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RESEARCH ARTICLE

Natural Radioactivity and the Associated Dose from the Terrestrial Ecosystem of Ismailia Canal, Egypt

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Abstract

Twenty-two soil samples were collected from different locations along Ismailia Canal. Natural radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K have been determined for all samples. The average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were 24, 21 and 323.8 Bq/Kg, respectively. The parameters which are used to assess the radiological hazard from exposure to these soil samples are estimated. The average absorbed dose rate of all measured samples is 37.75 nGy/h, while the average annual effective dose in air outdoors and indoors due to gamma radioactivity are calculated and found to be 46.30 and 185.20 μSv/y, respectively. The average values for radium equivalent activities, the external and internal hazard indices, and radiation level index are evaluated and found to be 78.27 Bq/kg, 0.21, 0.28 and 0.58, respectively.

1. INTRODUCTION

Human exposure to ionizing radiation is one of the scientific subjects that attracts most public attention [1]. Science natural radiation is responsible for most of the total radiation exposure of the human population, knowledge of the dose received from natural radioactivity, is very important in the discussion of its effect on health [2]. Naturally Occurring Radioactive Materials (NORM) are characterized by two groups of radionuclides, namely cosmogenic and primordial. Cosmogenic radionuclides are produced continuously following the bombardment from high-energy cosmic rays on atomic nuclei in the atmosphere (usually oxygen or nitrogen) [3].

In contrast, primordial radionuclides have been present on earth since its creation and are present in the wider environment such as in foods, soil, water, air, building materials and the human body (e.g. ^{40}K in bones) [4]. From a radiological point of view, the most important primordial radionuclides are ^{226}Ra (half-life 1620 years), ^{232}Th (half-life 1.41×10^{10} years) and ^{40}K (half-life 1.28×10^{9} years) [5]. The study of radioactive contents in soil is a major task in understanding the behavior of radioactivity in the ecosystem, because these materials emit radiations by the disintegration of natural radionuclides and contribute to the total absorbed dose via ingestion, inhalation and external irradiation [6]. The importance of Ismailia canal necessitates permanent investigations to follow the continuous change in its radioactive contaminations levels for the sake of safety requirements.

Ismailia Canal extending eastward for about 125 km from the River Nile at Shubra, north of Cairo, to Ismailia city on the Suez Canal (Figure 1).The importance of Ismailia Canal comes from that it stretches between residential areas and the presence of some of the factories on one of its banks. It is used to produce drinking water or to irrigate agricultural land.

The discharge wastes and toxic metals from such factories and living residents are directly led out into the canal. Since the construction of Aswan high dam in 1960, farmers along the River Nile and its canals and branches are forced to use high amounts of fertilizers, which have washed into the River and its canals and branches contaminating it and other water sources [6].

Although, several studies have been performed to evaluate the radionuclides concentrations in the both soil and deposit samples of Ismailia canal but still there is an urgent need to assess the specific activities and examine some of the hazard indices parameters in at least soil samples as an indicator [7]. The reason for that is the expected change in the radionuclides contents due to establishing new fertilizers and industrial factories, oil spill pollution, oil related effluent discharge, gas flare and waste water coming from the residential locations which may enhance the radionuclides concentrations levels of the place and consequently the human exposure [8]. To our knowledge there is no new study has been carried out for the area under study. The present work will be useful to constitute a radioactivity baseline and execute corrective action as well as to improve safety measures in the canal.

