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# NATURAL RADIOACTIVITY AND ASSESSMENT OF THE INTERNAL DOSE OF WATER RESOURCES FOR SELECTED SITES IN EGYPT

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## Abstract

***Purpose***: The current study aims to assess the activity concentrations of $^{226}$Ra ($^{238}$U series), $^{232}$Th series and $^{40}$K in different water resources in Egypt to determine its applicability for drinking process from the radiological view point.

***Methodology:*** Forty five water samples (15 tap water samples, 15 ground water samples and 15 surface water samples) from selected sites in the area under investigation (along the Northern part of Egypt from Sinai governorate in the East to Marsa Matrouh governorate in the West) were analyzed using HPGe detector. 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 AcuteDose calculator program.

***Findings*** $^{40}$K is the only detected while $^{226}$Ra and $^{232}$Th in all samples under investigation are below the detection limit (0.7 and 0.6 Bq kg$^{-1}$ respectively) of the used HPGe detector. The mean concentration from tap water is 1.06 BqL$^{-1}$ and values ranged from < 3 to 5.30 Bq L$^{-1}$. Ground water showed a mean of 1.01Bq L$^{-1}$ and values ranged from < 3 to 5.16 Bq L$^{-1}$ and in surface water, the mean was 3.16 Bq L$^{-1}$ and values ranged from < 3 to 32.09 Bq L$^{-1}$. For all water resources, the lower the age is the higher the dose delivered from $^{40}$K in water. For tap water, the highest annual dose delivered to 5 y age group (6.16 µSv y$^{-1}$) with a mean of 1.32 µSv y$^{-1}$ and the lowest annual dose was delivered to adults with a maximum of 1.79 µSv y$^{-1}$ and a mean of 0.33 µSv y$^{-1}$. For ground water, the highest annual dose (6.12 µSv y$^{-1}$) delivered to 5 y age group with a mean of 1.35 µSv y$^{-1}$, and the lowest annual dose was delivered to adults with a maximum of 1.71 µSvy$^{-1}$ and a mean of 0.34 µSv y$^{-1}$. All results of this work are below the maximum permissible limit for public exposure determined by ICRP.

***Unique contribution to theory, practice and policy***: Government and stakeholders should make funds available for more research to study the applicability of these water resources for drinking process from other points view such as chemical and biological toxicity.

**Keywords:** *Natural radioactivity, Water resources, AcuteDose calculator program, Annual dose*

## 1.0 INTRODUCTION

The radionuclides present in nature can be classified into two groups naturally occurring radionuclides and artificially occurring radionuclides (Choppin and Rydberg, 1980 and UNSCEAR, 1993). The naturally occurring radionuclides can be divided into three groups: Those formed from cosmic radiation, those with life time comparable to the age of the earth, and those that are members of the natural decay series. The artificially sources of radionuclides in nature are produced as a result of advent, development and subsequent expansion of nuclear science and proliferation of nuclear technology.

Non-ionizing radiation involves exposure to electromagnetic radiation of energy below that capable of producing ionization, type of this is Ultra Violet Radiation, is that part of the electromagnetic spectrum lying between X-rays and visible Violet light (Wakedford, 2004). Ionizing radiation the name indicates that the radiation has sufficient energy to ionize atoms and molecules. When ionizing radiation passes though cellular tissue, it produces charged water molecules (free radicals) and reactive organic molecules (UNSCEAR, 1993). These reactive species generated by radiation can cause DNA damage and play important role in mutagenesis, carcinogenesis and aging.

Biological effects of radiation are typically classified into two categories the first category consists of exposure to high doses of radiation over short periods of time producing acute or short term effects (Deterministic) while the second category represents exposure to low doses of radiation over an extended period of time producing chronic or long term effects (Stochastic). The high doses tend to kill cells, while low doses tend to damage or change them (Zakariya and Kahn, 2014). The effects on the human body as a result of damage to individual cells are divided into two classes, Somatic and Hereditary. Somatic effects arise from damage to the body's cells and only occur in the irradiated person. Hereditary (or genetic) effects result from damage to an individual’s reproductive cells making the damage possible to pass to later generations (Madison, 2005).

