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RESEARCH ARTICLE

RADIOLOGICAL RISK ESTIMATION OF DRINKING AND IRRIGATION WATER FOR SOME EGYPTIAN SITES

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Abstract

The objective of this work was to determine the radiological health risk due to natural radionuclides (e.g., ^{226}Ra, ^{228}Ra and ^{40}K) in drinking and irrigation water resources in different locations in Egypt. The water resources in Egypt are diverse and include the river Nile, ground water, springs and lakes in addition to rain waters. The total annual effective dose in all estimated water resources were ranged from 0.02, 0.03 and 0.03 mSvy-1 to 13.49, 26.13 and 13.13 mSvy-1 for infants, children and adults respectively. The average life-long cancer risk and the average hereditary effects due to ingestion of radionuclides by adults show that 12 out of 10,000 may suffer some form of cancer fatality and 43 out of 1000,000 may suffer some hereditary effects. It is concluded that the radiological health risk data obtained were within their safe values.

Introduction: -

Natural radioactivity has always been present and broadly distributed in the earth's crust and the atmosphere (Kolo et al., 2017) and it exists in various geological formations like air, rocks, plants, sand, water and soils. It is found also in our building materials constituting main sources of radiation exposure for human beings (Usikalu et al., 2017) Soil radionuclide activity concentration is one of the main determinants of the natural background radiation (Dizman et al., 2016).

Radium is considered as a highly toxic element in water and attention for human health requires more investigations for radium concentrations in water and its associated hazards. Two natural radium isotopes are a cause of worry in public water supplies; ^{226}Ra, which ismade as aresult ofthe decay of ^{238}U, and ^{228}Ra, which is explicitly created through ^{232}Th decay. Radium propelsinto groundwater through aquifer solid disintegration, through direct recoil over the liquid–solidlimit through its arrangement by its parent radioactive decay in the solid, and moreover through desorption. The movements of radium in water are a component of the geochemical properties of solids in the aquifer. The behavior of radium in the body is similar to that of calcium and a ratable fraction deposited in the bone, which in turn can cause bone and head-sinus cancer (Ajayi and Owolabi 2008).

^{40}K is discharged into water bodies, adding to the nearness of radioactive segments in drinking water. ^{40}K isthe primary radioactive isotope of potassium. It decays explicitly into ^{40}Ca in the ground state through β-emanation (89%) and also to ^{40}Ar in a 1.46 MeV excited state pursued by a prompt 1.46 MeV gamma emission through lectron capture (11%) due to water-shake/soil associations (Chowdhury et al., 2017).

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Natural radionuclide present in water beyond the safe levels can be considered to have potential risks to human. Increased concern for the radiological status of drinking water has led to an increased demand for data on water quality. The recommended reference dose level (RDL) of committed effective dose is 100 µSv from one-year consumption of drinking water (WHO, 2008). Gamma rays can enter the skin and interact with tissues or organs. Uranium and radium found in water do not emit strong gamma radiation, so showering with that water will not pose any significant risk. However, if this radionuclide is inhaled or ingested through eating and drinking, the emissions rays can come into direct contact with sensitive tissues or organs in the body (Irina et al., 2011). Findings of many studies have shown that long term exposure to uranium in drinking water may cause toxic effects to the kidney and can lead to cancer (Irina et al., 2011).

The potential harmfulness of radionuclides is based on their long half-lives and chemical behavior (^{232}Th: 1.4 × 10^{10}yr, ^{238}U: 4.47 × 10^{9}yr and ^{40}K: 1.28 ×10^{9}yr). ^{232}Th is mainly radiotoxic, ^{238}U is both radiotoxic as well as chemically toxic whereas ^{40}K is radiotoxic as well as nutritionally important element (Tykva and Sabol 1995). Owing to the health risks associated with the exposure to indoor radiation, many governmental and international bodies such as the international commission on Radiological Protection (ICRP), the World Health Organization (WHO), etc. have adopted strong measures aimed at minimizing such exposures (ICRP, 2006).