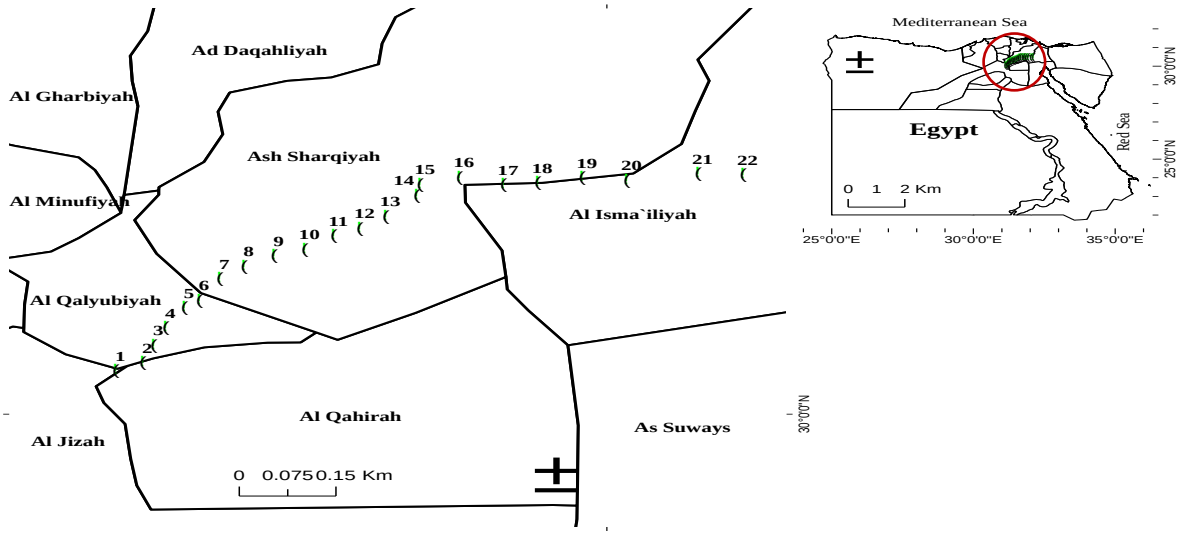

Fig.1 Map of study area.

2. Sample collection and preparation

Twenty-two soil samples were collected from different locations along the canal down to 30 cm depth. Samples' locations together with the corresponding Latitude and longitude coordinates were recorded by GPS location software via mobile phone connected to the internet directly. The obtained results are given in Table 1

Each sample has a weight of about 1 kg. Just after removing the stones and vegetations, the collected samples were dried in open air at room temperature for 3-4 weeks then they were stored. All the soil samples were dried using an oven, at 110 ^{0}C, and then the samples were crushed in powder form (approximately 2 mm mesh size) and homogenized.

The homogenized samples were packed in a 350 ml plastic container to its full volume with uniform mass. The containers have been sealed tightly hermetically and stored for 30 days to achieve the secular equilibrium before starting the measurements.

3. Experimental techniques (detection system set-up)

The energy and intensity of various gamma ray lines have been measured using a CANBERRA HPGe detector of relative efficiency 50% coupled to a 4096 multichannel analyzer. The full width at half maximum (FWHM) was found to be 1.7 keV for ^{60}Co-1332 keV γ-ray line. For accurate energy determination the spectrometer was calibrated using gamma ray lines of different standard sources.

The most intense gamma lines were chosen to calculate the activity concentration, as follows: for ^{232}Th {^{212}Pb (238.6 keV), ^{208}Tl (583.1 keV and 2614 keV), ^{228}Ac (911 keV and 968.9 keV)}, for ^{226}Ra {^{214}Pb (295.2 keV and 351.9 keV), ^{214}Bi (609.3 keV, 1120 keV and 1764.5 keV)} and for ^{40}K (1460 keV). ^{226}Ra was calculated from the energy lines of ^{238}U based on the hypothesis of the achieved secular equilibrium between them.

4. Measurements and Calculations

The spectra of all samples were perfectly analyzed using PC software program Genie 2000 in order to calculate the activity concentrations of the ^{226}Ra, ^{232}Th and ^{40}K. An example of the collected spectra is shown in figure 2.

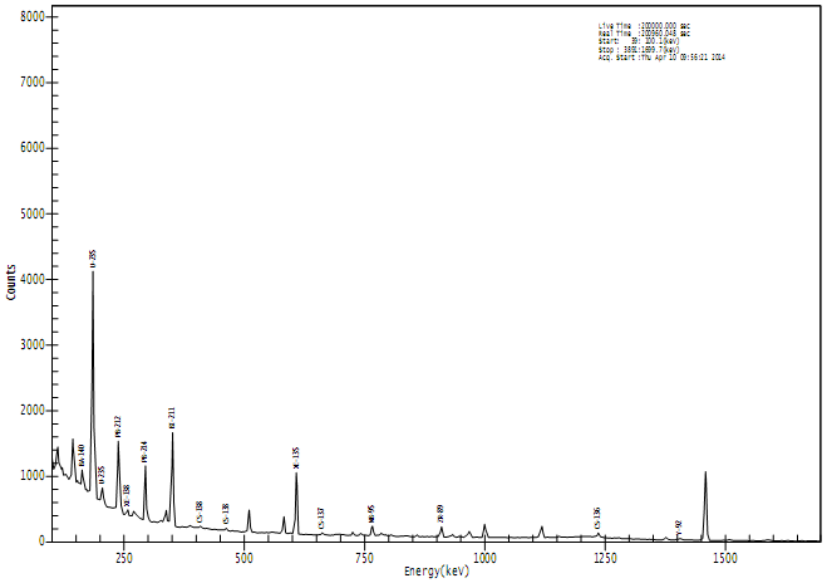

Fig. 2. Typical spectrum for sample 6 as obtained by gamma spectrometer with HPGe.