Water resources in Egypt are limited to the Nile River, rainfall and ground water in the deserts and Sinai. Each resource has its usage limitation, whether these limitations are related to quantity, quality, space, time, or exploitation cost. Egypt receives about 98% of its fresh water resources from outside its national borders (Abu-Zeid, 1992).

Surface water resources originating from the Nile River are currently fully exploited also ground water resources are being brought into full production. Egypt is facing increasing water needs as a result of; rapidly growing population, increased urbanization, higher standards of living and increased the agriculture area to feed the growing population (Abdin and Gaafar, 2009). Rapid growth of demand is planned to be partly supplied with additional water resources that can be obtained from ground water aquifers in the Sinai and the Eastern and Western deserts (Naidoo and Olaniran, 2014).

Water is a medium for the transport and interaction of radionuclides with and within different parts of the troposphere: soils, sediments, crustal rocks, biota, and air are continuously exchanging their radioactive contents with water. The presence of natural and artificial radionuclides at different levels in waters is correlated with above mentioned different parts. In fact, surface waters are coupled to subsurface aquifers, to soils, and to the atmosphere, allowing incorporation of several radionuclides following different routes (Mas et al., 2006). The occurrence of radionuclides in drinking water causes human internal exposure, caused by the decay of radionuclides taken into the body through ingestion and inhalation (Karahan et al., 2000). So the water content of radioactivity must be within the permissible limit determined by the international organizations.

The current study aims to evaluate the activity concentrations of gamma ray emitter radionuclides,$^{226}$Ra ($^{238}$U series), $^{232}$Th series and $^{40}$K indifferent water resources along the Northern part of Egypt from Sinai governorate in the East to Marsa Matrouh governorate in the West. Then the annual dose corresponding to ingestion of the radionuclide present in water was estimated by AcuteDose calculator program for various age groups to assess its values are within the permissible limit determined by ICRP.

## 2.0 METHODOLOGY

### 2.1 Sampling locations

The study area is extended along the northern part of Egypt from Sinai governorate in the East to Marsa Matrouh governorate in the West. 45 samples were collected from selected cities and towns in the area under investigation and they were divided into three categories according to water resources (15 Tap water samples, 15 ground water samples and 15 surface water samples). The coordinates of all sampling points were identified by the Global Positioning System device (GPS) as shown in Table 1.

### 2.2 Preparation of water samples

Six liters were collected in clean polyethylene containers. Samples were filtered into clean bottles, and acidified with concentrated nitric acid to prevent the adsorption of radionuclides ions on the walls of the container and prevent the growth of microorganisms (Farouk, 1996). Samples were evaporated at 90°C using a hot plate until its volume reached 100 mL. Then the sample was packed at plastic container, sealed and stored for a minimum period of 4 weeks to allow secular equilibrium between $^{226}$Ra, $^{222}$Rn and its daughter products.