There are a lot of papers discussed the natural radionuclide concentration in water resources in Egypt such as (El-Sayed 2015, Arafat 2017, Yehiaa 2017 and Atef 2019) but no attention was paid to estimation of annual effective dose and Cancer and Hereditary Risk. So, this work estimates annual effect dose, Cancer and Hereditary Risks due to ^{238}U, ^{232}Th series and ^{40}K present in water resources samples collected from different locations in Egypt.The obtained data and information from this study are highly needed to provide a basis for the sustainable development strategies in Egypt.

Materials andMethods: -

Study Area

The study area is extended along the northern part of Egypt from Sinai governorate in the Eastto Marsa Matrouh governorate in the West. Water samples were collected from selected cities and towns in the area under investigation (Tap water samples, ground water samples and surface water samples). The coordinates of all sampling points were identified by the Global Positioning System device (GPS) as shown in figure (1). The collected samples were analyzed using HPGe detector to determine Ra-226, Ra-228 and K-40. The data obtained were used to calculate the annual dose for different organs from consumption of water for four age groups (5 years, 10 years, 15 years and adults) using Acute Dose calculator program and the results were previously published (Atef et al., 2019).

In the present work, the specific activities of ^{226}Ra, ^{228}Ra and ^{40}K were used to estimate Cancer and Hereditary Risk for the studied area. Also, to obtain a complete overview about the Cancer and Hereditary Risk for different water resources in Egypt, the published results of ^{226}Ra, ^{228}Ra and ^{40}K of El-Alamein-Alam El-Rum Area (harvested rain water) (El-Sayed et al., 2015). Marsa Allam area (ground water) (Arafat et al., 2017) and Northern area of the western desert (ground water) (Yehiaa et al., 2017) were used to estimate the total annual effective dose and Cancer and Hereditary to these regions.

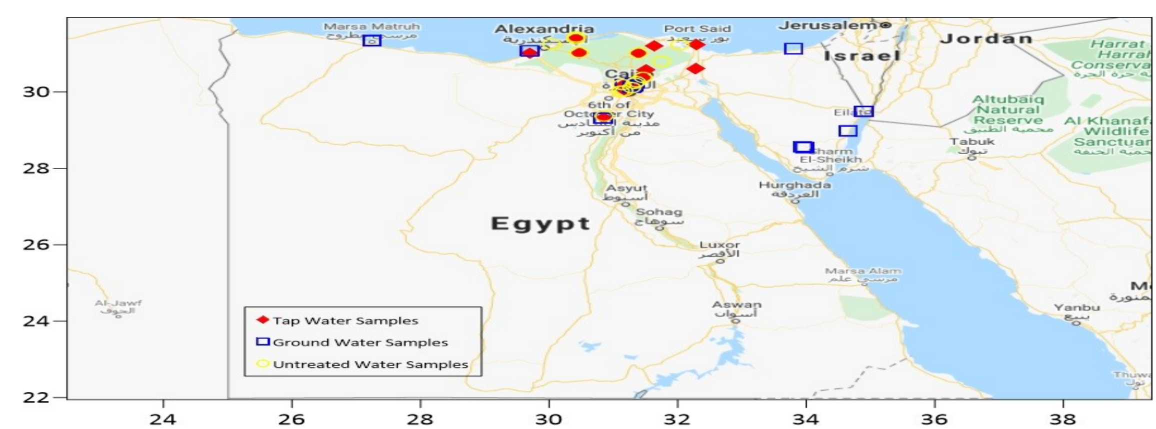

Fig.1: -Samples locations.

Annual Effective Dose

The annual effective dose (AED) due to ingestion of water was computed using the following formula (UNSCEAR 2008).

$$AED(mSvy^{-1}) = \sum_{i=1}^{3} DC\,F_{ing}(i) \times A_i \times L \quad (1)$$

Where; $DCF_{ing}(i)$ is the dose coefficient of a particular radionuclide in Sv. Bq^{-1} for a particular age category. A_i is the specific activity concentration of radionuclide in the water sample measured in Bq. l^{-1} and L is the radionuclide intake in liters per year for each age group categories.

