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# Radioactivity measurements in tap water in Gaza Strip (Al-Naser Area)

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**KEYWORDS**

CR-39;
Tap water;
Radiation;
Alpha concentration

**Abstract** Ionizing radiation comes from outer space (cosmic), the ground (terrestrial), and even from within our own bodies. It is present in the air we breathe, the food we eat, the water we drink, and in the construction materials used to build our homes. Exposure to radon and its progeny is believed to be associated with increased risks of several kinds of cancer. When radon or its progeny is inhaled, lung cancer accounts for most of the total incremental cancer risk. Ingestion of radon in water is suspected of being associated with increased risk of tumors of several internal organs, primarily the stomach.

In this work, the activity of alpha, beta and gamma radiation, in tap water in the north-east of Gaza (Al-Naser area) were measured. For this purpose we used a solid state nuclear track detectors (CR-39) and some other detectors (Geiger counter, NaI detector). The average gross alpha concentration from C4-39 is 35.50 Bq/m$^3$ (0.95 pci/L), the maximum concentration is 64.67 Bq/m$^3$, and minimum concentration is 24.20 Bq/m$^3$. Results obtained from all detectors, and their methods will be shown, and compared with the word average of 15 pci/L, all results indicate low level of activity.


## 1. Introduction

Most water sources have very low levels of radioactive contaminants (radio nuclides), levels low enough to not be considered a public health concern. Radio-nuclides emit "ionizing radiation", a known human carcinogen, when they naturally decay. Long-term exposure to radionuclides in drinking water may cause cancer. Of particular concern are naturally occurring uranium and the naturally occurring radium isotopes, radium-226 and radium-228, which have been observed to accumulate to levels of concern in drinking water sources. Most of the naturally occurring radionuclides are alpha particle emitters (e.g., the uranium isotopes and radium-226), naturally occurring beta particle emitters do occur (e.g., radium-228 and potassium-40) (Environmental Protection Agency (EPA), 2000; Beir, 2000). The source of naturally occurring radionuclides is the earth's crust. Among these radionuclides there exist three radioactive series originating from $^{238}$U, $^{235}$U and $^{232}$Th being one of the most abundant sources of naturally occurring radioactivity, the $^{238}$U series has been widely investigated.

Exposure to radionuclides from drinking water results in the increased risk of cancer. The radioactive particles (alpha, beta) and gamma photons emitted by radionuclides are called "ionizing radiation" because they ionize ("destabilize") nearby

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atoms as they travel through a cell or other material. In living tissue, this ionization process can damage chromosomes or other parts of the cell. This cellular damage can lead to the death of the cell or to unnatural reproduction of the cell. Exposure to elevated uranium levels in drinking water has been shown to lead to changes in kidney function that are indicators of potential future kidney failure (Beir, 2000; Sources and health effect of ionizing radiation 1980).

EPA has promulgated a limit for uranium as required by the 1986 amendments to the Safe Drinking Water Act. The current standards (''Risk Assessment of Radon in Drinking Water'', released September 15, 1998,) are: combined radium 226/228 of 5 pci/L; a gross alpha standard for all alphas of 15 pci/L, not including radon and uranium; a combined standard of 4 mrem/year for beta emitters (Risk assessment of radon in drinking water, 1998).

## 2. Experimental methods

Samples were collected from 40 places, from the north-west region of Gaza city, Al-Naser region of Gaza, which was divided into four regions in our survey, included Nasser west (A), Nasser east (B), Nasser shakhradwan (C), Nasser south (D). We have obtained ten samples from the houses of each area. After that, each sample was put in a one liter plastic jar to do the test of radiation activity, the detectors that used for making the measurements are:

(a) Solid State Nuclear Track Detectors (SSNTDs) are passive, low cost, long term method, most widely used for measuring radon and can be used for site assessment both indoors and outdoors. (Durani and Ilic, 1997).

The detectors are placed inside the dosimeters 1.5 cm above water. Detectors are usually exposed for 2–12 months. When alpha particles from the decay of radon and its progeny strike the detector, they cause damage tracks. After the exposure, the detector is chemically treated and the number of tracks over area counted by an optical microscope and radon concentration or gross alpha concentration is determined (David Bodansky et al., 1989). The water samples are placed in a calibrated (El-Ghossain and Abusaleh, 2007) plastic cup with plastic cover, the diameter of the cover equals 6 cm and the height of the cup is 11 cm as shown in Figs. 1 and 2. The CR-39 detector is fixed under the cover facing the water sample and the radium source at the same distance of 1.5 cm, same volume, same geometry, and same temperature.

