Current Clinical and Medical Education

Received 17 May 2024 | Revised 19 May 2024 | Accepted 20 Jul 2024 | Published Online 21 Jul 2024

Published By: Vision Publisher

CCME 02 (7), 126-136

ISSN 2942-0792

Hazards Assessment of Radon Exhalation Rate and Radium Content in the Soil Samples in Baghdad

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Abstracts: In this work the calculation of the concentration of Ra-226 (186 keV), Bi- 214 (609 keV), Cs-137 (662 keV),Ac-228 (969 keV) and K-40 (1460keV) in some samples of soil in Jisr Diyala / Baghdad have been done by gamma- ray spectroscopy NaI(TL) scintillation detector. The range of Ra226 activity was 0 Bq/kg for the sample (4), while the highest specific activity was (388.8) Bq/kg for sample (2), the mean with the total number of samples was (66.216) Bq/kg. The concentrations of radon gas in the air was determined. The doses resulting from the consumption of those were coming from the inhalation of radon gas were estimated using some of mathematical equations , it is found that the specific activity for all radionuclides are below the allowed value except in sample 2, this region was near the Iraqi Atomic Energy in Al-Twetha city.

Keyword: Soil,Energy,Human

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Introduction

The twentieth century witnessed advanced technological leaps to serve humanity, and this development was accompanied by the emergence of great risk with direct effects on the environment, which in turn were reflected on human health and the environment of society. Daily they contain components or radiation emitters with immediate or slow damage to humans and the environment [1].

Man is dependent on soils and good soils are dependent upon man and the use he makes of them. Soil is a mixture of natural bodies on the earth's surface containing living matter and supporting plants. Soil consists of a three-phase system of solids, liquids, and gasses [2]. Soil is a collection of natural bodies on the surface of the earth, containing living matter and supporting or capable of supporting plants [3].

Soil is a complex-substance because of its extreme variability in physical and chemical composition. It contains small but significant quantities of organic and inorganic compounds, which are essential for the growth of plants. Naturally occurring radionuclides of terrestrial origin emerge mostly from the primordial radionuclides that have considerably long half-lives [4].

Human is exposed to radiation permanently from two main sources: natural sources and man-made sources that are made for various purposes. Exposure by natural sources constitutes the main percentage of exposure, such as cosmic rays and rays emanating from naturally radioactive elements. Almost all materials surrounding us contain a small amount of a small number of radioactive materials [5]. For this reason, humans are exposed to a low level of background radiation, where radiation affects the environment, which effects may remain for several years. It may affect the genetic makeup of humans and animals, leading to a genetic defect that will appear in future generations. Moreover, the effect of this reaches the water.As well as soil entering the food chain of humans and animals Radon is a member of the radioactive chain of uranium and is produced by the alpha decay of radium. Almost 54% of the natural radiation that people are often exposed to in their daily lives is due to radon isotopes, especially [6]. The radon is produced by radium decay and by recoil emanating from the material into the air or water. When an underground well is opened, the radon is transported, by diffusion and convection, from the rocks to the environment through water or air circulation. The importance of each process depends on the geological nature of the formation. Radon exhalation rate varies due to alterations in the differential air pressure, the uranium and radium levels, the working conditions, and the degree of ventilation. The underground well environment is complex and variab. Radon, after being exhaled, migrates along ventilation currents while it generates the solid decay products: Po-218, Bi-214 and Po.214 [7].

1.1 Pollution and Pollutants

A pollutant is a substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource. A pollutant may cause long- or short-term damage by changing the growth rate of plant or animal species, by interfering with environmental good health or interfering with human, comfort, health, or property values. Some pollutants are biodegradable and therefore will not persist for the long term in the environment [8].

1.2 Major Forms of Pollution

The major forms of pollution are listed below along with the particular pollutants relevant to each of them [9]:

1- Soil pollution: Occurs when chemicals are released by spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, herbicides, pesticides, and chlorinatedhydrocarbons.

2- Radioactive contamination: Resulting from 20th century activities in atomic physics, such as nuclear power generation and nuclear weapons research, manufacture and deployment.

3- Air pollution: The release of chemicals and particulates into the atmosphere, common air pollutants include carbon monoxide, sulfur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides produced by industry and motor vehicles. Photochemical ozone and smog are created asnitrogen oxides and hydrocarbons react to sunlight.