**Table 1: The coordinates of sampling points by GPS.**

| | No | Sample Location | | No | Sample Location |
|---|---|---|---|---|---|
| Tape water | 1 | 31°01'15.8"N,30°28'09.1"E | Ground water | 24 | 30°13'57.7"N,31°19'48.9"E |
| | 2 | 31°12'37.6"N,31°38'05.5"E | | 25 | 30°11'59.8"N,31°19'20.5"E |
| | 3 | 31°24'11.1"N,30°25'01.6"E | | 26 | 30°11'32.5"N,31°09'44.0"E |
| | 4 | 31°04'30.5"N,29°41'56.8"E | | 27 | 28°32'22.3"N,33°58'29.9"E |
| | 5 | 30°07'15.5"N,31°17'15.5"E | | 28 | 28°33'41.2"N,33°56'48.5"E |
| | 6 | 31°00'53.4"N,31°23'19.4"E | | 29 | 28°58'54"N,34°39'10.5"E |
| | 7 | 29°19'06.2"N,30°51'02.4"E | | 30 | 29°29'33.6"N,34°53'53.9"E |
| | 8 | 30°00'45.9"N,31°12'31.4"E | Surface water | 31 | 31°23'59.5"N,30°25'00.3"E |
| | 9 | 30°36'44.5"N,32°16'41.7"E | | 32 | 31°26'32.6"N,30°25'19.9"E |
| | 10 | 31°14'25.1"N,32°17'22.8"E | | 33 | 31°02'09.4"N,30°27'57.2"E |
| | 11 | 30°13'50.7"N,31°19'48.8"E | | 34 | 30°06'56.6"N,31°17'05.8"E |
| | 12 | 30°16'09.8"N,31°21'55.8"E | | 35 | 31°15'16.1"N,30°02'22.2"E |
| | 13 | 30°11'32.5"N,31°09'44.0"E | | 36 | 31°00'53.4"N,31°23'19.4"E |
| | 14 | 30°23'01.4"N,31°27'34.9"E | | 37 | 31°14'17.3"N,32°02'03.9"E |
| | 15 | 30°34'43.5"N,31°30'15.3"E | | 38 | 29°22'20.2"N,30°51'11.9"E |
| Ground water | 16 | 31°04'30.5"N,29°41'56.5"E | | 39 | 30°01'13.0"N,31°06'26.3"E |
| | 17 | 30°08'13.7"N,31°17'35.3"E | | 40 | 30°01'45.3"N,31°09'53.1"E |
| | 18 | 30°07'14.5"N,31°17'16.0"E | | 41 | 30°16'08.5"N,31°21'26.3"E |
| | 19 | 29°19'02.5"N,30°50'30.0"E | | 42 | 30°13'48.3"N,31°19'57.1"E |
| | 20 | 31°21'09.1"N,27°14'32.0"E | | 43 | 30°11'43.9"N,31°07'59.3"E |
| | 21 | 31°20'25.1"N,27°15'02.6"E | | 44 | 30°23'01.4"N,31°27'34.9"E |
| | 22 | 31°07'59.3"N,33°48'13.1"E | | 45 | 30°48'04.8"N,31°44'43.7"E |
| | 23 | 30°09'33.5"N,31°19'02.7"E | | | |

NB: samples numbers; 1, 2, 3, 31, 32 and 33 from Albharah governorate, samples numbers 4, 16 and 35 from Alexandria governorate, 5, 17,18 and 34 from Cairo governorate, samples numbers 6, 36, and 37 from Dakahlia governorate, samples numbers 7, 19, and 38 from Fayoum governorate, samples numbers 8,39, and 40 from Giza governorate, sample number 9, from Ismailia governorate, sample number 10 from Port Said governorate, samples numbers 11, 12, 13, 23, 24, 25,26, 41, 42, and 43 from Qalyubiyah governorate, samples numbers from

20, and 21 Mersa Matrouh governorate, samples numbers 22 from North Sinai governorate, samples numbers 14, 15, 44, and 45, from Sharqia governorate, and samples numbers 27, 28, 29, and 30 from Southern Sinai governorate.

### 2.3 Measurements of Radionuclide Concentrations

All samples were counted by HPGe detector coupled to 8192 multichannel CANBERRA analyzer for data acquisition. The used detector is P type and has 30% relative efficiency and resolution (FWHM) 2 keV for 1332.5 keV. The spectrum was analyzed by GENIE-2000 software. The $^{232}$Th was determined from the average concentrations of $^{228}$Ac (338.32 keV, 911 keV, and 968.97 keV) and $^{208}$Tl (583.19 keV) in the samples and the $^{226}$Ra was determined from the average concentration of the $^{214}$Pb (351.9 keV) and $^{214}$Bi (609.3, 1120, and 1764.5 keV) decay products. The $^{40}$K was determined directly from 1460.8 keV.

