{40}K was 408.892±2.99 at St.4 to 458.726±3.17 Bq·kg^{-1} at St.3, with an average value of 433.122±2.98 Bq·kg^{-1}. The range of measured activity of ^{238}U in the soil of Hilla city was 3.675±0.24 at St.1 to 24.304±0.68 Bq·kg^{-1} at St.6 with an average of 14.181±0.49 Bq·kg^{-1}. The differences are attributable to the geochemical composition and origin of soil types in a particular area. The range of measured activity concentration of ^{232}Th for the soil was 0.870±0.11 at St.1 to 26.971±0.69 Bq·kg^{-1}at St.6 with an average of 10.807±0.39 Bq·kg^{-1}. The differences are significant in all samples as shown in figure(7) . The differences are attributable due to soil type in Hilla district which is sandy and clay soils. While in table (6) at the depth 30 cm the an average activity concentration of ^{40}K, ^{238}U, ^{232}Th was 428.783±2.97, 16.984±0.53, 7.710±0.33 respectively, the differences are significant in all samples as shown in figure(8). Moreover, our obtained average values fall within the range of corresponding world values. The world average activity concentration of ^{238}U is 35 Bq·kg^{-1} with ranges of 17 - 60 Bq·kg^{-1}, ^{232}Th is 30 Bq·kg^{-1} with ranges of 11 - 64 Bq·kg^{-1} and ^{40}K is 400 Bq·kg^{-1} with ranges of 140 - 850 Bq·kg^{-1} (UNSCEAR 2000) **.**

We see from table (5) that, the activity concentration of uranium is higher than thorium in some samples, which is evident from the fact that the average uranium is higher than that of the average thorium in earth's crust in this region. It is also observed that the measured activity concentration of ^{40}K exceeds markedly the values of both uranium and thorium, as it is the most abundant radioactive element under consideration. Moreover the excessive use of the potassium containing fertilizers in the area adjacent to the sampling sites may contribute to the higher values of ^{40}K activity. The same table (5**)** shows the radiological effects such as the radium equivalent and the absorbed dose rate. Using equation (8), the radium equivalent activity found in the soil samples are shown in table (5). The radium equivalent activity (Ra_{eq}) calculated for the same soil samples vary from 37.870 Bq·kg^{-1} to 95.416 Bq·kg^{-1} with an average value of 62.222 Bq·kg^{-1}. It is inferred that for all the soil samples analyzed, the radium equivalent activity value is well within and less the permissible limits of 370 Bq·kg^{-1}.While Table (6**)** shows the radium equivalent activity (Ra_{eq}) with an average value of 60.524 Bq·kg^{-1}. The calculated absorbed dose rate varied from 20.083 to 46.916 nGy·h^{-1}, with an average value of 31.324 nGy·h^{-1}. in table (5), while table (6) was 30.528 .Thus, the radioactive impact and the additional external radiation exposure for population due to radon flux from the soil, uptake by plants, natural alpha activity of food products must be minimal (K. M. Thabayneh 2012).

The calculated outdoor and indoor values are quoted in table (7). The results of outdoor, indoor and average effective dose for Hilla district are 0.0384, 0.1537 mSv·y^{-1}, respectively.While in table (8) was 0.0374, 0.1497. It can be seen that the above-mentioned values were lower than the corresponding worldwide values of 0.08, 0.42 mSv·y^{-1}, respectively (UNSCEAR 2000) **.**

The external hazard indexes (H_{ex}) were calculated in table (7). from 0.1022 to 0.2642, with an average value of the 0.1701 the calculated average values were less than the acceptable value (1.5 mGy·y^{-1}). These radionuclides are a few sources of radon (^{222}Rn) and its radioactive progeny. The internal exposure by radon and its progeny is controlled by the internal hazard index H_{in}. H_{in} ranged between 0.1122 and 0.2679 with an average value of the 0.2084 and less than 1 is suggested for materials used for house construction.

The external hazard indexes (H_{ex}) were calculated in table (8). from 0.1152 to 0.2568, with an average value of the 0.1646 **.** H_{in} ranged between 0.1272 and 0.3383 with an average value of the 0.2130**.** The calculated I_γ values for all the samples are presented in table(7) the values range from 0.3185 to 0.7345 with an average of 0.4914 and in table(8) the values range from 0.3540 to 0.7096 with an average of 0.4754 . The calculated values for most samples were lower than the international values (I_γ < 1) which corresponds to an annual effective dose < 0.3 mSv/y (UNSCEAR 2000) **.**

Table (5): Specific activities of radionuclides , radium equivalent and absorbed dose of soil samples taken from the surface (0-5)cm .