Cancer and Hereditary Risk

In addition to the estimated annual effective dose, the risk incurred by a population is estimated by assuming a linear dose-effect relationship with no threshold as per ICRP practice. For low doses ICRP fatal cancer risk factor is $5.5 \times 10^{-2} Sv^{-1}$ (IAEA 2004). The risk factor states the probability of a person dying of cancer increases by 5% for a total dose of 1 Sv received during his lifetime. Therefore, the probability of death from cancer due to 'natural incidence' increases from about 25% to 30% following a total lifetime exposure of 1 Sievert.

For hereditary effects, the detriment-adjusted nominal risk coefficient for the whole population as stated in (ICRP, 2007) for stochastic effects after exposure to low dose rates was estimated at 0.2 × 10-2. The risk to population was then estimated using risk coefficient presented in ICRP report (ICRP, 2007) and assumed 70 year's lifetimes of continuous exposure of the population to low level radiation. According to ICRP methodology, the Cancer Risk and Hereditary Efect were calculated using the following equations:

Cancer Risk = Total annual Effective Dose (Sv) × Cancer risk factor (2)

Hereditary Effect = Total annual Effective Dose (Sv) × Hereditary effect factor (3)

By applying equation 2 and 3 the radiation risk due to ingestion of ^{226}Ra, ^{232}Th and ^{40}K in drinking water andusing dose coefficient for ingestion of radionuclides for members of the public to 70 years of age (ICRP, 2012).

Results and Discussion: -

Radioactivity measurements

The specific activity concentrations of the measured samples are under the detection limit of the used analytical procedures (0.7 Bq L^{-1} for ^{226}Ra and 0.6 Bq L^{-1} for ^{228}Ra) while,^{40}K isthe only detected radionuclide.The specific activity concentrations results of ^{40}K of water resources ranged from < DL to 5.30 Bq $L^{-1}$with a mean 1.06 Bq L^{-1} for tap water, ranged from< DL to 5.16Bq $L^{-1}$with a mean of 1.01Bq L^{-1} for ground water and ranged from < DL to 32.09 Bq L^{-1} with amean of 3.16 Bq L^{-1} for surface water (Atef et al., 2019).The specific activity concentrations of harvested rain water collected from El-Alamein-Alam El-Rum Area ranges from <DL to 4.16, from <DL to 3.45 and from <DL to 26.18 Bq/l for ^{226}Ra, ^{232}Th and ^{40}K, respectively [10]. The specific activity concentrations of ground water samples collected from marsa allam area ranges from < DL to 10.66, from < DL to 2.33 and from 6.89 to 54.31Bq/l for ^{226}Ra, ^{232}Th and ^{40}K, respectively (Arafat et al., 2017).

These results are comparable with the results of 15 different water samples (wells and springs) collected from Elba protective area, south-eastern desert of Egypt (^{226}Ra, ^{232}Th and ^{40}K ranged from 1.6 to 11.1 Bq/L, from 0.21 to 0.97 Bq/L, and from 9.1 to 23 Bq/L respectively) (El Arabi et al., 2006) and higher than the activity concentrations levels for water (surface and groundwater) samples collected from the west bank of the Nile River in Assiut Governorate, Egypt (^{226}Ra, ^{232}Th and ^{40}K ranged from 0.0192 to 0.492Bq/L, from 0.015 to 0.351Bq/L, and from 0.05to 2.25Bq/L for ^{226}Ra, ^{232}Th, and ^{40}K, respectively) (El-Gamal et al., 2019).

Radiation Dose Estimation and the estimated Cancer Risks and the Hereditary Effects

The annual effective dose for different age groups calculated for 30 water samples collected from different locations from Egypt presented in table 1 considering the ingestion of ^{226}Ra, ^{232}Th and ^{40}K in drinking water. While the estimated Cancer Risks and the Hereditary Effects of adult member of the public are presented in table [2].

Table 1: -The annual effective dose in ($mSv.y^{-1}$) for different age categories.

