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Cancer Risk Assessment and Radioactivity Levels in Drinking Water Samples from Sidfa and El-Ghanayim, Assiut, Upper Egypt

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Abstract: *The activity concentrations of ^{226}Ra, ^{228}Ra, ^{232}Th, and ^{40}K were investigated in drinking water resources in Sidfa and El-Ghanayim of Assiut Governorate, Upper Egypt. Concentrations of radionuclides in a total of nine samples were determined via gamma-ray spectrometer using a reverse electrode high purity germanium(REGe) detector with a specially designed shield.The average activity concentrations ^{226}Ra, ^{228}Ra, ^{232}Th, and ^{40}K were 257.32±37.63, 68.47±11.48, 78.07±11.20, and 826.30±91.57 mBq L^{-1}, respectively. The annual effective dose changed from 12.12×10^{-3} to 79.75×10^{-3} mSvyr^{-1} with an average valueof 47.53×10^{-3} mSvyr^{-1}, from 20.91×10^{-3} to 14.12×10^{-2} mSvyr^{-1} with an average value of 83.73×10^{-3} mSvyr^{-1}, and from 22.49×10^{-3} to 11.16×10^{-2} mSvyr^{-1} with an average value of 69.44×10^{-3} mSv$yr^{-1}$the for different age groups infants, children and adults, respectively.The cancer risks due to water consumption during the life time (70 yr) were estimated and they were ranged between 1.33×10^{-5} and 1.66×10^{-4}.*

Key words: *Natural radioactivity, Upper Egypt, Cancer risk, Annual effective dose.*

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I. Introduction

The water has an importance in environmental studies because of its daily use for the humanconsumptionand its ability to transport pollutants. problems of health hazardwill be constituted owing to the natural radionuclides presence in drinking water, when the body ingests these radionuclides[1].Radium isotopes determination in water has been of an interest to public health[2]. The main radium isotopes, ^{226}Ra and ^{228}Ra, are reformed in the natural uranium and thorium radioactive series. The ^{226}Ra is the emitter of alpha and its half-life has comparative length (1602 years), and also, it is the fifth individual from the ^{238}U arrangement. Interestingly, ^{228}Ra is the second individual from the ^{232}Th arrangement and rots by beta emanation with half-life of 5.75 years. Radium enters groundwater by means of disintegration of aquifer solids, by radioactive decay of its parent in the solid. At the point when people ingest radium, about 20% is retained into the circulation system. Ingested radium is at first circulated to delicate tissues and bone, yet its maintenance is basically in developing bone[3].Estimations of radionuclides fill in as a helpful screening strategy that gives basic data about common radiation in water to apply conservative valuation of the corresponding potential public health impact[4].According to nature, the radionuclides concentration levels in ground waters are mainly dependent on uranium and thorium-bearing soil and rock mineral or with the deposits of uranium, thorium and radium. Accordingly, water's occurrence and the natural radioactivity dispensation rely on the local geological characteristic of the origin, soil or rock[5, 6].Potassium is a basic component which is extensively found in crustal rocks[7]. As a result, potassium is existed in various minerals and clays, which it may be dissolved from with the aid of weathering processes. This aids it to be transferred into the liquid phase. ^{40}K decays directly to ^{40}Ca beta emission; in addition, it decays within the electron capture to ^{40}Ar[8]followed by a prompt 1.46 MeV the emission of gamma. As a result of water/rock–soil interactions, ^{40}K is emitted to water bodies, shares in the presence of the drinking water radioactive constituents.

The object of this study is to determine activity concentrations of ^{226}Ra,^{228}Ra,^{232}Th, and ^{40}K in drinking water samples from the study area and to estimate radiation doses and cancer risks based on USEPA approach due to water consumption by people living in this area.

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II. Materials And Methods

2.1 Study area

Sidfa and El-Ghanayim are districts belonging to Assiut governorate in Upper Egypt, located on the west bank of the River Nile. Sidfa is located between Latitudes 26° 52′ 38.8″ and 27° 0′ 11.7″ N and Longitudes 31° 18′ 38.7″ and 31° 28′ 34″ E. It has almost 351,130 inhabitants. El-Ghanayem is located near the city of Abutig in the Assiut Governorate, between Latitudes 26° 51′ 27″ and 26° 59′ 47″ N and Longitudes 31° 16′ 18.4″ and 31° 22′ 48.2″E. it is population isapproximately 105,079 inhabitants. Physically it is bounded to the east by the River Nile and bordered on the western side by the Eocene limestone plateau. This district depends greatly on groundwater for drinking and domestic purposes.