4- Water pollution: By the release of waste products and contaminants into surface runoff into river drainage systems, leaching into groundwater, liquidspills, wastewater discharges, and eutrophication and littering.

5- Soil pollution: Occurs when chemicals are released by spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, herbicides, pesticides and chlorinated hydrocarbons.

6- Radioactive contamination: Resulting from 20th century activities in atomic physics, such as nuclear power

generation and nuclear weapons research, manufacture and deployment.

7- Noise pollution: This encompasses roadway noise, aircraft noise, industrial noise as well as high-intensity sonar.

8- Light pollution: Includes light trespass, over-illumination and astronomical interference.

9- Visual pollution: This can refer to the presence of overhead power lines, motorway billboards, and scarred landforms (as from strip mining), open storage of trash or municipal solid waste.

10- Thermal pollution: Is a temperature change in natural water bodies caused by human influence, such as use of water as coolant in a power plant.

1.3 Soil Pollution

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease-causing agents, which have adverse effects on plant growth and animal health [10]. Soil is the thin layer of organic and inorganic materials that covers the Earth's rocky surface. The organic portion, which is derived from the decayed remains of plants and animals, is concentrated in the dark uppermost topsoil. The inorganic portion made up of rock fragments was formed over thousands of years by physical and chemical weathering of bedrock. Productive soils are necessary for agriculture to supply the world with sufficient food [11].

Chapter Two Theory Concepts

2-1 Specific Activity

The specific activity (A) in soil samples of the present study was calculatedusing equation (2-1) [12,13].

$$A\left(\frac{Bq}{kg}\right) = \frac{Neat\ Area}{t(s) \times I_\gamma \times \varepsilon \times M(kg)} \qquad (2-1)$$

where, N is net area of photo peak, t is counting time(3600 s), Iγ is gamma probability, ε is the efficiency of NaI(Tl) detector that used in the present study, and M is mass of the soil sample in kg unit.

2-2 Radiation Hazard Index Calculation

There are seven radiation hazard index quantities of the soil sample in presentstudy were found as following:

2-2-1 Radium Equivalent Activity (Ra_{eq})

Radium Equivalent Activity (Ra_{eq}), the quantity value of Ra_{eq} was determined according to specific activity of A_{Ra} for ^{226}Ra (^{238}U), A_{Th} for $^{232}Th$and A_K for

^{40}K using equation (2-2) [14]:

$$\boldsymbol{Ra_{eq}\left(\frac{Bq}{kg}\right) = A_{Ra} + 1.43A_{Th} + 0.077A_K} \qquad (\mathbf{2-2})$$

2-2-2 Gamma Rate of Dose Absorption (Dγ)

Gamma Rate of Dose Absorption (Dγ), can be calculated by equation (2-3)[14,15].

$$(nGyh^{-1}) = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K \qquad (2-3)$$

2-2-3 External Hazard Index (H_{ext})

External Hazard Index (H_{ext}), is calculated using equation (2-4) [16].

$$H_{ext} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2-4)$$

2-2-4 Internal Hazard Index (H_{int})

Internal Hazard Index (Hint) is calculated using equation (2-5) [17].

$$H_{int} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2-5)$$

2-2-5 Index of Gamma Representative (I_γ)

Index of Gamma Representative (Iγ), Iγ can be calculated by equation (2-6)[15, 18].

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (2-6)$$

2-2-6 Annual Effective Dose Equivalent (AEDE)

Annual Effective Dose Equivalent (AEDE), AEDE in indoor, outdoor, andtotal are calculated using equations (2-7, 2-8 and 2-9), respectively, asfollowing [19, 20]:

$$AEDE_{indoor}\left(\frac{mSv}{y}\right)$$

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right)$$

$$= D\left(\frac{nGy}{hr}\right) \times 8760\left(\frac{hr}{y}\right) \times 0.7\left(\frac{Sv}{Gy}\right) \times 0.2 \times 10^{-6} \quad (2-8)$$

$$AEDE_{total}\left(\frac{mSv}{y}\right)$$

$$= AEDE_{indoor}\left(\frac{mSv}{y}\right) + AEDE_{outdoor}\left(\frac{mSv}{y}\right) \quad (2-9)$$

2-2-7 Excess Life Time Cancer Rate (ELCR)

Excess Life Time Cancer Rate (ELCR**),** ELCR is represented by thefollowing mathematical equation (10) [21, 22].

$$ELCR = AEDR \times D_L \times R_F \quad (2-10)$$

where, D_L is average period of life time (estimated to be 70 years) and R_F isconversion factor, the R_F value used by ICRP for the public is 0.05 Sv^{-1} .