	S. no	Annual effective dose of Ra-226			Annual effective dose of Ra-228			Annual effective dose of k-40			Total annual effective dose		
El-Alamein-Alam El-Rum Area													
		infant	children	adult	infant	children	adult	infant	children	adults	infant	children	adult
Harvested rain water	1	0.10	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.10
	2	0.00	0.00	0.00	0.02	0.03	0.03	0.01	0.02	0.03	0.03	0.05	0.07
	3	0.18	0.34	0.17	0.07	0.10	0.11	0.01	0.02	0.03	0.25	0.46	0.31
	4	0.41	0.80	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.80	0.40
	5	0.05	0.10	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.06	0.11	0.06
	6	0.02	0.04	0.02	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.06	0.05
	7	0.60	1.16	0.58	0.23	0.35	0.40	0.01	0.02	0.03	0.84	1.54	1.01
	8	0.10	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.10
	9	0.00	0.00	0.00	0.07	0.10	0.11	0.01	0.02	0.03	0.07	0.12	0.14
	10	0.02	0.04	0.02	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.07	0.05
	11	0.02	0.04	0.02	0.02	0.03	0.04	0.01	0.02	0.03	0.05	0.09	0.09
	12	0.10	0.20	0.10	0.09	0.13	0.15	0.01	0.02	0.03	0.20	0.35	0.28
	13	0.30	0.59	0.30	0.04	0.07	0.07	0.01	0.02	0.03	0.36	0.68	0.40
	14	0.14	0.27	0.13	0.00	0.00	0.00	0.02	0.05	0.07	0.16	0.31	0.20
Marasa Allam area													
		Annual effective dose of Ra-226			Annual effective dose of Ra-228			Annual effective dose of K-40			Total annual effective dose		
		infant	children	adult	infant	children	adult	infant	children	adult	infant	children	adult
Ground water	6	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.01	0.03	0.04
	7	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.02	0.04	0.06
	8	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.07	0.02	0.05	0.07
	10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.01	0.02	0.03
	11	1.09	2.13	1.06	0.00	0.00	0.00	0.02	0.05	0.07	1.12	2.18	1.14
	12	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.07	0.02	0.05	0.07
	13	0.36	0.70	0.35	0.00	0.00	0.00	0.02	0.06	0.08	0.38	0.76	0.43
	14	1.02	1.99	0.99	0.00	0.00	0.00	0.01	0.02	0.03	1.03	2.01	1.03
Northern area of the western desert													
		Annual effective dose of Ra-226			Annual effective dose of Ra-228			Annual effective dose of K-40			Total annual effective dose		
		infant	children	adult	infant	children	adult	infant	children	adult	infant	children	adult
Ground water	11B	6.31	12.26	6.13	0.11	0.16	0.19	0.01	0.01	0.02	6.42	12.44	6.33
	12B	7.58	14.74	7.37	0.18	0.26	0.30	0.01	0.01	0.02	7.76	15.02	7.69
	13B	5.54	10.77	5.39	0.19	0.28	0.32	0.01	0.01	0.02	5.73	11.07	5.73
	14B	8.68	16.88	8.44	0.10	0.15	0.17	0.00	0.01	0.01	8.79	17.04	8.63
	15B	9.98	19.41	9.70	0.13	0.19	0.22	0.01	0.01	0.02	10.11	19.61	9.94
	16B	9.04	17.58	8.79	0.22	0.32	0.37	0.01	0.02	0.03	9.26	17.92	9.18
	17B	6.43	12.51	6.25	0.15	0.23	0.26	0.01	0.03	0.05	6.60	12.77	6.56
	18Q	7.40	14.40	7.20	0.07	0.11	0.13	0.00	0.01	0.02	7.48	14.52	7.34
	19Q	4.87	9.48	4.74	0.15	0.22	0.25	0.01	0.03	0.04	5.03	9.72	5.02
	20Q	10.12	19.67	9.84	0.16	0.25	0.28	0.01	0.02	0.02	10.29	19.94	10.14
	21Q	6.81	13.24	6.62	0.31	0.46	0.52	0.02	0.04	0.05	7.13	13.74	7.19
	22Q	6.90	13.41	6.70	0.21	0.32	0.36	0.01	0.02	0.03	7.12	13.75	7.10
	23M	5.85	11.38	5.69	0.21	0.31	0.35	0.01	0.01	0.02	6.06	11.70	6.06
	24M	6.04	11.73	5.87	0.12	0.18	0.20	0.00	0.01	0.01	6.16	11.92	6.08
	25M	6.07	11.79	5.90	0.20	0.30	0.33	0.01	0.02	0.02	6.27	12.11	6.25
	26M	3.82	7.43	3.71	0.17	0.26	0.29	0.00	0.01	0.01	3.99	7.69	4.02
	27M	6.82	13.27	6.63	0.13	0.19	0.22	0.01	0.02	0.03	6.96	13.48	6.88
	28R	7.79	15.14	7.57	0.39	0.58	0.66	0.01	0.03	0.04	8.19	15.75	8.27
	29R	6.67	12.97	6.49	0.18	0.27	0.30	0.01	0.01	0.02	6.85	13.25	6.81