The activity concentrations of the natural radionuclides in the measured samples were calculated using the following relation [10]:

$$A_s = \frac{C_a}{\epsilon . P_r . M_s} \quad , \quad [Bq/Kg] \qquad (1)$$

Where C_a is the net gamma counting rate [counts/s], ϵ is the detector efficiency of the specific γ-ray, P_r is the absolute probability of gamma decay and M_s is the mass of the sample [kg].

Absorbed Dose Rate

The dose conversion factors F are used to convert the activity concentrations of ^{238}U series, ^{232}Th series and ^{40}K into doses [nGy/h per Bq/kg] as 0.427, 0.662 and 0.043, respectively [11]. The absorbed dose rate D [nGy/h] is calculated for each radionuclide using following relation:

$$D = C \times F \qquad (2)$$

Where C is the activity concentration [Bq/kg].

Effective Dose Rate

The effective dose rate in air outdoors D_{eff} [μSv/y] is calculated as follows:

$$D_{eff} = D \text{ x } h \text{ x } K_1 \text{ x } K_2 \text{ x } 10^{-3} \qquad (3)$$

where D is the absorbed dose rate [nGy/h], h is the number of hours in year (= 8760), K_1=0.7 Sv/Gy is the conversion coefficient from absorbed dose in air to effective dose received by adults, K_2=0.2 is the occupancy factor and in case of calculation of effective dose rate in air indoors it is equal to 0.8 [2, 11, 12].

Radium Equivalent Activity

Radium equivalent activity is a widely used hazard index. It is calculated as follows [13]:

$$Ra_{eq} = A_{Ra} + 1.43\, A_{Th} + 0.077 A_K \qquad (4)$$

Where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in Bq/kg. It is assumed that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th, and 4810 Bq/kg of ^{40}K produced the same gamma-ray dose rate. The maximum value of Ra_{eq} must be <370 Bq.kg^{-1} in order to keep the external dose <1.5 mGy/y [13, 14].

The External Hazard Index (H_{ex})

The external hazard index is obtained from Ra_{eq} expression through the proposition that its allowed maximum value (equal to unity) corresponds to the upper limit of Ra_{eq} (370 Bq/kg). The external hazard index ($\mathbf{H_{ex}}$) considers only the external exposure risk due to γ-rays. The external hazard index ($\mathbf{H_{ex}}$) is given by the following equation [15]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

Where (H_{ex}) is external hazard index. A_{Ra}, A_{Th} and A_K are the activity concentrations, expressed in (Bq/kg) for radium, thorium and potassium respectively.

The Internal Hazard Index (H_{in})

The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and its short-lived progeny and is giving by the following formula [16, 17]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{481} \quad (6)$$

Where (H_{in}) is internal hazard index. The A_{Ra}, A_{Th} and A_K are the activity concentrations, expressed in (Bq/kg) for radium, thorium and potassium respectively.

Radiation level index (I_γ)

This index can be used to estimate the level of γ-radiation hazard associated with the natural radionuclides. The radiation level index may be defined as [18, 19]:

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (7)$$

I_γ May be used to estimate the level of gamma radiation hazard associated with natural radionuclides in the used soil sample.

Table.1: Radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for the selected samples.