The formula that used to measuring the radioactive concentration of Rn^{222} inthe air as follow [23];

Firstly must be estimate the radioactive concentration of Rn^{222} inside the soilsamples by ;

$$Gs(n) = F_r \times \rho \times CRa(n) \quad \textbf{(2-11)}$$

where

Gs(n) : specific activity of radon gas inside the soil for sample(n) in (Bq/m^3).F_r : the constant of emission of Rn^{222} from the soil that is equal to (0.1). ρ : is the soil density that is equal to (1800 kg/m^3) .

CRa(n) : is the specific activity of Ra^{226} in soil sample (n) in (Bq/kg).

Now specific activity of Rn^{222} in the air can be calculated by the fallowing equation;

$$Ca(n)=Gs(n)\ (d_{soil} / D_{air})^{1/2} \quad \textbf{(2-12)}$$

where

Ca(n) : is the specific activity of Rn^{222} in the air for sample (n) in (Bq/m^3) .d_{soil} : is the diffusion rate constant of Rn^{222} in the soil (0.5×10^{-4} m^2/sec) . D_{air} : is the diffusion rate constant of Rn^{222} in the air (5 m^2/sec).

D : The doses rates that coming from inhalation of radon gas and vegetables consumption was determined using the below equation [24]

$$Hp = Ca(n) \times Ip \times DCF \quad \textbf{(2-13)}$$

where

Hp: is the dose rate resulting from inhalation of radon gas consumption in (Sv/y).

Ip: is the amount of consumption for air outside the home (600 m^3/y) [24]

DCF: is the dose conversion coefficient: for Rn^{222} equal to (1.3×10^{-9} Sv/Bq)[23]

Chapter Three Experimental Work

This study was conducted in the Baghdad governorate in the area of Jisr Diyala. Soil samples were collected from five points taken from different locations in the area. one kg of soil samples were collected from each point. Samples were taken from topsoil (0-5 cm depths). Soil samples were crushed in the laboratory, oven dried at a temperature of 105 °C for 8 h, and sieved through a 270 mesh. 1000 g of the homogenous soil samples were then packed in a polyethylene beaker, weighed and carefully sealed, and stored for at least 4 weeks before counting to allow time for U^{238} and Th^{232} to reach equilibrium with their respective radionuclide's daughters.

There are several direct and indirect methods for U^{238} measured in geological material samples. Among these, the most widely used one is scintillation gamma spectrometry. The details of this method had been discussed by Killeen (Kumru, 2003). This method was used for the determination of U, Th, and K in the present study. The natural radioactivity in soil of region has been measured by gamma ray spectrometry using 3'' ×3'' NaI (T1) detector (ORTEC-905-4). The best regulation achievable is typically <7.5 % for the 662 keV gamma ray from Cs-137. In this study, the 1.76 MeV peak of Bi-214 was used for quantitative determination of uranium, the 2.62 MeV peak of Tl-208 was used for the quantitative determination of thorium and the 1.46 MeV peak of radioactive potassium was used for the quantitative determination of potassium. The samples were counted for 3600 seconds. Background counts were taken under the same conditions.

In order to relate obtained count rate to the concentration of U, Th, and K in samples. In these equations α, β, γ are known as stripping rations and they indicate the interaction occurred among the K, U, Th channels during counting. Determinations of the stripping rations were done quite simply by taking accurate measurements of the counts rates produced in all channels by a pure series- equilibrium uranium and thorium sources. K_1, K_2 and K_3 are sensitivity factors for each channel and were determined by the measurements of the standard samples under the proper conditions. In the measurements, 118 ppm (U), 600 ppm (Th) and 52 % K standards were used

Chapter Four

Results, Discussion and Conclusions

The net area under the peak values in (C/h) units in six soil samples for natural and artificial radionuclides Ra-226 (186 keV), Bi-214 (609 keV),Cs- 137 (662 keV),Ac-228 (969 keV) and K-40 (1460keV) are listed in Table (4-1). The Specific Activity values in (Bq/kg) units in soil samples for these radionuclides are presented in Table (4-2) and showed in Fig.(1-1).

