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# Study of Radiation Hazards Indices and Radon Exhalation Rate in Soil Samples from Wadi Naseib Area, Sinai, Egypt

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**Abstract:** *The radiological effects from 21 one soil samples collected from Wadi Nasib Area, Sinai, Egypt, have been measured using gamma spectrometer. CR-39 plastic track detectors have been used for the measurement of radon exhalation rate (closed can technique). The radon exhalation rate in these samples has been found to vary from 1.48 to 63.36 Bq* $m^{-2}$ $h^{-1}$*. Uranium concentration varies from 1 to 89 ppm, whereas Radium concentration in soil samples has been found to vary from 2 to 114 ppm. The annual effective dose measured for this area exceeds the permissible values, especially for public, recommendations and precaution are suggested, and should be undertaken during any exploration processes or other works in areas of relatively high radioactive intensity.*

## 1. Introduction

Natural radionuclides are presented in all rocks in varying amounts depending on their concentration levels in source materials. Since its existence in the environment that we live in every living creature is exposed to ionizing radiation. This radiation is a part of the earth and comes from cosmos and affects all the goods, food and even the air that we breathe and makes them partly radioactive. So, human beings are exposed to natural background radiation every day from the ground, building materials, air, the universe, and even elements in their own bodies. It is because of some reasons that human and its environment are affected by radioactivity , such as, natural radionuclide's which are present in soil and the atmosphere, nuclear weapon testing, radioactive wastes and reactor accidents. It's important to know the distribution of radionuclide's and to understand the physical and geochemical processes that concentrate them in some rocks (Ahmed et al., 2007) [(1)].

## 2. The Aim of the Present Work

This study was undertaken for the purpose of estimating the radiation hazard indices in soils samples from west eastern Sinai bensuila and assessing the annual effective dose equivalents from the measured terrestrial radiation in the geographic area of study, as well as radon exhalation measurements.

## 3. Experimental Methods

To understand radiation hazards and exhalation of radon in naturally occurring soils of wadi Naseib area, Sinai, Egypt, soil samples were collected from 21 stations covering different lithologies, the separation distance between each two stations is nearly ranged from 150 to 200 m, covering an area of approximately 40 Km2. Geologically Wadi Naseib lies between Latitudes 29°10' 30" and 29° 05'/ North and Longitudes 33°22' and 33°25' East.

### 3.1. Measurements of Radon Exhalation Rate

In order to measure the radon exhalation rate the `can technique' (Khan et al., 1992) [(2)] was used. A CR-39 plastic track detector (1x1 cm) was fixed on the top inside of a cylindrical plastic can of 11 cm height and 8 cm diameter, figure(1).

Equal amounts of each sieved (200 mm grains size) samples (100-200 gm) was placed at the base of each can. The cans were sealed for 90 days. The lower sensitive part of the detector was exposed freely to the emergent radon from the samples in the can so that it could record a-particles resulting from the decay of radon in the remaining volume of the can and from 218Po and 214Po deposited on the inner walls of the can. Radon and its daughters reach equilibrium in about 4 h and hence the activity of emergent radon can be obtained from the geometry of the can and the time of exposure.

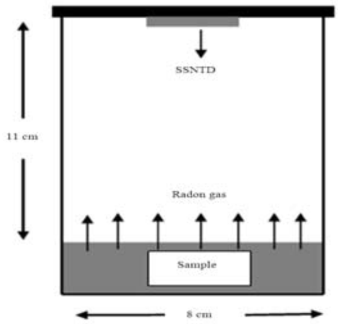


**Fig 1.** *Experimental set-up for the measurement of radon exhalation* [(3)]

After exposure, the detectors were etched in 6.25 N NaOH at 70+1C for 8 hour in a constant temperature water bath to reveal the tracks. The resulting α-tracks were counted using an optical microscope at a magnification of 400X. The activity was calculated from the track density in the etched detectors using the calibration factor of 0.2217 ± 0.035 (T.cm-2.d-1/Bq.m-3) obtained from the earlier calibration experiment (S. F. Hassan et al, 2000) [(4)]. The exhalation rate of radon is obtained from the expression (Khan et al., 1992) [(2)].