Sample ID	Latitude	Longitude	Sample texture	Activity concentration [Bq/Kg]		
				Ra-226	Th-232	K-40
1	30.106066	31.245375	Clay sandy	18 ± 4	10 ± 1	342 ± 10
2	30.124837	31.287459	Clay	25 ± 4	31 ± 3	397 ± 8
3	30.166204	31.304447	Clay	30 ± 5	20 ± 1.5	388 ± 16
4	30.207337	31.322895	Clay	33 ± 4	36 ± 4	473 ± 14
5	30.255599	31.351927	sandy	9 ± 3	9 ± 1	178 ± 4
6	30.272496	31.375127	Clay sandy	35 ± 1	18 ± 3	465 ± 14
7	30.324113	31.406628	Clay	18 ± 1	21 ± 2	344 ± 10
8	30.352713	31.444607	Clay	13 ± 1	14 ± 1	185 ± 6
9	30.377170	31.490783	Clay	53 ± 5	28 ± 3	288 ± 9
10	30.393036	31.538636	Clay sandy	8 ± 1	10 ± 1	137 ± 5
11	30.424857	31.583921	Clay	22 ± 3	11 ± 1.5	187 ± 6
12	30.443079	31.624231	Clay	24 ± 1	24 ± 3	389 ± 12
13	30.470846	31.664007	sandy	16 ± 1	17 ± 1	388 ± 12
14	30.521227	31.712406	Clay	30 ± 1	20 ± 3	321 ± 13
15	30.546514	31.717804	Clay	30 ± 3	25 ± 4	426 ± 12
16	30.563651	31.778334	Clay	21 ± 1	24 ± 3	355 ± 11
17	30.545356	31.846784	Clay	25±2	24 ± 2	369 ± 7
18	30.550638	31.899790	Clay sandy	20 ± 2	26 ± 4	351 ± 7
19	30.562126	31.968828	Clay	18 ± 1	16 ± 3	259 ± 5
20	30.555994	32.038171	Clay	54 ± 4	35 ± 4	386 ± 12
21	30.571008	32.148448	Clay	13 ± 1	16 ± 3	244 ± 5
22	30.568670	32.218379	Clay	12 ±2	17 ± 3	252 ± 8
Mean				24±1.4	21±1.1	323.8±3.41

5. Results and discussion

The activity concentrations of the samples under investigation in Bq/Kg were determined from the photopeaks of the gamma spectra corresponding to ^{238}U, ^{232}Th series and ^{40}K. The obtained results are represented in table 1 along with the soil samples specifications (ID, geographical location and texture).

As shown in Table 1 the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples varies from 8 to 54, 9 to 36 and 137 to 473 Bq/Kg with a mean values of 24, 21 and 323.8 Bq/Kg, respectively. These mean values are lower than the world recommend levels (33, 45 and 420 Bq/Kg for ^{238}U, ^{232}Th and ^{40}K respectively) [2, 21]. It is to be noted that, there are several locations such as (sample ID 9 and 20) have higher values than that of the world recommend levels. These higher values are mainly due to polluted waste water coming from residents and industrial factories. Figures 3 and 4 represent the radioactivity concentrations of the aforementioned radionuclides.

The absorbed dose rate varies from 15.93 to 62.83 nGy/h with a mean value of 37.75 nGy/h. The sample with ID 20 is relatively higher than the recommended world level [20]. The annual effective dose in air outdoors and indoors are varying from 19.53 to 77.05 and 78.13 to 308.20 μSv/y, respectively as shown in table 2.. The mean value of the annual effective dose in air outdoors and indoors is 46.30 μSv/y and 185.21μSv/y. Figures 5 and 6 represent the absorbed dose rate and the annual effective dose in air (outdoors and indoors).

The Radium equivalent activity is ranging from 32.85 to 133.77 Bq/Kg with a mean value of 78.27 Bq/Kg. The external hazard index is varying from 0.09 to 0.36 with a mean value of 0.21 and. The internal hazard index is also varying from 0.11 to 0.51 with a mean value of 0.28 and. The radiation level index is calculated, and it is found to be ranged from 0.25 to 0.97 with a mean value of 0.58. The Radium equivalent activities, the external and internal hazard indices and the radiation level index are all less than the world criteria as shown in table 3 and figures 7, 8 and 9 [2, 13-15,18, 19].

Table.2: Absorbed and effective dose rates in air (outdoors and indoors).

Sample ID	Absorbed Dose Rate [nGy/h]	Effective Dose in air outdoors [μSv/y]	Effective Dose in air indoors [μSv/y]
1	29.0	35.6	142.32
2	48.3	59.2	236.78
3	42.7	52.4	209.64
4	58.3	71.5	285.81
5	17.5	21.4	85.63
6	46.9	57.5	229.86
7	36.4	44.6	178.47
8	22.8	27.9	111.72
9	53.6	65.7	262.70
10	15.9	19.5	78.13
11	24.7	30.3	121.25
12	42.9	52.6	210.27
13	34.8	42.6	170.57
14	39.9	48.9	195.50
15	47.7	58.5	233.89
16	40.1	49.2	196.81
17	42.4	52.0	208.14
18	40.8	50.1	200.37
19	29.4	36.1	144.30
20	62.8	77.0	308.20
21	26.6	32.7	130.66
22	27.2	33.4	133.50
Mean	37.75	46.30	185.21

Table.3: The radiological hazards from exposure to the studied soil samples.