Table (4-1): Net Area Under the Peak (C/h) values in soil samples for Radionuclides Ra-226 (186 keV), Bi-214 (609 keV),Cs-137 (662 keV),Ac-228 (969 keV) and K-40 (1460keV)

No. of sample	Net Area Under the Peak for Radionuclides (C/h)				
	Ra-226 186 keV	Bi-214 609 keV	Cs-137 662 keV	Ac-228 969 keV	K-40 1460keV
1	473	0	0	0	427
2	210	0	0	0	3
3	761	0	39	20	252
4	0	0	0	71	958
5	2634	0	0	0	108
6	892	0	0	0	2

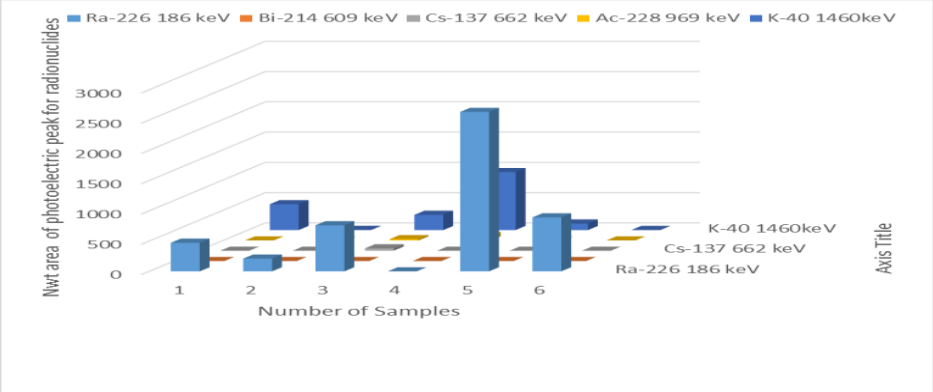

Fig. (4-1): Net Area Under the Peak (C/h) values in soil samples for Radionuclides Ra-226 (186 keV), Bi-214 (609 keV),Cs-137 (662 keV),Ac-228 (969 keV) and K-40 (1460keV)

Table (4-2): Specific Activity (Bq/kg) values in soil samples for Radionuclides: Ra-226 (186 keV), Bi-214 (609 keV), Cs-137 (662 keV), Ac-228 (969 keV) and K-40 (1460keV)

No. of sample	Specific Activity for Radionuclides (Bq/kg)				
	Ra-226 186 keV	Bi-214 609 keV	Cs-137 662 keV	Ac-228 969 keV	K-40 1460keV
1	1.094	0	0	0	0.0045
2	388.8	0	0	0	0.042
3	0.880	0	0.123	0.082	1.346
4	0.000	0	0	71	8.188
5	4.877	0	0	0	0.923
6	1.651	0	0	0	0.017
Mean	66.217	0	0.0205	0.0137	1.753