$$E_x = \frac{CV\lambda}{A\left[T + 1/\lambda\left(e^{-\lambda t} - 1\right)\right]} \quad (1)$$

Where Ex=radon exhalation rate (Bq m-2 h-1); C=integrated radon exposure as measured by LR-115 type II detector (Bq m-3); V=effective volume of the can (m3); λ=decay constant for radon (h-1); T=exposure time (h) and A=area of the can (m2).

### 3.2. Radiation Hazards Indices Factors

The rock samples were crushed mechanically, dried and then ground to grain size of about -100 mich by rotating metal discs. The powder rock samples were transferred to polyethylene circular containers of 10 cm diameter and 3 cm height. Every sample was then pressed manually in its container till it was completely filled and then it is tightly closed and stored sealed for about one month to reach the state of equilibrium between radium and its daughters. The analysis was carried out in the Egyptian Nuclear Materials Authority laboratories.

#### 1. Exposure Rate and Dose Rate

A measure of ionization caused by X-ray and /or γ-radition is called exposure. The exposure rate (μR/h) is related to the measured radio-nuclide concentration. It can be calculated from the following equation [(5)].

The exposure rate (μR/h) =0.653U (ppm) + 0.287Th (ppm) + 1.505 K % eq(2)

Where 0.653, 0.287 and 1.505 are the conversion factors for U, Th and K% respectively. The same method also can be used to calculate the absorbed dose rate (nGy/h) from the following equation:-

The dose rate (nGy/h) = 5.476 U(ppm) + 2.494 Th (ppm) + 13.078 K % (3)

Beck et al. (1992) [5] was calculated the absorbed dose rate (ngy/h) by using specific activity concentration (in Bq/kg) from the following equation:-

The dose rate (nGy/h) = 0.4299 $S_u$ + o.666 $S_{Th}$ + o.042 $S_{K\%}$ (4)

Where, 0.4299 Su, o.666 STh and o.042 SK% are the specific activity of Ra, Th and K in Bq/kg.

## 2. Effective Dose Rate

The estimation of the annual effective dose, the conversion factor from absorbed dose in air to effective dose and the outdoor occupancy factor must be taken into in unit of mSv per year, is calculated from the following equation [6]:-

$mSvy^{-1}$ = (n GY $h^{-1}$) ×24h×365.24d×0.2×0.7 Sv $Gy^{-1}$ ×$10^{-6}$ (5)

Where, $mSvy^{-1}$ is the effective dose rate, (n Gy $h^{-1}$) is the dose rate and Sv $Gy^{-1}$ is the conversion coefficient.

The international commission of radiological protection [6] recommended that no individual should receive more than 50 $mSvy^{-1}$ from all natural and artificial radiation sources. The recent recommendation of IAEA (1996)[7] indicated that the permissible level of dose rates reaching up to 5 mSv $y^{-1}$ for public members and up to 20 mSv $y^{-1}$ for the occupational members.

## 3. The Radium Equivalent Concentration (Raeq) Activity

The combined specific activity of $^{226}$Ra, $^{232}$Th, and $^{40}$K develop a numerical indicator of an external dose to public [8]. Suggested the following equation to calculate radium equivalent and stated the value of 379Bq/kg as the maximum allowed dose for public.

$Ra_{eq}= A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \leq 370$ (6)

Where, $A_{Ra}$, $A_{Th}$ and $A_K$ are the specific activities of Ra, Th and K, in Bq/kg, respectively.

## 4. External Hazard

The external hazard index (Hex) was used to measure the external hazard due to the emitted gamma radiation. It was calculated by the equation from (Krieger, 1981) [9].

$H_{ex}= A_{Ra}/370 + A_{Th}/259 + A_K /4810 \leq 1$ (7)

Where $H_{ex}$ is the external hazrd index.