To determine the background spectrum observed by the germanium detector, an empty marnilli beaker was counted from time to another. The background was subtracted from the peak area for the measured samples. The background was used to determine the limit of detection and minimum detectable activity (MDA) according to Currie (1968). The minimum detectable activities at 95% confidence level for the detecting system were 0.7, 0.6, and 3 Bq kg$^{-1}$ for $^{226}$Ra, $^{232}$Th and $^{40}$K respectively. The radiological analysis was performed at Central Laboratory for Environmental Radiation Measurement and Inter-comparison (CLERMIT), Egyptian Nuclear and Radiological Regularity Authority (ENRRA).

### 2.4 Dose calculation

The annual effective dose has been calculated for water consumption according to the equation introduced by (Sorel, 1985).

$$D\ (\text{mSv year}^{-1}) = A \times I_a \times D_f \qquad (1)$$

Where; D is the annual effective dose (mSv year$^{-1}$), A is the activity (BqL$^{-1}$), $I_a$ is the intake of water for person in one year and $D_f$ is the effective dose equivalent conversion factor (mSv Bq$^{-1}$) introduced by Sorel, (1985). Doses were estimated by considering the water consumption rate of 1.5 L d$^{-1}$ for ages 5 and 10 years and 2 L d$^{-1}$ for 15 years and adults.

AcuteDose calculator program was used to calculate the dose resulting from consumption of water containing the determined radionuclide for the 30 major organs constituting the human body namely; Adrenals, Urinary Bladder Wall, Bone, Brain, Breasts, Stomach Wall (St-wall), Small Intestine (SI-Wall), Upper Large Intestine Wall (ULI_Wall), Lower Large Intestine wall (LLI_wall), Kidneys, Liver, the extra thoracic organs; the anterior nasal passage (ET1), the posterior nasal passages, the pharynx and larynx (ET2), their associated lymphatic tissue (LN-ET), The thoracic region includes bronchial (BBi-bas, BBi-sec), bronchiolar (bbe-sec), alveolar-interstitial region (AI), together with associated lymphatic tissue (LN-Th), Muscle, Ovaries, Pancreas, Bone Marrow, Skin, Spleen, Testes, Thymus, Thyroid, Uterus and Lung. The doses were calculated for four age groups; 5 years, 10 years, 15 years and adults.

## 3.0 RESULTS AND DISCUSSIONS

### 3.1 The activity concentrations results

Results of all water samples taken from all water resources showed that, the activity concentrations of $^{226}$Ra and $^{232}$Th 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). However, several studies have measured $^{226}$Ra and $^{232}$Th concentrations in water resources in Egypt. In Beni Suef governorate, $^{226}$Ra and $^{232}$Th concentrations ranged from 11.7 to 16.2 mBq $L^{-1}$ and from 5.6 to 9.5 mBq $L^{-1}$ respectively in tap water and from 8.5 to 40.8 mBq $L^{-1}$ and from 4.2 to 19.9 mBq $L^{-1}$ respectively in ground water. The averaged annual effective doses resulting from water consumption of 1.5 $Ld^{-1}$ were 0.0026 $mSvy^{-1}$ for tap water and 0.41 $mSvy^{-1}$ for ground water (Khalil et al., 2009).

In Qena mean $^{226}Ra$ and $^{232}Th$ concentrations in drinking water were 48.8±25.9 and 27.4±16.3 mBq $L^{-1}$ respectively and 56.2±28.5 and 27.4±16.3 mBq $L^{-1}$ respectively in Safaga and Quiser, while in ground water were 79.2±28.9 and 40.7±22.9 mBq $L^{-1}$ respectively in Qena and 112.9±33.3 and 51.4±22.2 mBq $L^{-1}$ respectively in Safaga and Quiser (Ahmed, 2004). The annual effective dose resulting from consumption of 1$Ld^{-1}$ of this water resulted in very low exposures that ranged from 0.005 to 0.0115 $mSvy^{-1}$ for $^{224}Ra$ and from 0.0022 to 0.0081 $mSvy^{-1}$for $^{232}Th$ (Ahmed, 2004).