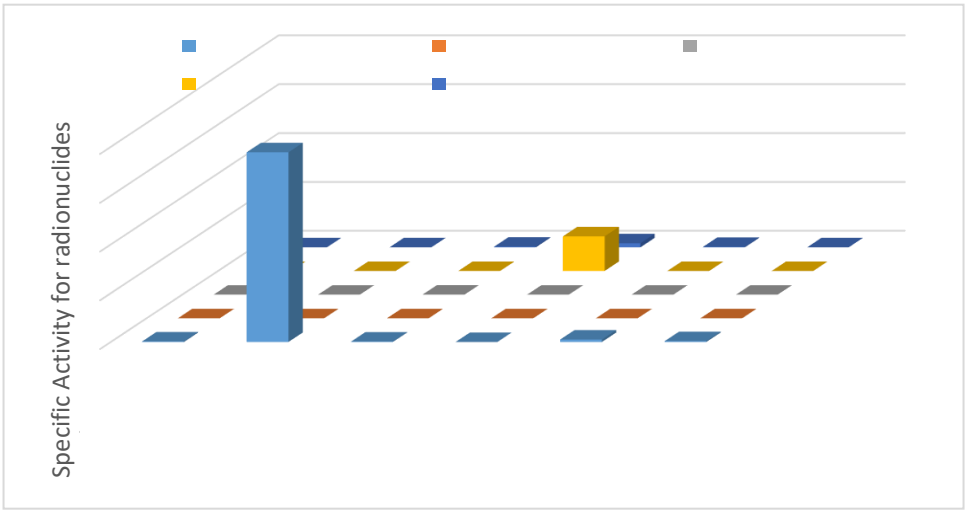

Fig. (4-2): Specific Activity (Bq/kg) values in soil samples for Radionuclides: Ra-226 (186 keV), Bi-214 (609 keV), Cs-137 (662 keV), Ac-228 (969 keV) and K-40 (1460keV)

Form table 4-2, it is found that, the lowest specific activity of ^{40}K was (0.0045 Bq/kg) for the sample 1,while the highest specific activity was (8.188) Bq/kg in sample (4), the mean value of ^{40}K with the total number ofsamples was 1.753Bq/kg. The lowest specific activity of ^{226}Ra was 0 Bq/kgfor the sample (4), while the highest specific activity was (388.8) Bq/kg forsample (2), the mean with the total number of samples was (66.216) Bq/kg,also the lowest specify activities of ^{232}Th (^{228}Ac) was (0) Bq/kg for the samples (1,2,5 and 6), while the highest specific activity was (71) Bq/kg forsample (4), the average for all samples was (0.0137) Bq/kg.

The results of Ra_{eq}, D_γ, H_{ex}, H_{in}, Iγ, AEDE and ELCR in all samples were be listed in Table (4-3)

Table (4-3): The values of hazard index in soil samples Ra_{eq} (Bq/kg), A_D $(nGyh^{-1})$, $AEDE_{out}$ and $AEDE_{in}$ $\times 10^{-6}$ $(\frac{S_v}{Gy})$, H_{ex}, H_{in} And ELCR

No. ofsample	Ra_{eq} Bq/kg	A_D $(nGyh^{-1})$	$AEDE_{out}$ Sv $10^{-6}(\ )$ Gy	$AEDE_{in}$ Sv $10^{-6}(\ )$ Gy	H_{ex}	H_{in}	Iγ	ELCR 10^{-6}
1	1.094	0.506	6.0	2.48	0.00296	0.0059	0.0073	21.70
2	388.8	174.6	220.3	881.07	1.05082	2.1020	2.592	771.03
3	0.880	0.513	6.3	2.51	0.00297	0.0056	0.0059	21.99
4	0.000	0.624	7.6	3.06	0.00349	16.673	0.0000	26.79
5	4.877	2.292	28.2	11.24	0.01337	0.0266	0.0325	98.54
6	1.651	0.763	9.4	3.74	0.00446	0.0089	0.0110	32.77
	66.217	29.883	46.3	150.68	0.17967	3.1370	0.4414	162.14

The radium (Ra_{eq}) can be attained as shown in equation (2-2). The Radium equivalent that is of the largest activity value was equal to (388.8) Bq/kg insample 2 which is larger of allowed value (370Bq/kg), while the lowest value of radium equivalent activity was equal to (0) Bq/kg in sample 4, withan average rate of (66.217) Bq/kg. The rate at which Gamma absorption dose is taken (Dγ) is acquired by applying equation (2-3), the largest amount of the ratio for the gamma dose absorption was equivalent to (174.6 nGy/h),while the lowest rate of the absorbed gamma dose rate was (0.506 nGy/h), with an average rate of (29.883) nGy/h. The external hazard index (H_{ex}) acquired through the application of equation (2-4), the highest value of external hazard index was (1.05082) which is larher than allowed value 1.00, while the lowest value of external hazard index was (0.00296) ,with an average value of (0.17967). The internal hazard index (H_{in}) obtained using an equation (2-5), the highest value of internal hazard index was (16.673), while the lowest value of internal hazard index was (0.0056), with an average value of (3.1370). The Gamma Index Representative the contributions of natural radionuclides to the absorbed dose rate in air depend on the concentrations of the radionuclides in the soil. There is a direct connection between terrestrial gamma radiation and radionuclide concentrations in soil. The contribution of terrestrial gamma radiation to absorbed doses in air can be calculated using eq.2-6).