## 5. Internal Hazard

In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. So, the internal radon and its daughter products are quantified by the internal hazard index Hin whish is given by:

$H_{in}= A_{Ra}/185 + A_{Th}/259 + A_K /4810 \leq 1$ (8)

## 6. (Level index) I-gamma

The estimation of radiation risk level (I-γ) which controlling by gamma ray associated with radio-nuclides in specific materials. It is calculated from the following equation [5]:-

The (I-γ) =$S_{Ra}/150 + S_{Th}/100 + S_{K\%}/1500 \leq 1$ (9)

# 4. Results and Discussion

## 4.1. Radon Exhalation Rate

The obtained data for the track density concentration measured in (T $cm^{-2}$ $d^{-1}$) were presented in table(1), these data were used to calculate the radon exhalation rates ($Bqm^{-2}h^{-1}$) and radon concentration (Bq $m^{-3}$) using closed-can techniques employing a solid state nuclear track detector and applying equations (1) were also presented .

**Table 1.** *The track density, radon concentration and radon exhalation rate*

| S. NO. | Track Density (T cm$^{-2}$ d$^{-1}$) | Radon Concentration. (Bq m$^{-3}$) | Radon Exhalation Rate Ex (Bq m$^{-2}$ h$^{-1}$) |
|---|---|---|---|
| 1 | 266±33 | 1202±147 | 2.437 |
| 2 | 275±37 | 1242±166 | 2.520 |
| 3 | 316±35 | 1424±159 | 2.889 |
| 4 | 200±34 | 900±153 | 1.825 |
| 5 | 468±42 | 2109±189 | 4.278 |
| 6 | 637±80 | 2872±360 | 5.825 |
| 7 | 299±45 | 1349±205 | 2.736 |
| 8 | 400±54 | 1803±246 | 3.658 |
| 9 | 6925±49 | 31235±219 | 63.360 |
| 10 | 522±91 | 2353±412 | 4.773 |
| 11 | 627±104 | 2829±471 | 5.738 |
| 12 | 1422±107 | 6413±481 | 13.009 |
| 13 | 183±23 | 824±103 | 1.672 |
| 14 | 163±40 | 733±177 | 1.487 |
| 15 | 2157±698 | 9727±3146 | 19.730 |
| 16 | 1831±99 | 8256±444 | 16.746 |
| 17 | 3416±165 | 15405±741 | 31.248 |
| 18 | 1111±81 | 5009±363 | 10.159 |
| 19 | 1476±103 | 6657±461 | 13.504 |
| 20 | 3707±97 | 16721±440 | 33.917 |
| 21 | 276±38 | 1246±170 | 2.528 |
| average | 1270±98 | 5729±441 | 11.620 |

From the table we can get that the track density (T cm$^{-2}$ d$^{-1}$) ranged from (162±39) station number (14) to (6925±49) station number (9) with an average value of (1270±98). The results for the radon concentrations shows that it ranges from 733±177 to 31235±219 (Bq m$^{-3}$) with an average value of (5729±441), finally the exhalation rates were ranged from 1.487 to 63.36 Bq m$^{-2}$ h$^{-1}$, with an average 11.62 Bq m$^{-2}$ h$^{-1}$.

From the data it is obvious that there is a wide range for the obtained date between the high and low values which is mainly due to the large spread in the measured U- concentration also as will be shown in Table (2).