2.2 Sampling and sample preparation

Nine drinking water samples were collected from different locations in Sidfa and El-Ghanayim, and classified into three groups depending on the origin groundwater: deep wells (drinking water stations), hand-dug wells and surface water. Standard Polyethylene Marinelli beakers (1liter) were utilized as measuring containers. Before utilize, the containers were washed with dilute hydrochloric acid (HCl) and flushed with distilled water. A tad bit of nitric acid, around 0.5 ml HNO_3 per liter, was added to clear solutionto prevent any loss of radium isotopes around the container walls, and to avoid growth of microorganisms[9]. After filling up the beaker to the brim, a tight cap is pressed on so as to completely remove the air from it. Storing the samples for a minimum of one month allowed the daughter products to come into radioactive equilibrium with their parents ^{226}Ra and ^{232}Th. Each sample is counted for almost 48 hours relying on the radionuclides concentrations.

2.3 Gamma spectrometry

Water samples were subjected to a gamma ray spectrometer with a reverse electrode germanium detector model GR4020connected to a Canberra digital spectrum analyzer model DAS-1000 as a data acquisition system. The detector had closed-end coaxial G*amma*-raycrystal made of high purity germanium in a vertical configuration cooled with liquid nitrogen. The energyresolution of the detector reads approximately 2.000 keV and ≤0.925 keV at 1.33 MeV and 122 keV, respectively, while the relative efficiencyis 40%. The germanium crystalis located inside a lead shield to reduce the environmental background.The shield consists of 4 layers with the following specifications: a low carbon steel of 9.5 mm thick as an outer jacket, a bulk Shield oflead of 10 cm thickness, andgraded linings to absorb low energy X-rays of 1.0 mm tin and 1.6 mm copper[10].

The spectrometer was energy-calibrated using radioactive standards of known energies such as ^{137}Cs (662keV) and ^{60}Co (1172 and 1332 keV) and it was calibrated for efficiency utilizing Canberra's ISOCS calibration utility. All recorded spectra were analyzed using GENIE 2000 of Canberra[10].

The concentration of ^{226}Ra was measured utilizing gamma-lines of ^{214}Pb (295.22,351.93 keV) and ^{214}Bi (609.31, 1120.29, and 1764.49 keV).The concentration of ^{232}Th was determined utilizing gamma lines of ^{228}Ac (911.2, and 968.97 keV),^{212}Pb (238.63 keV) and ^{208}Tl (583.19, and 2614 keV). Finally, the concentration of ^{40}K was determined by measuring its single peak at 1460.8 keV.

2.4 Dose calculation

In order to calculate potential health hazards, the effective radiation, DR_W, doses arising from the ingestion of these waters were assessedusing following equation [11, 12].

$$DR_W = A_W \times IR_W \times ID_F \qquad (1)$$

WhereA_w is the activity in (Bq L^{-1}), IR_w is the intake of water for a person in a year and $ID_F$is the effective dose equivalent conversion factor in mSv Bq^{-1}. Doses were estimated by considering a consumption rate of 150, 350 and 730 L yr^{-1} for infants, children, and adults, respectively. The conversion factors for adults 2.8×10^{-7}, 2.3×10^{-7}, 6.2×10^{-9}, and 0.69×10^{-6} Sv/Bq were applied for ^{226}Ra,^{232}Th,^{40}K, and ^{228}Ra, respectively. Different sets of conversion factors for children and infants, (8×10^{-7}, 2.9×10^{-7} and 1.3×10^{-8}Sv/Bq) and (9.6×10^{-7}, 4.5×10^{-7} and 4.2×10^{-8}Sv/Bq), were applied for ^{226}Ra, ^{232}Th and ^{40}K respectively as reported by IAEA, ICRP, and WHO[13-15]

2.5 Cancer Risk

The health effects subcommittee suggests that the risks related to all the radium species should be united to know the total risk. The calculated average ratio from the data of occurrence is manipulated to calculate each radium isotope's concentration that would match the required risk level. The cancer risk caused by the intake of radium isotopes was assessed as follows[2, 16].

$$Cancer\ Risk\ (CR) = MCL \times RC \times TWI \qquad (2)$$

where:
CR = Lifetime cancer risk corresponding to MCL (unit less)
MCL= Maximum contaminant level (Bq L^{-1})
RC=Mortality risk coefficient for ^{226}Ra (7.17×10^{-9} Bq^{-1}), and for ^{228}Ra (2.0×10^{-8} Bq^{-1})

TWI= Total water intake (2 L d^{-1}×365.4 d yr^{-1}×70 yr).