Sample ID	Radium equivalent activity (Ra_{eq}) Bq.Kg^{-1}	External hazard index (H_{ex})	Internal hazard index (H_{in})	Radiation level index (I_γ)
1	58.634	0.158	0.207	0.448
2	99.899	0.270	0.337	0.741
3	88.476	0.239	0.320	0.659
4	120.901	0.327	0.416	0.895
5	35.576	0.096	0.120	0.269
6	96.545	0.261	0.355	0.723
7	74.518	0.201	0.250	0.560
8	47.265	0.128	0.163	0.350
9	115.216	0.311	0.455	0.825
10	32.849	0.089	0.110	0.245
11	52.129	0.141	0.200	0.381
12	88.273	0.238	0.303	0.659
13	70.186	0.190	0.233	0.535
14	83.317	0.225	0.306	0.614
15	98.552	0.266	0.347	0.734
16	82.655	0.223	0.280	0.617
17	87.733	0.237	0.305	0.653
18	84.207	0.227	0.282	0.627
19	60.823	0.164	0.213	0.453
20	133.772	0.361	0.507	0.967
21	54.668	0.148	0.183	0.409
22	55.714	0.151	0.183	0.418
Mean	78.27	0.21	0.28	0.58

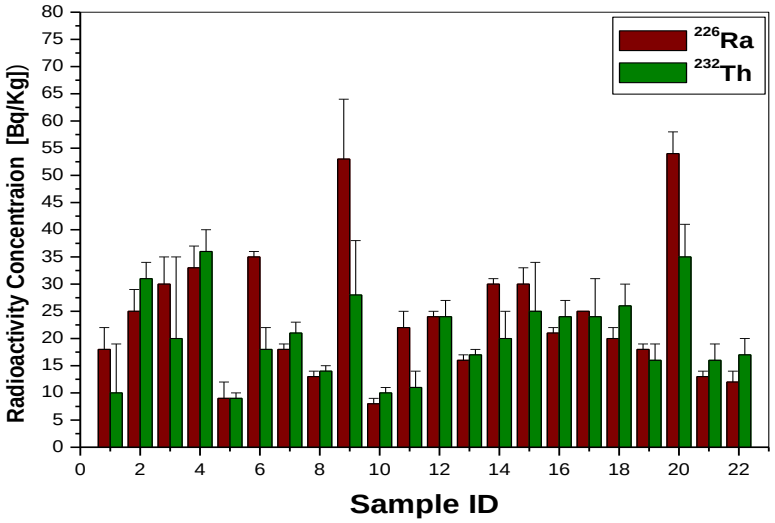

Fig.3: Radioactivity concentration of ^{226}Ra, ^{232}Th for the selected samples.

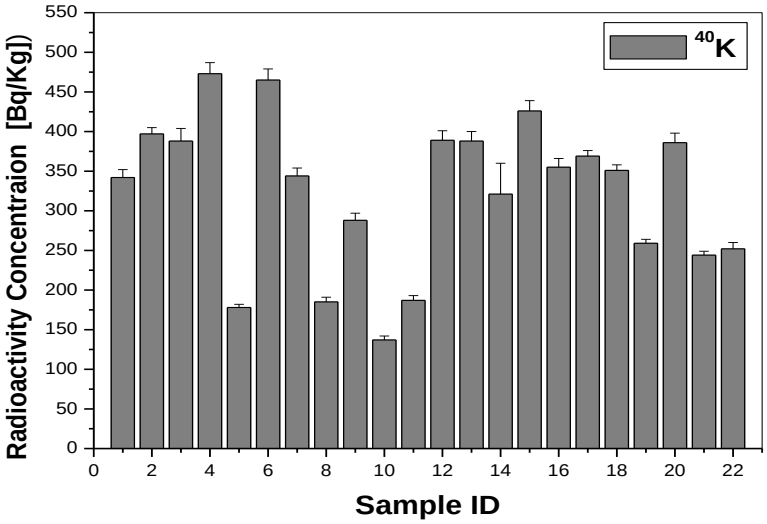

Fig.4: Radioactivity concentration of ^{40}K for the selected samples.