In other parts worldwide $^{226}Ra$ and $^{232}Th$ has been reported. The concentration of $^{226}Ra$ in KSA and Nigeria was reported between < minimum detectable activity (MDA) – 2500 mBq $L^{-1}$(with an average 1810 mBq $L^{-1}$), and <MDA – 5400 mBq $L^{-1}$(with an average 1200 mBq $L^{-1}$) respectively. The concentration of $^{232}Th$ was reported between < MDA and 3300 mBq $L^{-1}$ (with an average 1470 mBq $L^{-1}$) in KSA (Fakeha et al., 2011), and reported between < MDA and 6200 mBq $L^{-1}$(with an average 1600 mBq $L^{-1}$) in Nigeria (Fasunwon et al., 2010).

Table 2 represents the activity concentrations results of $^{40}K$ of water resources. The results ranged from < 3 to 5.30 Bq $L^{-1}$with a mean 1.06 Bq $L^{-1}$ for tap water, ranged from < 3 to 5.16 Bq $L^{-1}$with a mean of 1.01Bq $L^{-1}$ for ground water, and ranged from < 3 to 32.09 Bq $L^{-1}$ with a mean of 3.16 Bq $L^{-1}$ for surface water.$^{40}K$ concentrations in water resources showed an apparent elevation than in tap water and ground water (3.16 Bq $L^{-1}$ vs. 1.06 and 1.01 Bq $L^{-1}$ respectively).

**Table 2: The activity concentrations results of $^{40}K$ in water resources (Bq $L^{-1}$).**

| $^{40}K$ | Tap water (n = 15) | Ground water (n = 15) | Surface water (n = 15) |
|---|---|---|---|
| Min. – Max. | < 3 – 5.30 | < 3 – 5.16 | < 3 – 32.09 |
| Mean ± SD. | 1.06 ± 1.72 | 1.01 ± 1.81 | 3.16 ± 8.11 |

Many studies in Egypt determined$^{40}K$ concentration in water such as in Beni Suef $^{40}K$ concentration in tap water ranged from 0.37 to 2.9 Bq $L^{-1}$ and ranged from 0.2 to 3.4 Bq $L^{-1}$ in ground water (Khalil et al., 2009). In Assiut city, $^{40}K$ concentration in tap water ranged from 3.4 to 5.2 Bq $L^{-1}$ and ranged from 3.5 to 7.1 Bq $L^{-1}$ in ground water (El-Gamal and Abdel Mageed, 2014). $^{40}K$ activity concentrations in our results were lower than several studies around the world. Such as in Yemen ground water, $^{40}K$ averaged as 19.03 Bq $L^{-1}$(Harb et al., 2013) and In Iran ranged from < MDA to 103 Bq $L^{-1}$with a mean of 39.8 ± 3.3 Bq$L^{-1}$ (Pourimani and Nemati 2014).

### 3.2 The annual effective doses Results

When estimating the total internal dose from ingestion of water, all radioactive isotope was found in water must be detected. Then the total dose would be the sum of all doses to all detected isotopes. But in the current study, only $^{40}K$ was detected in water. So, the total dose in this work is equal to the dose resulting from ingestion of $^{40}K$ only. The annual effective doses (µSv) delivered to LLI-wall, ULI-wall, ST-wall and the remaining organs; in addition to the total dose delivered to the whole body resulting from ingestion of $^{40}K$ from the studied water resources for the 4 age groups are represented in Table 3.

Upon application AcuteDose calculator program, the highest annual effective dose from $^{40}K$ ingestion were those delivered to Upper Large Intestine Wall (ULI wall), Lower Large Intestine wall (LLI wall) and Stomach wall (ST wall), while the dose to the 27 remaining organs was lower but uniformly distributed. The total dose to the body is presented as the sum of all doses to all 30 organs constituting the body.