The Gamma Index Representative (Iγ), that is acquired through the application of equation 2-6, that largest rate it was (2.592). On the other hand, the lowest rate point of Gamma Index Representative was (0.000), with an average value of (0.4414). The indoor annual effective dose equivalent (AEDE) in received through the application of equation (2-7), the largest indoor yearly dynamic dose equivalent was (881.07×10^{-6}) mSv/y, while the lowest rate of indoor annual effective dose equivalent was (2.48×10^{-6}) mSv/y, with an average ratio of (150.68×10^{-6}) mSv/y. The outdoor annual effective dose equal (AEDE) out obtained using an equation(2-8), the highest rate of outdoor annual effective dose equal was (220.3×10^{-6}) mSv/y, while the lowest rate of outdoor annual effective dose equivalent was (6.00×10^{-6}) mSv/y,

with an average value of (46.3 $\times 10^{-6}$) mSv/y. The values of ELCR$\times 10^{-6}$were ranged from 21.7 to 771.03, with an average value of 162.14.

Concentration of radon in soil samples Bq/kg for each samples werecalculated using equation (2-11), **Concentration of radon in air Bq/m3 for each samples** were calculated using equation (2-12) and Dose rate resulting from inhalation of radon gas consumption in (Sv/y) in soil samples were calculated using equation (2-13). Table (4-4) and Figs.(4-3) , (4-4) and(4-5) presented the results of these quantities.

Table (4-4): Dose rate resulting from inhalation of radon gasconsumption in (Sv/y) in soil samples

No. of sample	Ra-226 186 keV	Gs(n) (Bq/m^3)	Ca(n) (Bq/m^3)	Hp (Sv/y) $\times 10^{-9}$
1	1.094	196.92	0.6227	485.706
2	388.8	69984	221.309	172621.02
3	0.880	158.4	0.5001	390.000
4	0.000	0.000	000000	0.0000
5	4.877	877.86	2.7750	2164.5
6	1.651	297.18	0.9397	732.966
Average	66.217	11919.22	37.692	29399.76