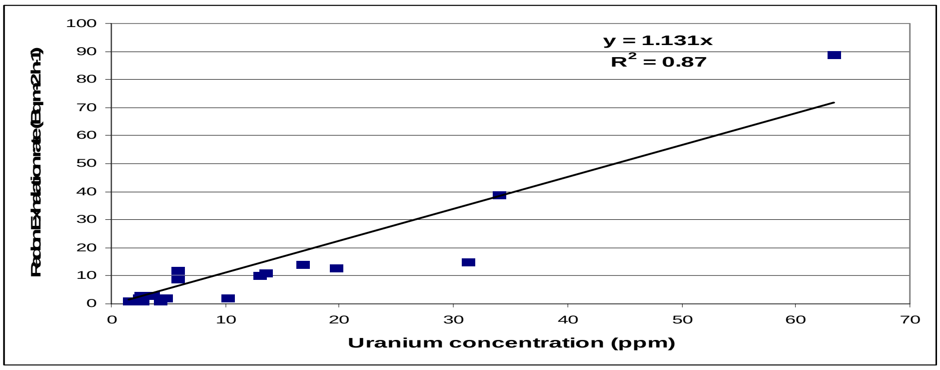


**Fig 4.1.** *Correlation between radon exhalation rat and the uranium concentration for the studied sample.*

The results also indicates that the measured radon activity and exhalation rates are consistent with the measured uranium concentration (ppm) in most samples especially those having a relatively high concentration

From the figure we can get that, there is a positive correlation between radon exhalation rates and uranium concentration with liner coefficient of 0.87.

The same behavior was also observed between the measured radium concentration -Table(4.19)-, and radon exhalation rates, again positive correlation has been found with a correlation factor of 0.758 which is nearly equal to that obtained for uranium concentration this relation were represented graphically in fig. (4.2).

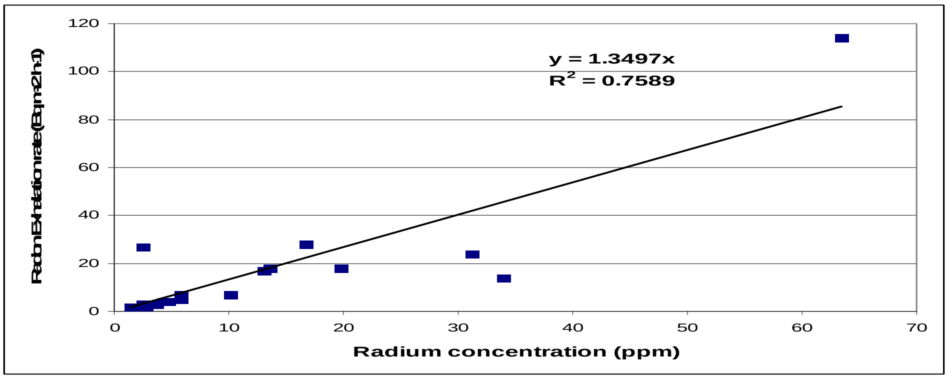


**Fig 4.2.** *Correlation factor between radon exhalation and equivalent radium concentration for the studied samples*

Finally, the correlation between uranium concentrations and radium equivalent in the studied samples were represented graphically in fig. (4.3), a very high value 0.837 for the liner coefficient was also observed.

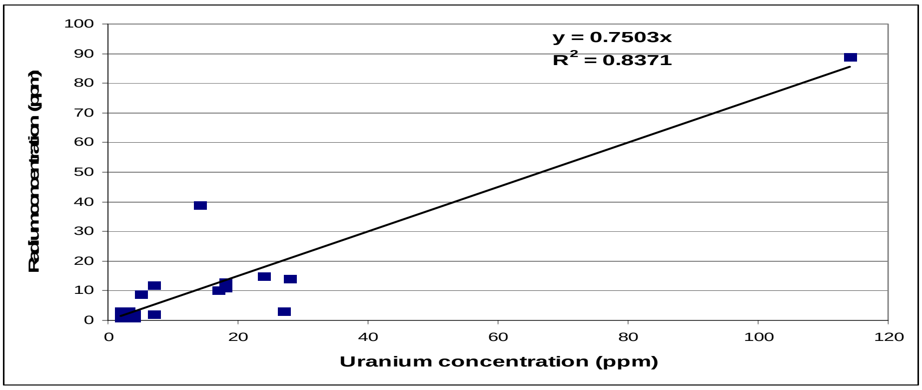


**Fig 4.3**. *Correlation between uranium concentration and equivalent radium for the studied samples*.

That indicates a state of secular equilibrium between uranium and radium in the studied samples