	30R	2.58	5.02	2.51	0.21	0.32	0.36	0.00	0.01	0.01	2.80	5.34	2.88
	31R	10.44	20.30	10.5	0.25	0.37	0.42	0.01	0.02	0.03	10.70	20.69	10.60
	32R	13.24	25.75	12.7	0.25	0.37	0.42	0.00	0.01	0.02	13.49	26.13	13.31
	33F	5.41	10.52	5.26	0.15	0.22	0.25	0.01	0.02	0.02	5.56	10.75	5.53
	34 L	9.34	18.15	9.08	0.29	0.44	0.49	0.01	0.01	0.02	9.63	18.60	9.59
	35G	7.42	14.43	7.21	0.18	0.27	0.30	0.01	0.03	0.04	7.61	14.72	7.56
	36G	5.73	11.15	5.57	0.24	0.37	0.41	0.01	0.01	0.02	5.98	11.52	6.00
	37G	10.61	20.63	10.2	0.30	0.46	0.52	0.01	0.02	0.03	10.92	21.11	10.86

NB: All zero values in the table are a result of ^{226}Ra, ^{228}Ra, and ^{40}K values which are less than the minimum detection Activity by the used technique. The locations of the studied samples for the three areas are presented in previous work (El-Sayed 2015, Arafat 2017 and Yehiaa 2017)

In our pervious study (Atef et al., 2019) all water resources under investigation, the lower age is the higher the annual effective dose. For tap water, the highest annual dose delivered to 5 y age group (6.16 µSvy^{-1}) with a mean of 1.32 µSv y^{-1} and the lowest annual dose delivered to adults with a maximum of 1.79 µSvy-1 and a mean of 0.33 µSvy-1. For ground water, the highest annual dose (6.12 µSvy^{-1}) delivered to 5 y age group with a mean of 1.35 µSv y^{-1}, and the lowest annual dose delivered to adults with a maximum of 1.71 µSvy-1 and a mean of 0.34 µSvy^{-1} (Atef et al., 2019).

The annual effective dose of the harvested rain water (Table 1) for infants ranged from 0.02, 0.1and 0.01mSvy^{-1}to 0.6, 0.23, and 0.02 mSvy^{-1}for ^{226}Ra, ^{228}Ra, and ^{40}K respectively. The annual effective dose of the harvested rain water for children ranged from 0.04, 0.01, and 0.02mSvy^{-1} to 1.16, 0.35 and 0.05 mSvy^{-1} for ^{226}Ra, ^{228}Ra, and ^{40}K respectively. The annual effective dose of the harvested rain water for adults ranged from 0.03, 0.05, and 0.05 m Svy^{-1} to 0.84, 1.54 and 1.01 mSvy^{-1} for ^{226}Ra, ^{228}Ra, and ^{40}K respectively. The total annual effective dose ranged from 0.03, 0.05 and 0.05 mSvy^{-1}to 0.84, 1.54, and 1.01 mSvy^{-1}for infants, children and adults respectively. The children have the maximum total dose values because the children have the maximum annual effective dose values for ^{226}Ra. The adults have the maximum annual effective dose values for ^{228} Ra and ^{40}K.