In our study, all doses estimates whether to individual organs or to the whole body were below the limit set by the ICRP for public exposure from internal radiation (100 $\mu Svy^{-1}$). For all water resources, the lower the age, the higher the dose delivered from $^{40}K$ in water. For tap water, the highest annual dose delivered to 5 y age group of 6.16 $\mu Svy^{-1}$, and the lowest annual dose was that delivered to adults with a maximum of 1.79 $\mu Svy^{-1}$. For ground water, the highest annual dose delivered to 5 y age group of 6.12 $\mu Svy^{-1}$, and the lowest annual dose was that delivered to adults with a maximum of 1.71 $\mu Svy^{-1}$. It is noted that exposure levels for different age groups from tap water and from ground water are very similar. For surface water the highest annual dose delivered to 5 y age group of 37.45 $\mu Svy^{-1}$ and the lowest annual dose was that delivered to adults with a maximum of 10.82 $\mu Svy^{-1}$.

Our results were in agreement with several reports concerning annual effective dose resulting from water consumption, which were all below the maximum permissible ICRP limit for public exposure. Water from Beni Suef reported doses ranged from 2.6 to 4.2 $\mu Svy^{-1}$ from tap water and doses from 2.4 to 7.9 $\mu Svy^{-1}$ from ground water (Ahmed, 2004) and (Khalil et al., 2009) . In Qena and Red Sea, doses reported from 2.2 to 5.7 $\mu Svy^{-1}$ for tap water and from 3.3 to 11.5 $\mu Svy^{-1}$ for ground water (Fakeha et al., 2011).

**Table 3: The annual effective doses in µSv resulting from ingestion of $^{40}$K from the studied water resources for the 4 different age groups.**