## 4.2. Radiation Hazard Indices Factors for the Selected Station

By using a high efficiency multi-channel analyzer of γ-ray spectrometry NaI(Tl) detector for measuring the concentration of 238U,232Th,226Ra and 40K. for the selected samples. The values of eU, eTh and eRa, in ppm, as well as K, in %, were converted to the activity concentration, in Bq kg-1 using the conversion factors given by table (2)

**Table 2.** *Conversion of radioelement concentration to specific activity* [10]

| Radio-element | Chemical concentration | Specific activity |
|---|---|---|
| 40K | 1% K in rock | 313.0 Bq/Kg |
| 238U and 226Ra | I ppm U in rock | 12.35 Bq/Kg |
| 232Th | I ppm Th in rock | 4.060 Bq/Kg |

Table (3) shows the concentration of natural radionuclide's as measured by the gamma spectrometric techniques.

Table 3. *The measured radioelement concentration.*

| Sample No. | Ra (ppm) | U (ppm) | Th (ppm) | k% |
|---|---|---|---|---|
| 1 | 3 | 2 | 2 | 0.88 |
| 2 | 2 | 3 | 4 | 1.12 |
| 3 | 3 | 3 | 4 | 0.97 |
| 4 | 2 | 1 | 4 | 0.91 |
| 5 | 4 | 1 | 4 | 0.43 |
| 6 | 7 | 12 | 15 | 0.35 |
| 7 | 2 | 1 | 5 | 1.42 |
| 8 | 3 | 3 | 4 | 1.05 |
| 9 | 114 | 89 | 1 | 0.56 |
| 10 | 4 | 2 | 4 | 0.16 |
| 11 | 5 | 9 | 1 | 0.28 |
| 12 | 17 | 10 | 11 | 1.15 |
| 13 | 2 | 1 | 1 | 1 |
| 14 | 2 | 1 | 1 | 0.02 |
| 15 | 18 | 13 | 18 | 0.8 |
| 16 | 28 | 14 | 14 | 1.33 |
| 17 | 24 | 15 | 8 | 1.01 |
| 18 | 7 | 2 | 21 | 1.91 |
| 19 | 18 | 11 | 11 | 1.19 |
| 20 | 14 | 39 | 15 | 1.77 |
| 21 | 27 | 3 | 13 | 3.19 |
| average | 14.57 | 11.19 | 7.66 | 1.02 |

**Table 4.** *The specific activies in Bq/Kg for the collected samples*

| Sample No. | eU(Ra) *12.35 (Bq/kg) | U*12.35 (Bq/kg) | Th*4.06 (Bq/kg) | k*313 (Bq/kg) |
|---|---|---|---|---|
| 1 | 37.05 | 24.7 | 8.12 | 275.44 |
| 2 | 24.7 | 37.05 | 16.24 | 350.56 |
| 3 | 37.05 | 37.05 | 16.24 | 303.61 |
| 4 | 24.7 | 12.35 | 16.24 | 284.83 |
| 5 | 49.4 | 12.35 | 16.24 | 134.59 |
| 6 | 86.45 | 148.2 | 60.9 | 109.55 |
| 7 | 24.7 | 12.35 | 20.3 | 444.46 |
| 8 | 37.05 | 37.05 | 16.24 | 328.65 |
| 9 | 1407.9 | 1099.15 | 4.06 | 175.28 |
| 10 | 49.4 | 24.7 | 16.24 | 50.08 |
| 11 | 61.75 | 111.15 | 4.06 | 87.64 |
| 12 | 209.95 | 123.5 | 44.66 | 359.95 |
| 13 | 24.7 | 12.35 | 4.06 | 313 |
| 14 | 24.7 | 12.35 | 4.06 | 6.26 |
| 15 | 222.3 | 160.55 | 73.08 | 250.4 |
| 16 | 345.8 | 172.9 | 56.84 | 416.29 |
| 17 | 296.4 | 185.25 | 32.48 | 316.13 |
| 18 | 86.45 | 24.7 | 85.26 | 597.83 |
| 19 | 222.3 | 135.85 | 44.66 | 372.47 |
| 20 | 172.9 | 481.65 | 60.9 | 554.01 |
| 21 | 333.45 | 37.05 | 52.78 | 998.47 |
| average | 179.95 | 138.20 | 31.12 | 320.45 |