No.	Location	Activity Concentration [Bq/kg]			Radium Equivalent (Ra_{eq}) [Bq/kg]	Observed Dose(ERD) [nGy/h]
		^{40}K	^{238}U	^{232}Th		
1	St.1	427.935 ± 2.73	3.675 ± 0.24	0.870 ± 0.11	37.870	20.083
2	St.2	451.468 ± 2.81	6.008 ± 0.30	10.606 ± 0.39	55.938	28.188
3	St.3	458.726 ± 3.17	17.499 ± 0.58	20.184 ± 0.59	79.867	39.748
4	St.4	408.892 ± 2.99	21.330 ± 0.64	2.122 ± 0.19	55.658	28.223
5	St.5	412.627 ± 3.00	5.928 ± 0.34	13.538 ± 0.49	55.841	28.352
6	St.6	454.162 ± 3.15	24.304 ± 0.68	26.971 ± 0.69	95.416	46.916
7	St.7	434.321 ± 3.08	22.779 ± 0.66	1.315 ± 0.15	57.983	29.451
8	St.8	435.556 ± 3.08	9.836 ± 0.43	13.363 ± 0.48	61.280	31.005
9	St.9	425.804 ± 2.73	11.163 ± 0.41	11.785 ± 0.41	60.802	30.232
10	St.10	421.733 ± 3.03	19.291± 0.61	7.313 ± 0.36	61.564	31.040
Least value		408.892 ± 2.99	3.675 ± 0.24	0.870 ± 0.11	37.870	20.083
Highest value		458.726 ± 3.17	24.304 ± 0.68	26.971 ± 0.69	95.416	46.916
Mean		433.122 ± 2.98	14.181± 0.49	10.807 ± 0.39	62.222	31.324

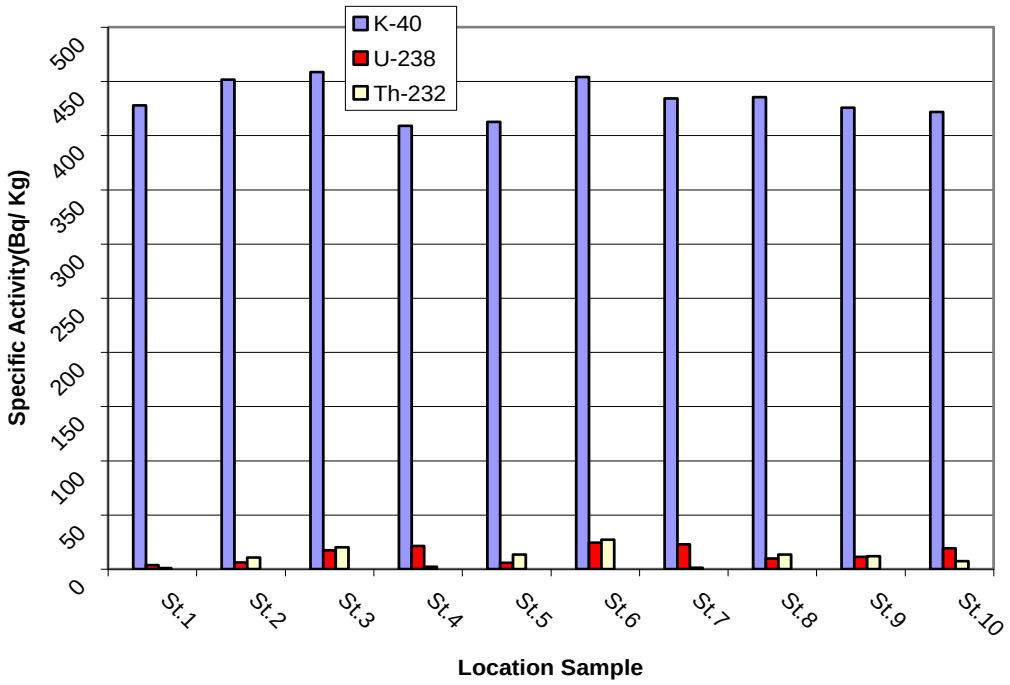


Fig.(7):Average activity concentrations of K^{40},U^{238} and Th^{232} at surface(0-5)cm in Hilla city

Table (6): Specific activities of radionuclides , Radium equivalent and absorbed dose of soil samples taken from the depth (5-30)cm .