Table 1 indicates that the annual effective dose of the ground water (Marsa Allam area) for infants ranged from 0.36 and 0.01mSvy^{-1} to 1.09 and 0.02 mSvy^{-1}for ^{226}Ra and ^{40}K respectively. The annual effective dose of the ground water (Marsa Allam area) for children ranged from 0.7 and 0.02 mSvy^{-1} to 2.13 and 0.06 mSvy^{-1}for ^{226}Ra and ^{40}K respectively. The annual effective dose of the ground water (Marsa Allam area) for adults ranged from 0.35 and 0.03 mSvy^{-1} to 1.06 and 0.08 mSvy^{-1}for ^{226}Ra and ^{40}K respectively. The total annual effective dose ranged from 0.01, 0.02 and 0.03 mSvy^{-1} to 1.12, 2.18, and 1.14 mSvy^{-1} for infants, children and adults respectively.

Table 1 indicates that the annual effective dose of the ground water (Northern area of the western desert) for infants ranged from 2.85, 0.07 and 0.01mSvy^{-1}to13.24, 0.39 and 0.02mSvy^{-1} for ^{226}Ra, ^{228}Ra, and ^{40}K respectively. The annual effective dose of the ground water (Northern area of the western desert) for children ranged from 5.02, 0.11, and 0.01mSvy^{-1} to 20.63, 0.58, and 0.04 mSvy^{-1} for ^{226}Ra, ^{228}Ra, and ^{40}K respectively. The annual effective dose of the ground water (Northern area of the western desert) for adults ranged from 2.51, 0.13 and 0.01 mSvy^{-1}to 12.87, 0.66 and 0.05 mSvy^{-1} for ^{226}Ra, ^{228}Ra, and ^{40}K respectively. The total annual effective dose ranged from 2.80, 5.34 and 2.88 mSvy^{-1} to 13.49, 26.13 and 13.31mSvy^{-1} for infants, children and adults respectively. The children have the maximum total dose values because the children have the maximum annual effective dose values for ^{226}Ra.The adults have the maximum annual effective dose values for ^{228}Ra and ^{40}K.

The total annual effective doses of our samples (Atef et al., 2019) are lower than the recommended reference level of 0.26, 0.2 and 0.1 mSvy^{-1} for annual effective doses for infants, children and adults, respectively which published by (WHO, 2004, IAEA 1996 and UNSCEAR 2000), from one-year consumption of drinking water. While the total annual effective doses (Table 1) are more than theses recommended reference levels.

Table 2: -Estimated Cancer Risks and Hereditary Effects of adult member of the public.

The studied area					
	S. no	**Fatality Cancer Risk per year**	**Estimated lifetime Cancer Risk**	**Severe Hereditary Effects per year**	**Estimated Lifetime Hereditary Effects**