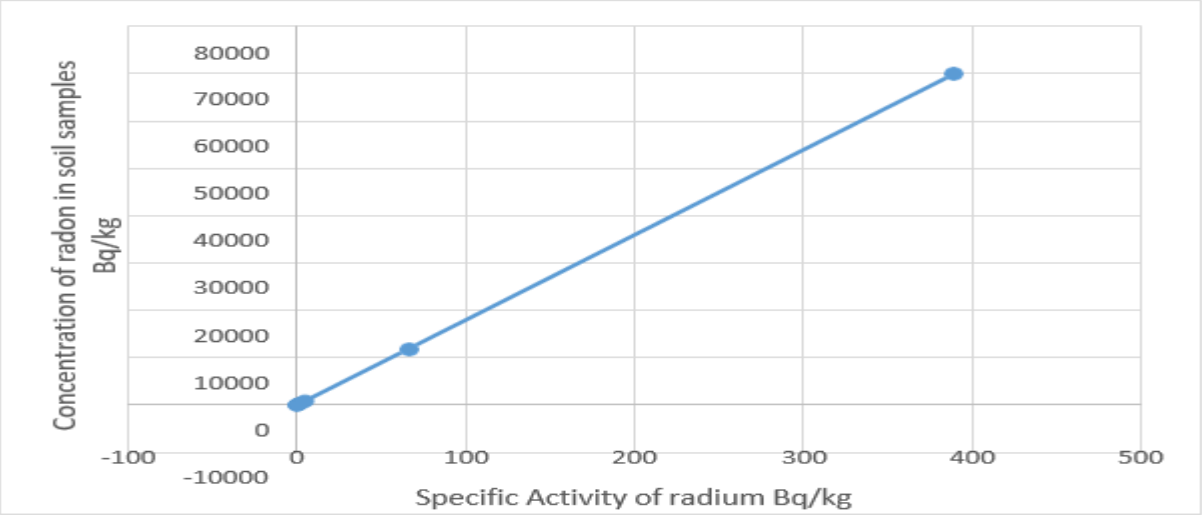

Fig. (4-3): Concentration of radon in soil samples Bq/kg for eachsamples

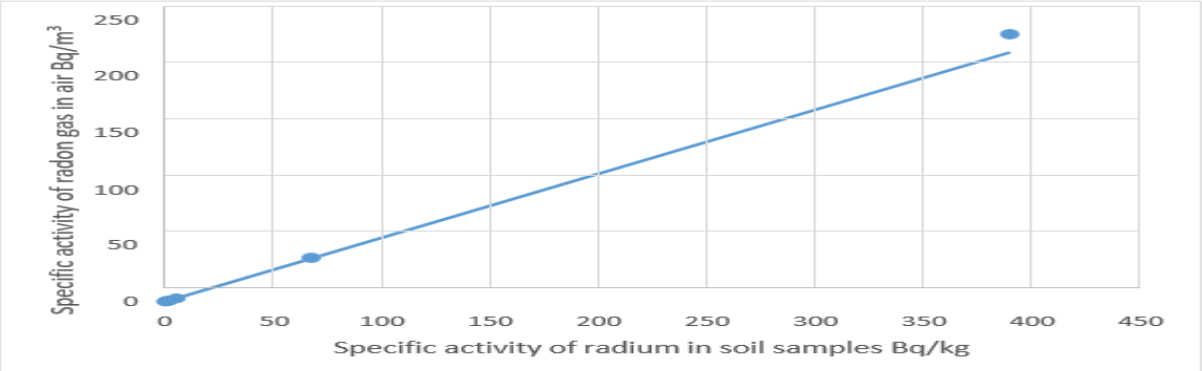

Fig. (4-4): Concentration of radon in air Bq/m^3 for each samples

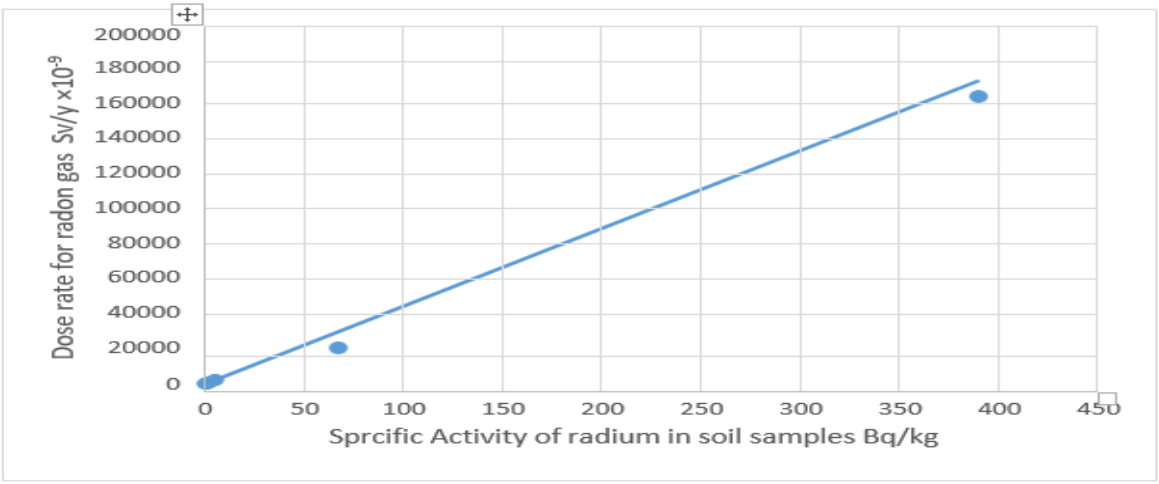

Fig. (4-5): Dose rate resulting from inhalation of radon gas consumption in (Sv/y) × 10^{-9} in soil samples

Conclusions

1. The present work developed that all soil samples that taken from all regions from the Jisr Diyala / Baghdad have the Ra^{226} radioisotope with different activity concentrations.

2. The obtained values of natural radioactivity and γ-absorbed dose rates due to the activity concentrations of soil samples and in the air show that allof the studied samples is considered a radiological hazard except sample 2.

3-Soils can be safely used in construction of buildings and exploits for the agriculture without posing any significant radiological threat to populationexcept sample 2.

4- The specific activity for all radionuclides are below the allowed value except in sample 2, this region was near the Iraqi Atomic Energy in Al- Twetha city.

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