The data for Raeq (ppm), it ranges from 2 to 114 with an average of 14.57., for U(ppm) it ranges from 1 to 89 with an average of 11.19 ., for Th(ppm) it ranges from 1 to 21 with an average of 7.66 and that for K(%) it range from 0.02 to 3.19 with an average of 1.02.Generally, The obtained data are very greater than the normal value of the crustal abundance of these elements quoted in the literature in range of 2-3 ppm U, 8-12 ppm Th and 2- 2.5 K%.

Table (4) shows the specific activities in Bq/kg for the collected samples The average activity concentration of 226Ra (Bq/kg) ranged from 24.7 to 1407.9 with an average 179.95, which is larger than the world activity concentration (40 Bq/kg) and the world range of (15-50 Bq/kg).

Uranium (eU) (Bq/kg) ranged from 12.35 to 1099.15 with an average 138.20, which is larger than the world average value (50 Bq/kg), UNSCEAR, (1993, 2000) [10, 11].

The activity for 232Th (Bq/kg) ranged from 4.06 to 85.26 with an average 31.12, this value is less than the world average value (40 Bq/kg) and world ranges of (7-50 Bq/kg), UNSCEAR, (1993, 2000) [10,11].

Finally the obtained results for 40K (Bq/kg) ranged from 6.26 to 998.47 with an average 320.45, the measured average values is small compared with the world permissible value for the 40K which is (500 Bq/kg). And the world range (100-700 Bq/kg), UNSCEAR, (1993, 2000) [10, 11].

Table (5) shows the calculated values of Exposure rate (μR/h) , Dose rate(nG/h) , Effective dose rate(mSv/y) , Radium equivalent activity (Raeq) (Bq/kg), External hazard(Bq/Kg), Internal hazard(Bq/Kg) and level index I-gamma(Bq/Kg) respectively as measured by the gamma spectrometric techniques, Using equations ( 2. 3, 5, 6, 7, 8and 9 ) and the data obtained in tables(3) and (4).

**Table 5.** *Hazard indices factor*

| S. No. | $Ra_{eq}$ | Dose rate (nGy/h) | Exposure rate (μR/h) | Effective dose rate (μSv/y) | Internal hazard $H_{in}$ | External hazard $H_{ex}$ | Radioactive index (I-γ) |
|---|---|---|---|---|---|---|---|
| 1 | 69.87 | 27.59 | 3.20 | 0.13 | 0.28 | 0.18 | 0.51 |
| 2 | 74.92 | 41.46 | 4.79 | 0.20 | 0.26 | 0.20 | 0.56 |
| 3 | 83.65 | 39.49 | 4.56 | 0.19 | 0.32 | 0.22 | 0.61 |
| 4 | 69.86 | 22.77 | 2.51 | 0.11 | 0.25 | 0.18 | 0.51 |
| 5 | 82.99 | 16.46 | 1.79 | 0.08 | 0.35 | 0.22 | 0.58 |
| 6 | 181.97 | 108.87 | 12.66 | 0.53 | 0.72 | 0.49 | 1.25 |
| 7 | 87.95 | 32.18 | 3.57 | 0.15 | 0.30 | 0.23 | 0.66 |
| 8 | 85.58 | 40.54 | 4.68 | 0.19 | 0.33 | 0.23 | 0.62 |
| 9 | 1421.4 | 479.88 | 58.95 | 2.35 | 7.64 | 3.84 | 9.50 |
| 10 | 76.48 | 23.53 | 2.69 | 0.11 | 0.34 | 0.20 | 0.52 |
| 11 | 74.30 | 54.16 | 6.58 | 0.26 | 0.36 | 0.20 | 0.51 |
| 12 | 301.53 | 97.95 | 11.41 | 0.48 | 1.38 | 0.81 | 2.08 |
| 13 | 30.51 | 2.70 | 0.28 | 0.01 | 0.14 | 0.08 | 0.20 |
| 14 | 30.99 | 8.27 | 0.97 | 0.04 | 0.15 | 0.08 | 0.20 |
| 15 | 346.09 | 128.20 | 14.85 | 0.62 | 1.53 | 0.93 | 2.37 |
| 16 | 459.14 | 129.66 | 15.16 | 0.63 | 2.17 | 1.24 | 3.15 |
| 17 | 367.19 | 114.54 | 13.61 | 0.56 | 1.79 | 0.99 | 2.51 |
| 18 | 254.40 | 92.51 | 10.20 | 0.45 | 0.92 | 0.68 | 1.82 |
| 19 | 314.84 | 103.78 | 12.13 | 0.50 | 1.45 | 0.85 | 2.17 |
| 20 | 302.65 | 270.88 | 32.43 | 1.32 | 1.28 | 0.81 | 2.13 |
| 21 | 485.81 | 93.01 | 10.49 | 0.45 | 2.21 | 1.31 | 3.41 |
| average | 247.72 | 91.83 | 10.83 | 0.44 | 1.15 | 0.66 | 1.70 |