| Samples | Years | | LLI-wall (n = 15) | ULI-wall (n = 15) | St wall (n=15) | Remaining organs (n = 15) | Total Dose |
|---|---|---|---|---|---|---|---|
| Tap Water | 5 | Min. – Max. | 0.00– 0.71 | 0.00 – 0.367 | 0.00–0.20 | 0.00–0.18 | 0.00– 6.16 |
| | | Mean ± SD. | 0.14± 0.23 | 0.07 ± 0.12 | 0.04±0.07 | 0.04 ± 0.06 | 1.23 ± 2.01 |
| | 10 | Min. – Max. | 0.00– 0.42 | 0.00 – 0.22 | 0.00 – 0.12 | 0.00–0.11 | 0.00 - 3.70 |
| | | Mean ± SD. | 0.09± 0.14 | 0.04 ± 0.07 | 0.02 ± 0.04 | 0.02 ± 0.04 | 1.387± 3.06 |
| | 15 | Min. – Max. | 0.00 – 0.24 | 0.00 – 0.13 | 0.00 – 0.07 | 0.00 – 0.07 | 0.0 - 2.20 |
| | | Mean ± SD. | 0.05 ± 0.08 | 0.03 ± 0.04 | 0.02 ± 0.02 | 0.01 ± 0.02 | 0.44± 0.711 |
| | Adults | Min. – Max. | 0.00 – 0.20 | 0.00 – 0.10 | 0.00 – 0.06 | 0.00 – 0.05 | 0.0 – 1.79 |
| | | Mean ± SD. | 0.04 ± 0.06 | 0.02 ± 0.03 | 0.01 ± 0.02 | 0.01 ± 0.02 | 0.33 ± 0.66 |
| Ground Water | 5 | Min. – Max. | 0.00 – 0.71 | 0.00 – 0.37 | 0.00 – 0.20 | 0.00 – 0.18 | 0.00 - 6.12 |
| | | Mean ± SD. | 0.15 ± 0.24 | 0.08 ± 0.12 | 0.04 ± 0.07 | 0.04 ± 0.06 | 1.35 ± 2.05 |
| | 10 | Min. – Max. | 0.00 – 0.42 | 0.00 – 0.22 | 0.00 – 0.12 | 0.00 – 0.11 | 0.00 – 3.73 |
| | | Mean ± SD. | 0.09 ± 0.14 | 0.05 ± 0.07 | 0.03 ± 0.04 | 0.02 ± 0.03 | 0.71 ± 1.06 |
| | 15 | Min. – Max. | 0.00 – 0.24 | 0.00 – 0.13 | 0.00 – 0.07 | 0.00 – 0.06 | 0.00 – 2.06 |
| | | Mean ± SD. | 0.05 ± 0.08 | 0.03 ± 0.04 | 0.02 ± 0.02 | 0.01 ± 0.02 | 0.37 ± 1.76 |
| | Adults | Min. – Max. | 0.00 – 0.20 | 0.00 – 0.10 | 0.00 – 0.06 | 0.00 – 0.05 | 0.00 - 1.71 |
| | | Mean ± SD. | 0.04 ± 0.07 | 0.02 ± 0.03 | 0.01 ± 0.02 | 0.01 ± 0.02 | 0.34 ± 0.66 |
| Surface Water | 5 | Min. – Max. | 00.0 – 4.3 | 0.00 – 2.23 | 0.00 – 1.22 | 0.00 – 1.10 | 0.00 - 37.45 |
| | | Mean ± SD. | 0.42 ± 1.09 | 0.22 ± 0.56 | 0.12 ± 0.31 | 0.11 ± 0.28 | 3.73 ± 9.32 |
| | 10 | Min. – Max. | 0.00 - 2.56 | 0.00 – 1.33 | 0.00 – 0.73 | 0.00 – 0.66 | 0.00– 22.44 |
| | | Mean ± SD. | 0.25 ± 0.65 | 0.13 ± 0.34 | 0.07 ± 0.18 | 0.06 ± 0.17 | 2.07 ± 5.76 |
| | 15 | Min. – Max. | 0.00 - 1.47 | 0.00 – 0.77 | 0.00 – 0.44 | 0.00 – 0.39 | 0.00 - 13.21 |
| | | Mean ± SD. | 0.14 ± 0.37 | 0.07 ± 0.19 | 0.04 ± 0.11 | 0.04 ± 0.10 | 1.33 ± 3.37 |
| | Adults | Min. – Max. | 0.00 – 1.2 | 0.00 – 0.62 | 0.00 - 0.36 | 0.00 – 0.32 | 0.00– 10.82 |
| | | Mean ± SD. | 0.12 ± 0.30 | 0.06 ± 0.16 | 0.04 ± 0.09 | 0.03 ± 0.08 | 1.03 ± 2.71 |

NB: All zero values in the table are a result of $^{40}$K values which are less than the minimum detection Activity by the used technique (< 3 Bq $L^{-1}$).

## 4.0 CONCLUSION AND RECOMMENDATIONS

Forty five samples (15 tap water samples, 15 ground water samples and 15 surface water samples) were collected from selected sites in the area under investigation (along the Northern part of Egypt from Sinai governorate in the East to Marsa Matrouh governorate in the West) and were analyzed using HPGe detector. The annual dose was calculated using AcuteDose calculator program for different organs from consumption of water for four age groups (5 years, 10 years, 15 years and adults).

Results showed that $^{40}$K the only detected while $^{226}$Ra and $^{232}$Th in all samples under investigation are below the detection limit (0.7 and 0.6 Bqkg$^{-1}$ respectively) of the used HPGe detector. The mean concentrations of $^{40}$K are1.06, 1.01 and 3.16 BqL$^{-1}$for tap water, ground water and surface water respectively. For all water resources, the lower the age, the higher the dose delivered from $^{40}$K in water. For tap water, the highest annual dose delivered to 5 y age group of 6.16 µSv y$^{-1}$ with an average of 1.32 µSv y$^{-1}$, and the lowest annual dose was that delivered to adults with a maximum of 1.79 µSv y$^{-1}$ and a mean of 0.33 µSv y$^{-1}$. All results are below the maximum permissible limit determined by ICRP for public exposure. Our study concluded that the examined water resources are applicable for drinking process from the radiological view point.

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