No.	Location	Activity Concentration [Bq/kg]			Radium Equivalent (Ra_{eq}) [Bq/kg]	Observed Dose(ERD) [nGy/h]
		^{40}K	^{238}U	^{232}Th		
1	St.1	405.433 ± 2.66	29.493 ± 0.67	8.107 ± 0.34	72.304	35.657
2	St.2	418.479 ± 3.02	11.590 ± 0.47	0.701 ± 0.11	44.815	23.240
3	St.3	451.083 ± 3.14	17.670 ± 0.58	6.190 ± 0.33	60.698	30.818
4	St.4	402.472 ± 2.96	9.836 ± 0.43	12.311± 0.46	57.323	28.972
5	St.5	424.004 ± 3.04	15.688 ± 0.55	2.280 ± 0.20	51.392	26.345
6	St.6	450.865 ± 3.14	6.573 ± 0.35	0.965 ± 0.13	42.583	22.437
7	St.7	444.750 ± 3.12	2.936 ± 0.24	4.893 ± 0.29	43.738	22.941
8	St.8	433.460 ± 3.08	15.402 ± 0.54	7.471± 0.36	58.790	29.830
9	St.9	433.753 ± 2.75	30.499 ± 0.68	11.630 ± 0.40	80.529	39.400
10	St.10	424.528 ± 3.04	30.156 ± 0.76	22.552 ± 0.63	93.064	45.640
Least value		402.472 ± 2.96	2.936 ± 0.24	0.701 ± 0.11	42.583	22.437
Highest value		451.083 ± 3.14	30.499 ± 0.68	22.552 ± 0.63	93.064	45.640
Mean		428.783 ± 2.97	16.984 ± 0.53	7.710 ± 0.33	60.524	30.528

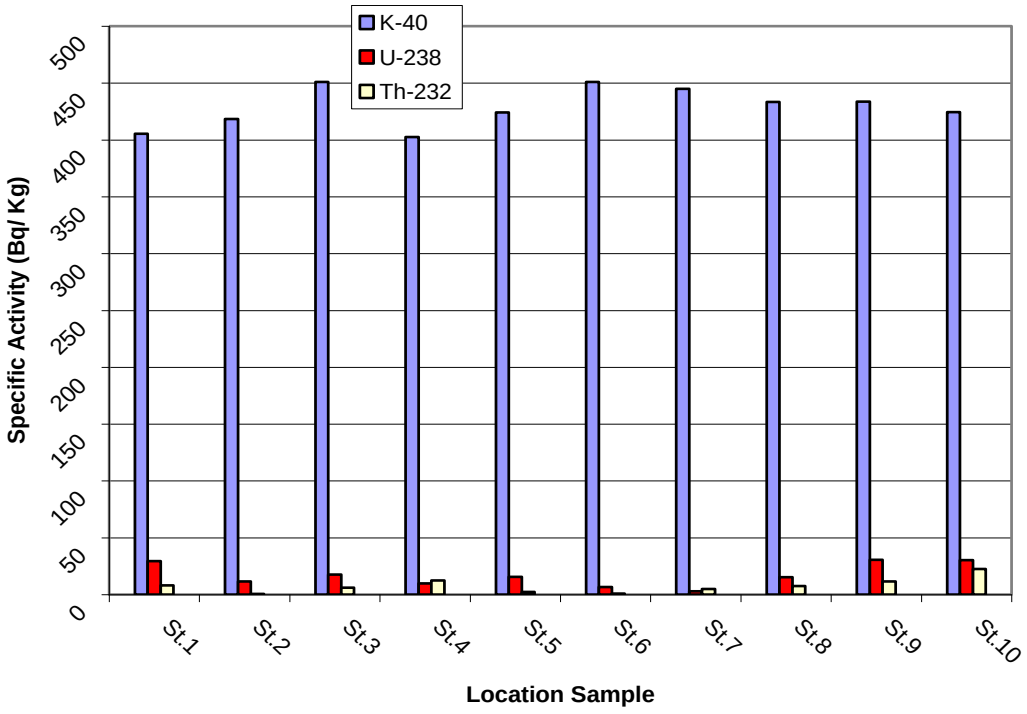


Fig.(8):Average activity concentrations of K^{40},U^{238} and Th^{232} at depth(5-30)cm in Hilla city.