From the previous table we find that the values of exposure rate (μR/h) ranges from (0.28 μR/h) to (58.95 μR/h) with an average of (10.83 μR/h) and that average is smaller than the world exposure rate. Since the world exposure rate was (50 μR/h) [5].

Table (5) shows that: the dose rate range from (2.70 n Gy/h) to (479.88 n Gy/h) with an average (91.83 n Gy/h), since the world exposure dose rate was (70 n Gy/h) (Beck.1992) [5], we find that the dose rate average dose rate is larger than the world average dose rate.

Table (4.21) shows that: the effective dose rate range from (0.01 mSv/y) to (2.35 mSv/y) with an average of (0.44 μ Sv/y). Since the world effective dose rate was (0.5 mSv/y) [6], we find that the average effective dose rate is smaller than the world effective dose rate.

Table (5) shows that: the average values of Raeq were (247.72 (Bq/kg), which is much less than the recommended maximum value (370 (Bq/kg)) [8].

Table (5) shows that: the internal hazard range from (0.08 (Bq/kg)) to (3.84 (Bq/kg)) with an average of (0.66 (Bq/kg)). Since the world external hazard was (unity (1)) [9], we find that the average internal hazard is smaller than the world internal hazard.

Table (5) shows that: the internal hazard ranges from 0.14 to 7.64 with an average (1.15). Since the world internal hazard was (unity (1)) [9], we find that the average internal hazard is larger than the world internal hazard.

From table (5) we find that the level index I-gamma range from (0.20) to (9.50) with an average (1.70). Since the world level index I-gamma was (unity (1)) [5], we find that the average level index I-gamma is larger than the world level index I-gamma.

## 5. CONCLUSION

A positive correlation has been found between the radon exhalation rate and the uranium concentration as well as radium concentration of the samples. The activity of the radionuclides in Wadi Nasib as determined for the selected samples gives rise to effective dose values that is higher than the world's soil average value, especially for public.

To avoid any possible environmental impacts from area and/or raw materials of high intensity of natural radiation source according to as-low-as-reasonably achievable principle (ALARAP), the following recommendation should be undertaken during any exploration processes or other works in area of relatively high radioactive intensity:

1) The direct contact and handling of the highly radioactive sample and/or ores (if present) as well as their products, should be minimized or eliminated to reduce the time of radiation exposure.
2) Use personal protective masks to minimize inhalation of α-particles.
3) Provide medical surveillance for workers.
4) Provide the use of potable dosimeters and their periodical inspection.
5) Apply shift work when exposed to the hazardous mineralized sediments.

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