III. Results And Discussion

The activity concentrations of ^{226}Ra, ^{228}Ra, ^{232}Th, and ^{40}K in drinking water samples areexhibited in Table1.They activity concentrations ranged from 46.14±6.86 to 453.27±67.50 with an average value of 257.32±37.63 mBq/L, from 13.04±2.36 to 122.99±20.57 with an average value of 68.47±11.48 mBq/L, from 55.14±7.41 to 105.99±13.22 with an average value of 78.07±11.20 mBq/L and from 50.31±5.58 to 1676.38±185.68 with a mean value of 826.30±91.57 mBq/L for ^{226}Ra, ^{228}Ra, ^{232}Th, and ^{40}K, respectively.

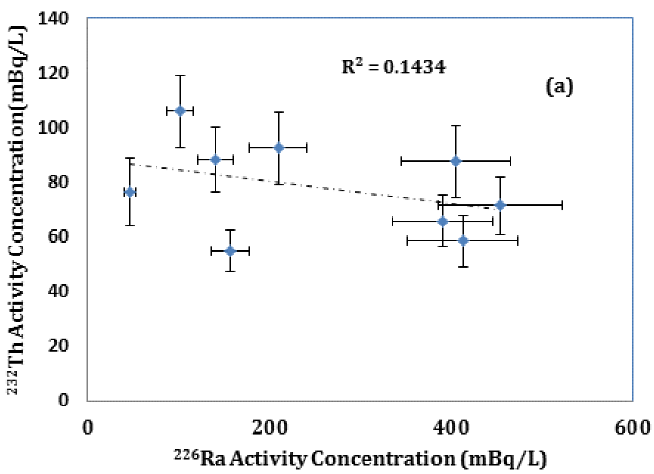
Table 1 Activity concentration (mBq l^{-1}) of natural radionuclides in water sample in study area.

Sample No.	Type of water	Coordinates (dms)		Activity concentration (mBq l^{-1})			
		N	E	^{226}Ra	^{228}Ra	^{232}Th	^{40}K
S1	Deep Well	26° 54' 37.9"	31° 22' 41.6"	156.42±21.53	13.04±2.36	55.14±7.41	760.98±83.96
S2	Deep Well	26° 57' 41.2"	31° 21' 20.1"	101.49±15.21	ND	105.99±13.22	402.50±44.50
S3	Deep Well	26° 55' 25.7"	31° 25' 9.3"	140.98±19.30	54.04±9.42	88.42±11.91	333.32±37.02
S4	Deep Well	26° 58' 19.5"	31° 23' 2.9"	46.14±6.86	122.99±20.57	76.42±12.31	50.31±5.58
S5	Surface water	26° 57' 45"	31° 22' 37.3"	210.07±31.61	93.18±15.90	92.50±13.36	421.37±46.68
G1	Deep Well	26° 56' 0.1"	31° 17' 50.9"	412.84±60.76	31.68±5.18	58.79±9.42	984.54±109.42
G2	Hand-dug Well	26° 53' 27.3"	31° 18' 35.6"	404.46±60.04	97.04±15.76	87.74±13.28	1277.24±141.47
G3	Deep Well	26° 53' 35.1"	31° 19' 48.1"	390.18±55.84	ND	66.02±9.47	1676.38±185.68
G4	Surface water	26° 53' 43.1"	31° 19' 47.2"	453.27±67.50	67.33±11.21	71.64±10.42	1530.03±169.80
Average				257.32±37.63	68.47±11.48	78.07±11.20	826.30±91.57

ND =Not Detected

The average value of ^{226}Ra is higher than the average value of ^{232}Th, this is because radium is more soluble in groundwater than thorium. The abundance of ^{40}K activity observed in all samples may be due to agricultural activities in the study area, which involve the use of potassium fertilizers, ^{40}K is a highly soluble element so that it can be easily transported to ground water[17].