Table(7): Rate of annual effective dose and hazard indices of soil samples taken from the surface (0-5)cm .

NO.	Location	Effective Dose Rate (mSv. y^{-1})		Hazard Index		Activity Concentration Index (I_γ)
		Outdoor	Indoor	External ($H_{ex} \leq 1$)	Internal ($H_{in} \leq 1$)	
1	St.1	0.0437	0.1749	0.1953	0.2750	0.5480
2	St.2	0.0285	0.1140	0.1210	0.1524	0.3633
3	St.3	0.0378	0.1512	0.1654	0.2132	0.4804
4	St.4	0.0354	0.1417	0.1557	0.2074	0.4483
5	St.5	0.0323	0.1292	0.1394	0.1818	0.4101
6	St.6	0.0275	0.1101	0.1152	0.1330	0.3540
7	St.7	0.0281	0.1125	0.1193	0.1272	0.3650
8	St.8	0.0366	0.1463	0.1606	0.2022	0.4664
9	St.9	0.0483	0.1933	0.2175	0.2999	0.6088
10	St.10	0.0560	0.2239	0.2568	0.3383	0.7096
Least value		0.0281	0.1101	0.1152	0.1272	0.3540
Highest value		0.0560	0.2239	0.2568	0.3383	0.7096
Mean		0.0374	0.1497	0.1646	0.2130	0.4754

Table(8): Rate of annual effective dose and hazard indices of soil samples taken from the depth (5-30) cm.

No.	Location	Effective Dose Rate (mSv. y^{-1})		Hazard Index		Activity Concentration Index (I_γ)
		Outdoor	Indoor	External ($H_{ex} \leq 1$)	Internal ($H_{in} \leq 1$)	
1	St.1	0.0246	0.0985	0.1022	0.1122	0.3185
2	St.2	0.0346	0.1383	0.1510	0.1673	0.4471
3	St.3	0.0487	0.1950	0.2206	0.2679	0.6243
4	St.4	0.0346	0.1385	0.1509	0.2085	0.4360
5	St.5	0.0348	0.1391	0.1541	0.1701	0.4500
6	St.6	0.0575	0.2302	0.2642	0.3299	0.7345
7	St.7	0.0361	0.1445	0.1569	0.2185	0.4546
8	St.8	0.0380	0.1521	0.1687	0.1953	0.4896
9	St.9	0.0371	0.1483	0.1642	0.1944	0.4761
10	St.10	0.0381	0.1523	0.1681	0.2202	0.4829
Least value		0.0246	0.0985	0.1022	0.1122	0.3185
Highest value		0.0575	0.2302	0.2642	0.2679	0.7345
Mean		0.0384	0.1537	0.1701	0.2084	0.4914

6- Conclusion

In this study the activity of radon and thoron levels have been measured in the soil of the ten districts in Hilla city. In this investigation the maximum radon activity (12700 $Bq.m^{-3}$)has been observed in Al-Bakerly Althanya district, station number 5 for soil from the depth (45 cm), while the minimum radon activity (25 $Bq.m^{-3}$) has been observed in Wardya Karij Althanya district, station number 6 for soil from the surface and the maximum thoron activity (9448 $Bq.m^{-3}$)has been observed in Al-Wardya Karij Althanya district, station number 6 for soil from the depth (45 cm), while the minimum thoron activity (0.00 $Bq.m^{-3}$) has been observed in Wardya Karij Althanya district, station number 6 for soil from the surface.

High levels of radon concentrations which observed in the soil samples for any stations in this study are come may be from the high concentrations of uranium and thorium in this soil the study of uranium concentrations of these soils are in progress. The ratio (^{220}Rn / ^{222}Rn) <1 , this means thoron concentration is smaller than radon concentration over all study area may be because of the short half life for thoron in comparison with radon and the long irradiation time, the data in this study is the first investigation and this study provided a basis for the radiation pollution and radon map in Hilla city.

Measurment of natural radioactivity in soil is very important to determine the amount of change in natural background with time as a result of any radioactive release . Monitoring of any release of radioactivity to the environment is important for environmental protection .The important radiological concentration consequence of natural radioactivity in soil is effects of $\gamma - rays$ on the human body. The measurements show that the values of the absorbed dose rates in air in investigated area are lower than the recommended limit by the united nation scientific committee of the effect of atomic radition (UNSCEAR,2000).From the previous discussion we can see that there is no radioactive hazard for beings working and living in this area.

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