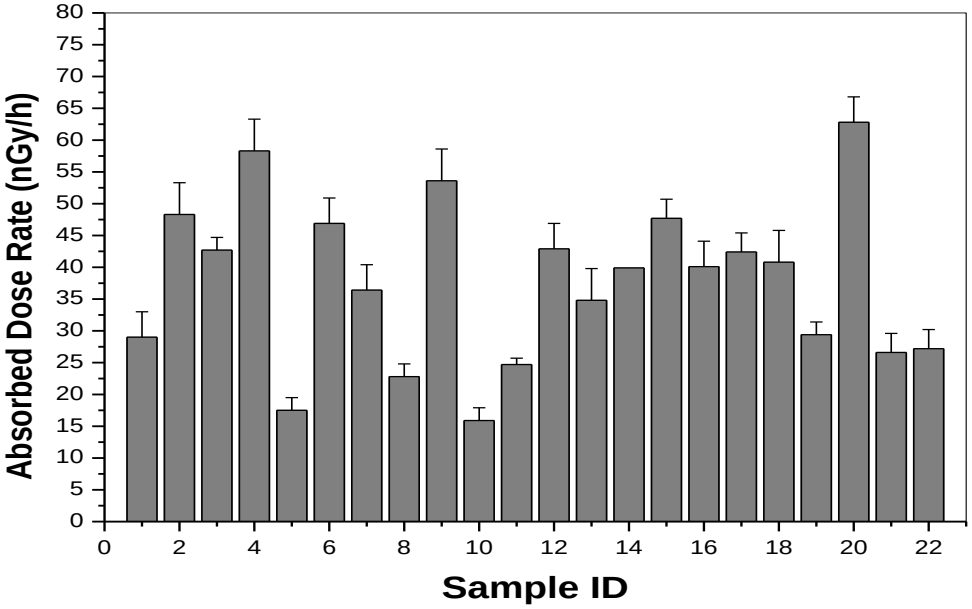

Fig.5: Absorbed dose rates of the selected soil samples.

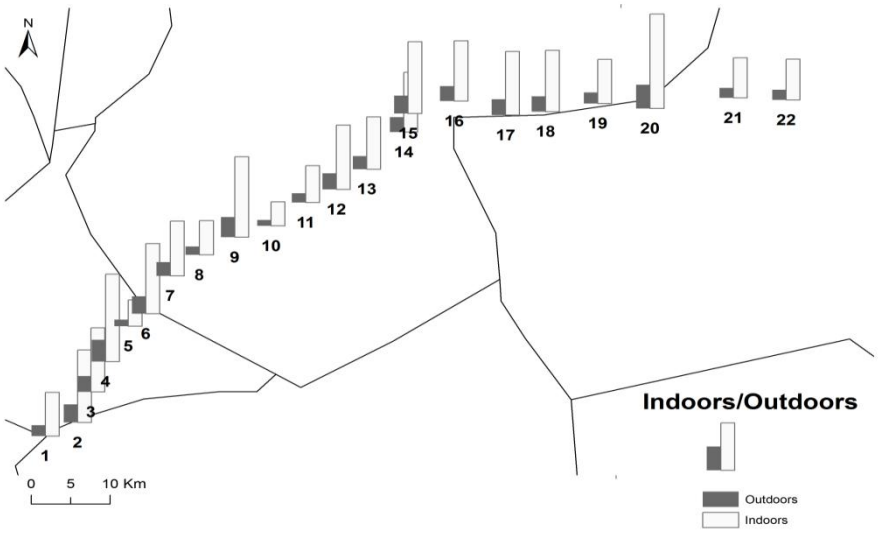

Fig.6: Effective Dose Rates in air (outdoors and indoors) of the selected soil samples.