The correlation between activity concentrations of ^{226}Ra, ^{228}Ra, ^{232}Th and ^{40}K are shown in Fig., 1(a, b, c, and d). A small negative correlation can be observed between(^{226}Ra and ^{232}Th) and (^{232}Th and ^{40}K) with correlation coefficient of R^2 = 0.143 and 0.187 respectively (Fig. 1-a, and d), while Fig. 1-b shows a perfect positive correlation between ^{226}Ra and ^{40}K with correlation coefficient of R^2 =0.826 and no obvious correlation can be observed between ^{226}Ra and ^{228}Rawith correlation coefficient of R^2 =0.0366 (Fig. 1-c).



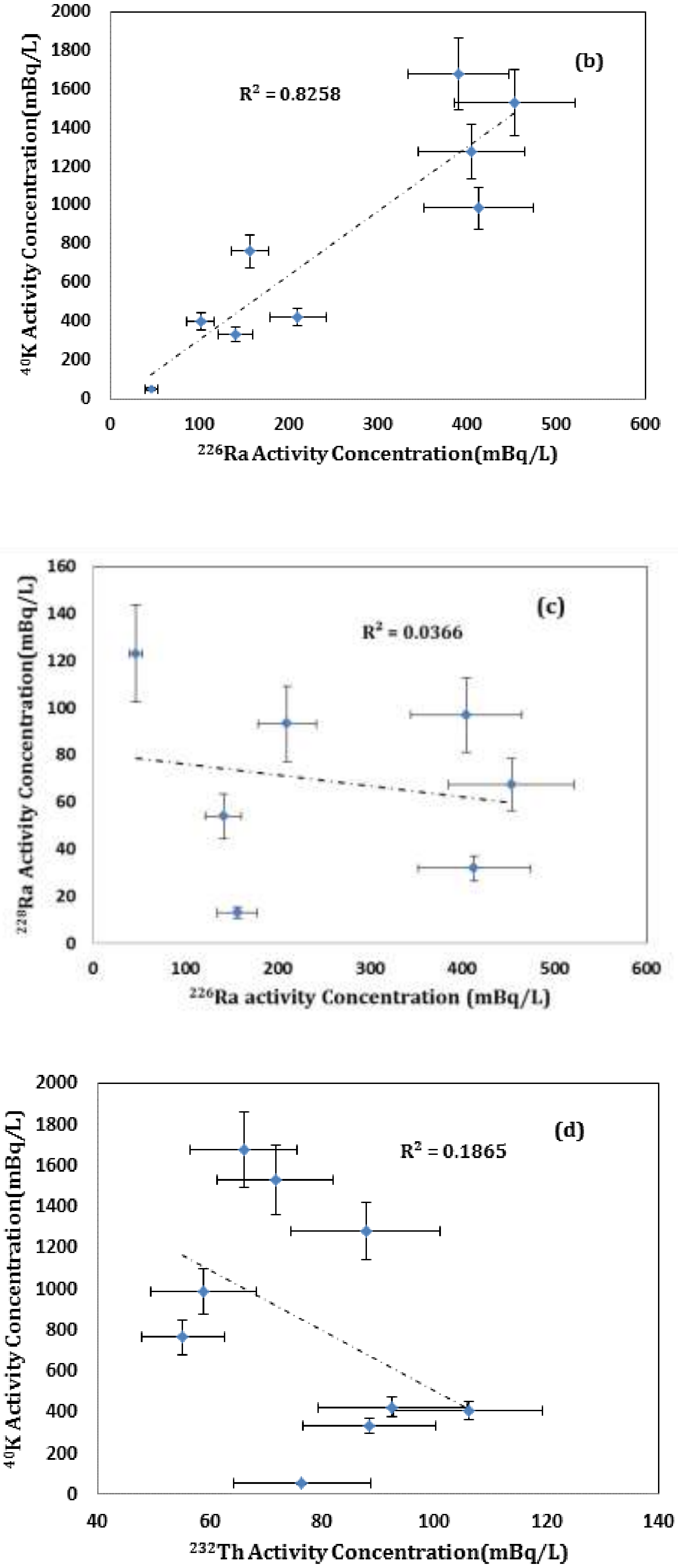


Fig. 1 The correlations between activity concentrations of radionuclides in (mBq/L) for drinking water samples.