Tape water	1	4.53E-09	3.17E-07	1.65E-10	1.15E-08
	2	3.17E-09	2.22E-07	1.15E-10	8.06E-09
	5	2.06E-09	1.44E-07	7.48E-11	5.24E-09
	6	1.91E-09	1.33E-07	6.93E-11	4.85E-09
	7	3.53E-08	2.47E-06	1.28E-09	8.98E-08
	8	2.97E-09	2.08E-07	1.08E-10	7.56E-09
	10	5.68E-09	3.98E-07	2.07E-10	1.45E-08
	14	1.92E-09	1.34E-07	6.97E-11	4.88E-09
Ground water	16	9.76E-08	6.83E-06	3.55E-09	2.48E-07
	18	3.56E-09	2.49E-07	1.30E-10	9.07E-09
	19	3.70E-09	2.59E-07	1.35E-10	9.43E-09
	22	4.20E-09	2.94E-07	1.53E-10	1.07E-08
	23	1.50E-09	1.05E-07	5.45E-11	3.82E-09
	24	2.71E-09	1.90E-07	9.85E-11	6.90E-09
	25	5.47E-09	3.83E-07	1.99E-10	1.39E-08
	26	5.58E-09	3.91E-07	2.03E-10	1.42E-08
	27	5.62E-09	3.94E-07	2.05E-10	1.43E-08
Surface water	32	2.23E-09	1.56E-07	8.11E-11	5.67E-09
	36	2.25E-09	1.57E-07	8.17E-11	5.72E-09
	38	1.82E-09	1.27E-07	6.62E-11	4.63E-09
El-Alamein-Alam El-Rum Area					
		Fatality Cancer Risk per year	**Estimated Lifetime Cancer Risk**	**Severe Hereditary Effects per year**	**Estimated Lifetime Hereditary Effects**
Harvested rain water	1	5.56E-09	3.89E-07	2.02E-10	1.41E-08
	3	9.41E-09	6.58E-07	3.42E-10	2.39E-08
	4	2.20E-08	1.54E-06	8.00E-10	5.60E-08
	5	2.85E-09	1.99E-07	1.04E-10	7.25E-09
	6	1.16E-09	8.09E-08	4.20E-11	2.94E-09
	7	3.20E-08	2.24E-06	1.16E-09	8.15E-08
	8	5.39E-09	3.77E-07	1.96E-10	1.37E-08
	10	1.23E-09	8.62E-08	4.48E-11	3.14E-09
	11	1.08E-09	7.55E-08	3.92E-11	2.74E-09
	12	5.39E-09	3.77E-07	1.96E-10	1.37E-08
	13	1.62E-08	1.14E-06	5.90E-10	4.13E-08
	14	7.32E-09	5.12E-07	2.66E-10	1.86E-08
Marasa Allam area					
		Fatality cancer risk per year	**Estimated Lifetime Cancer Risk**	**Severe hereditary Effects per year**	**Estimated Lifetime hereditary Effects**
Ground water	6	2.45E-09	1.72E-07	8.92E-11	6.24E-09
	7	3.23E-09	2.26E-07	1.17E-10	8.22E-09
	8	4.00E-09	2.80E-07	1.45E-10	1.02E-08
	10	1.77E-09	1.24E-07	6.42E-11	4.49E-09
	11	6.27E-08	4.39E-06	2.28E-09	1.60E-07
	12	3.64E-09	2.55E-07	1.32E-10	9.27E-09
	13	2.38E-08	1.66E-06	8.64E-10	6.05E-08
	14	5.67E-08	3.97E-06	2.06E-09	1.44E-07
Northern area of the western desert					
		Fatality Cancer Risk per year	**Estimated Lifetime Cancer Risk**	**Severe Hereditary Effects per year**	**Estimated lifetime Hereditary Effects**

Ground water	11B	3.48E-07	2.44E-05	1.27E-08	8.86E-07
	12B	4.23E-07	2.96E-05	1.54E-08	1.08E-06
	13B	3.15E-07	2.21E-05	1.15E-08	8.02E-07
	14B	4.75E-07	3.32E-05	1.73E-08	1.21E-06
	15B	5.47E-07	3.83E-05	1.99E-08	1.39E-06
	16B	5.05E-07	3.53E-05	1.84E-08	1.29E-06
	17B	3.61E-07	2.53E-05	1.31E-08	9.18E-07
	18Q	4.04E-07	2.83E-05	1.47E-08	1.03E-06
	19Q	2.76E-07	1.93E-05	1.00E-08	7.03E-07
	20Q	5.56E-07	3.89E-05	2.02E-08	1.41E-06
	21Q	3.95E-07	2.77E-05	1.44E-08	1.01E-06
	22Q	3.91E-07	2.73E-05	1.42E-08	9.94E-07
	23M	3.33E-07	2.33E-05	1.21E-08	8.48E-07
	24M	3.34E-07	2.34E-05	1.22E-08	8.51E-07
	25M	3.44E-07	2.41E-05	1.25E-08	8.75E-07
	26M	2.21E-07	1.55E-05	8.04E-09	5.63E-07
	27M	3.78E-07	2.65E-05	1.38E-08	9.63E-07
	28R	4.55E-07	3.18E-05	1.65E-08	1.16E-06
	29R	3.75E-07	2.62E-05	1.36E-08	9.53E-07
	30R	1.58E-07	1.11E-05	5.76E-09	4.03E-07
	31R	5.83E-07	4.08E-05	2.12E-08	1.48E-06
	32R	7.32E-07	5.12E-05	2.66E-08	1.86E-06
	33F	3.04E-07	2.13E-05	1.11E-08	7.74E-07
	34 L	5.27E-07	3.69E-05	1.92E-08	1.34E-06
	35 G	4.16E-07	2.91E-05	1.51E-08	1.06E-06
	36 G	3.30E-07	2.31E-05	1.20E-08	8.40E-07
	37 G	6.00E-07	4.20E-05	2.18E-08	1.53E-06