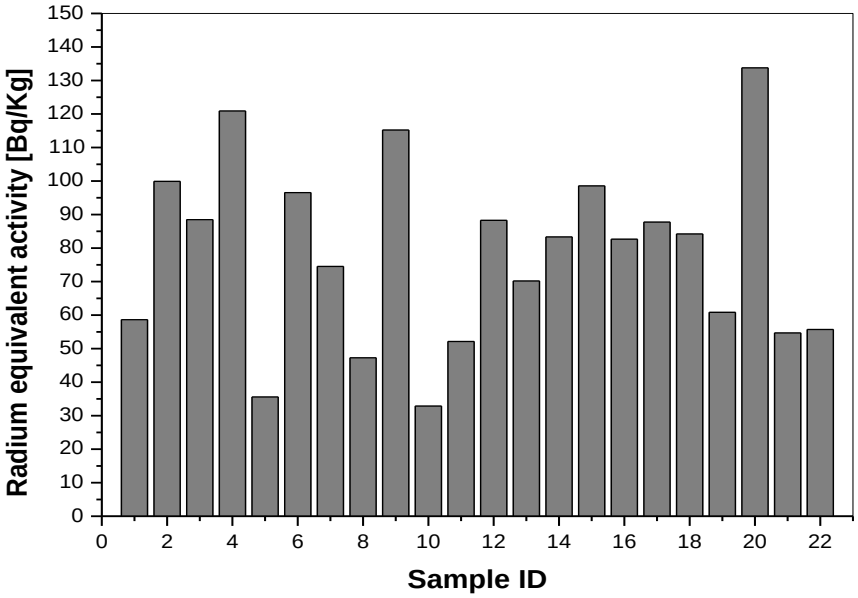

Fig.7: Radium equivalent activity of the selected soil samples.

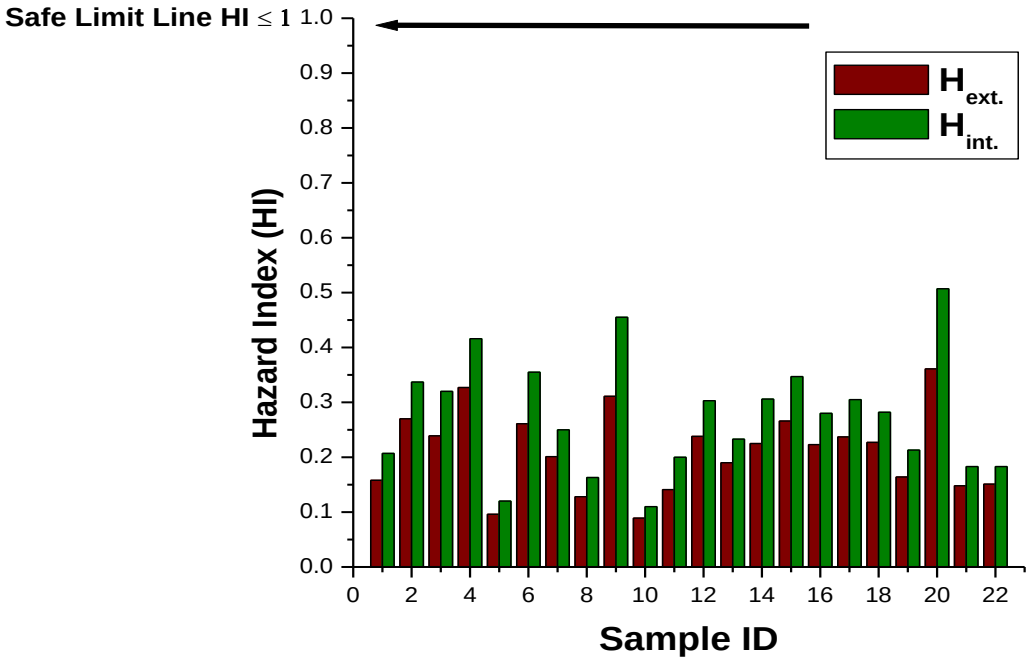

Fig.8: External and Internal Hazard Index of the selected soil samples.

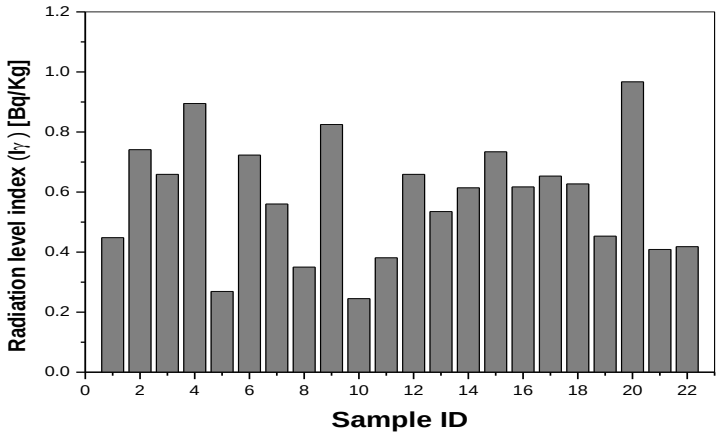

Fig.9: Radiation level index (I_γ) of the selected soil samples.

6. Conclusions

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for twenty-two soil samples have been determined. In samples with ID 4, 6, 9 and 21 as shown in table 1, the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K are relatively high because of the presence of ceramic and fertilizer factories near those sample locations. Although, the average values of the activity concentrations are lower than the world recommended level but still there are some sample locations (samples 9 and 20) have higher values than that of the recommended levels.