3.1 Radiation dose estimation

Table 2 shows the effective dose calculated for different age groups infants, children, and adults, considering the ingestion of^{226}Ra, ^{232}Th and ^{40}K in drinking water. The calculated effective doses were changed from 1.212×10^{-2}to 7.975×10^{-2} mSvyr^{-1} with an average value of4.753×10^{-2} mSvyr^{-1}, from 2.091×10^{-2}to 1.412×10^{-1} mSvyr^{-1}with an average value of 8.373×10^{-2} mSvyr^{-1} and from 2.249×10^{-2} to 1.116×10^{-1} mSvyr^{-1} with an average value of 6.944×10^{-2}mSvyr^{-1} for infants, children, and adults respectively. From Table 2, it can be inferred that, the doses received by children are higher than those received by infants and adults.

Table 2 Estimates of annual effective doses*mSvyr^{-1}* due to ingestion of ^{226}Ra, ^{232}Th, and ^{40}K for different age groups.

Sample No.	^{226}Ra×10^{-3}(mSv yr^{-1})			^{232}Th ×10^{-3} (mSv yr^{-1})			^{40}K ×10^{-3} (mSv yr^{-1})			Total doses×10^{-3} (mSv yr^{-1})		
	Infants	Children	Adults	Infants	Children	Adults	Infants	Children	Adults	Infants	Children	Adults
S1	22.525	43.798	31.972	3.7219	5.5967	9.258	4.7942	3.46245	3.444	31.041	52.857	44.675
S2	14.615	28.417	20.745	7.1546	10.758	17.796	2.5358	1.83138	1.822	24.305	41.007	40.363
S3	20.301	39.475	28.817	5.968	8.9742	14.845	2.0999	1.51661	1.509	28.369	49.966	45.170
S4	6.6444	12.92	9.431	5.1586	7.7571	12.832	0.317	0.22892	0.228	12.12	20.906	22.491
S5	30.25	58.819	42.938	6.2438	9.3888	15.531	2.6546	1.91722	1.907	39.148	70.125	60.376
G1	59.449	115.6	84.384	3.9686	5.9675	9.871	6.2026	4.47966	4.456	69.62	126.04	98.712
G2	58.243	113.25	82.672	5.9222	8.9052	14.731	8.0466	5.81145	5.781	72.211	127.97	103.184
G3	56.186	109.25	79.752	4.4562	6.7008	11.084	10.561	7.62753	7.587	71.203	123.58	98.424
G4	65.27	126.91	92.648	4.8358	7.2716	12.029	9.6392	6.96164	6.925	79.745	141.15	111.6011
Average										47.53	83.73	69.44

As indicated by the recommended reference level of 0.26, 0.2 and 0.1 mSvyr−1 for effective dose for infants, children andadults distributed by WHO, IAEA and UNSCEAR[1, 13, 15]the measurements got in our investigation are considerably less than the recommended reference level. Average annual effective dosesdue to all radionuclides are 47.53×10^{-3}, 83.73×10^{-3} and 69.44×10^{-3} mSvyr^{-1} for infants, children, and adults respectively in this area, which are %18, %42, and %69.44 of the values of 0.26, 0.2, and 0.1 mSvyr^{-1}, respectively for the recommended reference level of committed effective dose.

3.2 Risk based on the radium isotopes.

The annual effective doses for adults in light of ^{226}Ra and ^{228}Ra concentrations and the cancer risk are displayed in Table 3. The annual effective doses due to water consumption are changed from 9.43×10^{-3} to 9.265×10^{-2}mSvyr^{-1}with an average value of 5.26×10^{-2} mSvyr^{-1} and from 6.57×10^{-3} to 6.195×10^{-2} mSvyr^{-1} with an average value of 3.448×10^{-2} mSvyr^{-1}for ^{226}Ra and ^{228}Ra respectively, which is less than the recommended reference values of 0.1 mSvyr^{-1}. On the other side, the combined doses of ^{226}Ra and ^{228}Ra are changed from 2.074×10^{-2} to 1.316×10^{-1} mSvyr^{-1} with an average of 7.942×10^{-2} mSvyr^{-1}. Three samples G1, G2 and G4 are higher than the reference dose level as shown in Table 3.