NB**:** The locations of the studied samples for the four areas are presented in previous work (El-Sayed 2015, Arafat 2017, Yehiaa 2017 and Atef 2019)

The fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects of tape water (studied area) ranged from 1.91×10^{-9}, 1.33×10^{-7}, 6.93×10^{-11} and 4.85×10^{-9} to 3.53×10^{-8}, 2.47×10^{-6}, 2.07×10^{-10} and 8.98×10^{-8} respectively. The fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects of ground water (studied area) ranged from 1.5×10^{-9}, 1.05×10^{-7}, 5.45×10^{-11} and 3.82×10^{-9} to 9.76×10^{-8}, 6.83×10^{-6}, 3.55×10^{-9} and 2.84×10^{-7} respectively. The fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects of surface water (studied area) ranged from 1.82×10^{-9}, 1.27×10^{-7}, 6.62×10^{-11} and 4.63×10^{-9} to 2.25×10^{-9}, 1.57×10^{-7}, 8.17×10^{-11} and 5.72×10^{-9} respectively.

The fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects of the harvested rain water (El-Alamein-Alam El-Rum Area) ranged from 1.08×10^{-9}, 7.55×10^{-8}, 3.92×10^{-11} and 2.74×10^{-9} to 3.2×10^{-8}, 2.24×10^{-6}, 8.00×10^{-10} and 8.15×10^{-8} respectively. The fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects of ground water (Marsa Allam area) ranged from 1.77×10^{-9}, 1.24×10^{-7}, 6.42×10^{-11} and 4.49×10^{-9} to 6.27×10^{-8}, 4.39×10^{-6}, 2.28×10^{-9} and 1.6×10^{-7}respectively. The fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects of ground water (Northern area of the western desert) ranged from 1.58×10^{-7}, 1.11×10^{-5}, 5.76×10^{-9} and 9.94×10^{-7} to 7.32×10^{-7}, 5.12×10^{-5}, 2.66×10^{-8} and 1.86×10^{-6} respectively.

By comparing all the results in table 2 we can conclude that; the ground water (Northern area of the western desert) Northern area of the western desert has the maximum values for the fatality cancer risk per year, estimated lifetime cancer risk, severe hereditary effects per year and estimated lifetime hereditary Effects.

Conclusion: -

The present work provides information dealing with associated hazards of Ra-226 (U-238) series, Th-232 series and K-40 radionuclides in water resources. Such information should be known before executing the economic projects related to the development process in Egypt. This work depends on laboratory measurements and mathematical calculations. Surface water and tape water have total annual effective dose levels lower than the recommended reference level determined by ICRP while ground water and harvested rain water have values more than these recommended reference levels. In all the studied water resources, the estimated fatal cancer risk to adult per year ranged from 1.08×10^{-9} to 7.32×10^{-7} with the associated lifetime fatality cancer risk ranged from 7.55×10^{-8} to 5.12×10^{-5}. And the estimated hereditary effect to adult per year ranged from 3.92×10^{-11} to 2.66×10^{-8} with its associated lifetime hereditary effect ranged from 2.74×10^{-9} to 1.86×10^{-6}.

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