The annual effective dose rates in air (outdoors and indoors) are lower than the recommended limits in the investigated area. The Radium equivalent activities, the external and internal hazard indices and the radiation level index are all lower than the recommended limits and the soil samples are very safe to be used as a building material except the two locations (sample ID 9 and 20) which have levels of activity concentrations greater than the worldwide average.

Accordingly, the obtained results concerning those locations of high radioactivity concentrations may be utilized to collaborate in the development of polluted places taking into consideration the possible solutions such as preventing waste water from pouring into canal, implementing new machinery systems to get red of wastes released from industrial or fertilizer factories and using suitable chemicals to remove radionuclides from the water of the canal.

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References

1. Flores OB, Estrada AM, Suarez RR, Zerquera JT, Pe´rez AH(2008) J Environ Radioact. 99:1834.
2. UNSCEAR (2000) "United Nations Scientific Committee on the Effects of Atomic Radiation, Sources, Effects and Risks of Ionizing Radiation", New York, United Nations, 2000.
3. D. Malain, P. H. Regan, D. A. Bradley, M. Matthews, H. A. Al-Sulaiti , T. Santawamaitre, Applied Radiation and Isotopes 70 (2012)1467-1474.
4. Wilson, W.F., 1994. A Guide to Naturally Occurring Radioactive Material (NORM). PennWell Publishing Company, USA.
5. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1993. Sources and Effects of Ionizing Radiation, Report to General Assembly, with Scientific Annexes. New York.
6. P. K. Manigandan and B. Chandar Shekar, 2014, "Evaluation of radionuclides in the terrestrial environment of Western Ghant", Journal of Radiation Research and Applied Science, pp. 310-316.
7. S. Fares et al., 2011, "Natural radioactivity and the resulting radiation doses in some kinds of commercially marble collected from different quarries and factories in Egypt", Natural Science Vol. 3, PP. 895-905.
8. W.E.Y. Abdel Malik et al., 2010, "Radiological Review Studies on Ismailia Canal Ecology", Tenth Radiation Physics & Protection Conference,, Nasr City - Cairo, Egypt.
9. Bridge, J.S, 2002.In: Malden, M. A. (Ed.), Rivers and Floodplains: forms, processes and sedimentary Records, Blackwell, Oxford.
10. Noorddin, I. (1999) ″Natural activities of U, Th and K in building materials″, J. Environ. Radioact., Vol.43(3), pp 255-258.
11. Tzortzis,M, Tsertos,H, Christfides,S, Christodoulides, G. (2003) ″Gamma - ray measurements of naturally occurring radioactive samples from Cyprus characteristic geological rocks″, Rad. Measurements, Vol. 37.
12. UNSCEAR (1988) ″UN Scientific Committee on the Effect of Atomic Radiation″, Report to general assembly. Annex B: Exposures from natural radiation sources.
13. Huy, N.Q., and Luyen, T.V., (2006): "Study on external exposure doses from terrestrial radioactivity in southern Vietnam". Radiat. Prot. dosimetry. V.118, pp.331-336.
14. OECD, Organization for Economic Cooperation and Development, (1979): "Exposure to Radiation from Natural Radioactivity in Building Materials". Report by a Group of Experts of the OECD Nuclear Energy Agency, OECD, Paris.
15. Krieger, R., (1981): "Radioactivity of construction materials", Betonwerk. Fertigteil-Technol. 47, 468.
16. Beretka, J., Mathew, P.J., (1985): "Natural Radioactivity of Australian Building Materials Industrial Waste and By-products". Health Physics 48, 87-95.
17. Cottens, E., (1990): "Actions against radon at the international level". In: Proceedings of the Symposium on SRBII, Journee Radon, Royal Society of Engineers and Industrials of Belgium, 17 January 1990, Brussels.
18. Ruixiang, L., Atomic Energy Science Technology 20(5), 596-601, (1986).
19. Radiation Quantities and Units, ICRU, Report 33, Inter. Commission on Radiation Units and Measurements, Washington (1980).
20. ICRP, (2007): "The 2007 Recommendations of the International Commission on Radiological Protection". ICRP Publication 103. Ann. ICRP 37 (96).
21. UNSCEAR, (2008): "Exposure of the Public and Workers from Various Sources of Radiation", Report to General Assembly, with Scientific Annexes, United Nation, New York.