Cancer risks associated with ingestion of radium isotopes (^{226}Ra and ^{228}Ra) are presented in Table 3. The USEPA established a range of 1×10^{-4} to 1×10^{-6} as an acceptable cancer incidence risk in the Notice of data availability for radionuclides in drinking water that was published on April 21, 2000. However, the USEPA elaborates that under appropriate circumstances, risks of greater than 1×10^{-4} may be acceptable[2].

The cancer risks result of drinking water consumption during the life time (70yr) estimated of radium isotopes ranged from 1.69×10^{-5} to 1.66×10^{-4} with an average value of 9.44×10^{-5} for ^{226}Ra, from 1.33×10^{-5} to 1.26×10^{-4} with an average value of 7.01×10^{-5} for ^{228}Ra and from 3.72×10^{-5} to 2.48×10^{-4} with an average value of 1.49 ×10^{-4}.The values of the samples in Table 3 are ranged in the USEPA established, which are an acceptable cancer incidence risk.

Table 3 The annual effective doses and cancer risk associated due to consumption of water.

Sample No.	Annual Effective Committed dose(mSvyr^{-1})			The Cancer Risk		
	^{226}Ra ×10^{-3}	^{228}Ra ×10^{-3}	Combined (^{226}Ra+^{228}Ra) ×10^{-3}	^{228}Ra ×10^{-5}	^{226}Ra ×10^{-5}	Combined (^{226}Ra+^{228}Ra)×10^{-5}
S1	31.97	6.57	38.54	1.33	5.74	7.07
S2	20.74	ND	20.74	ND	3.72	3.72
S3	28.82	27.22	56.04	5.53	5.17	10.7
S4	9.43	61.95	71.38	12.6	1.69	14.3
S5	42.94	46.93	89.87	9.53	7.71	17.2
G1	84.38	15.96	100.34	3.24	15.1	18.4
G2	82.67	48.88	131.55	9.93	14.8	24.8
G3	79.75	ND	79.75	ND	14.3	14.3
G4	92.65	33.91	126.56	6.89	16.6	23.5
Average	52.6	34.48	79.42	7.01	9.44	14.9

3.3 COMPARISON WITH SIMILAR STUDIES IN OTHER REGIONS

Table 4 compresses the estimations of annual effective measurement for ^{226}Ra and^{228}Ra concentrations in other Egyptian cities and those from the present work. The estimations of annual effective doses and the cancer risk from the present work are higher than the estimations of annual effective doses andthe cancer risk from Cairo, El Mansoura, Qualuab, Octobar, Alex, Tanta, Baniswif, Sinai and Siwa for ^{226}Ra. On the other side, the values of annual effective doses and the cancer risk from the present work are less than the values of annual effective doses and the cancer risk from Qualuab, Alex and Sinai for ^{228}Ra as shown in Table 4 as reported by[2].

Table 4 The average committed effective doses and associatedcancer risk due to consumption of water in the present investigation in comparison with other cities in Egypt[2].

Cities	Annual Effective Committed dose (mSvyr^{-1})		The Radiological Risk	
	^{226}Ra×10^{-3}	^{228}Ra×10^{-3}	^{226}Ra×10^{-7}	^{228}Ra×10^{-5}
Assiut (Sidfa&ElGhanayim)	52.6	34.48	944	7.01
Cairo	0.34	ND	6.09	ND
El Mansoura	0.24	ND	4.29	ND
Qualuab (Treatment factory)	0.35	36.50	6.20	7.42
Octobar	0.19	ND	3.38	ND
Alex	0.37	58.80	6.57	11.95
Tanta	0.11	ND	1.94	ND
Baniswif	0.10	20.93	1.83	4.25
Sinai	4.50	36.77	80.70	7.47
Siwa	0.37	ND	3.57	ND

IV. Conclusions

The natural radioactivity levels of ^{226}Ra, ^{228}Ra, ^{232}Th, and ^{40} K have been measured in drinking water samples from Sidfa and El-Ghanayim areas using gamma ray spectroscopy. The activity concentrations of the measured radionuclides have plainly indicated low activity concentrations across the study area. The total effective doses obtained in our studied because of all radionuclides from one year utilization of drinking water are less than the recommended reference level and subsequently the hazard evaluation information demonstrate that the radionuclides under this examination don't represent any huge wellbeing danger to people in general. Along these lines the researched waters are worthy forever long human utilization.

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