The detector should remain undisturbed above the sample for at least 3 weeks. Solid State Nuclear Track Detector (CR-39) is used to measure Radon-222 or gross alpha concentration in water, soil & air at the collected sample. Each sample was put inside the cup as shown in Fig. 2. Forty detectors were exposed to forty samples which concern the north-west region

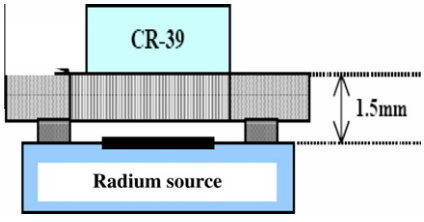


**Figure 1** Measurement technique for a solid radium source.

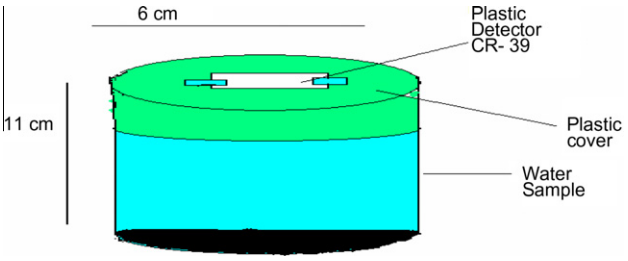


**Figure 2** Measurement technique using CR-39 to measure alpha activity in water.

of Gaza Strip. This distribution of detectors is based on the nature of the tap water type and geological location. The detectors are left in isolated place in the laboratory, about 74 days during the months April, May and June of 2005; this is the exposure time to allow radon gas to come to an equilibrium level with radioactive parents. After the exposition was finished, the forty detectors were collected and chemically etched using a 6 M (Mole) solution of NaOH, at the temperature of 70 °C, for 6 h, (standard etching condition). The CR-39 detectors were mounted vertically in a stainless steel spring and then immersed in the etching solution. At the end of the etching process the detectors were washed thoroughly with distilled water and then left to dry. Tracks in each detector counted visually using an optical microscope with a power of $(40 \times 10)$. We counted the average number of tracks in 1 $cm^2$.

(b) Another method used to measure alpha and beta activity in water samples was using the Electra Plus (DP6AD, measured CPM as Geiger counter, LLD 3-12 CPM) (Nuclear Energy and Radiation Protection (NERP), 2005). It is a portable rate meter based on the variety of GM and scintillation probes. A rectangular wooden box was filled with a water sample. The scintillation probes were put on the surface of the water sample the window area equals to 100 $cm^2$

(c) Also field space digital spectrometer (Dose rate 10 nSv/h-10 Sv/h) (Nuclear Energy and Radiation Protection (NERP), 2005) was used to measure the activity of gamma radiation in water. The probe of the device was put over the surface of the water. The distance between the probe and the water sample in the cup equals 0 cm.

(d) The scintillation counter (Na I) (Nuclear Energy and Radiation Protection (NERP), 2005) is a very common tool in nuclear and particle physics. It is used for measuring the energies of gamma-ray photons and other elementary particles (Bell, 2005). The intensity of the light is proportional to the amount of energy deposited in the crystal by radiation. The cup of the sample was used to taking a spectrum which resulted from the water by using scintillation counter where the probe of the device was put on the surface of water. The distances between the probe and the water sample in the cup equals 1 cm. The measurements obtained from the scintillation counter confirm there is low level radiation of gamma radiation in the water in north-west of Gaza Strip. The basic technique for this measurement is to count the number of pulses during a fixed time interval as a function of pulse height, and make a graph of the number of pulses versus pulse height.

(e) Geiger-Müller counters are used where the mechanism and methods are based on the interaction of the radiation with matter. Since ionization is an important process for radioactivity, most detectors exploit the signals generated due to ions

**Table 1** Final results for the four regions are of min, max and mean (E) concentrations from CR-39 detectors for (A), (B), (C) and (D) regions.

| Location | No. of detectors | Min. concentr. (Bq/m$^3$) | Max. concentr. (Bq/m$^3$) | $E$ (Bq/m$^3$) | S.D. (Bq/m$^3$) |
|---|---|---|---|---|---|
| A | 10 | 21.32 | 46.33 | 32.59 | 1.77 |
| B | 10 | 24.19 | 71.34 | 33.08 | 3.10 |
| C | 10 | 24.22 | 103.73 | 45.59 | 7.60 |
| D | 10 | 24.20 | 38.95 | 30.48 | 1.40 |
| Average | | 24.20 | 64.67 | 35.50 | 3.45 |

and electrons all these detectors calibrated with normal radioactive sources Co, Cs, and Na.

## 3. Calculations of gross alpha concentration using CR-39

Gross alpha contamination (El-Ghossain and Abusaleh, 2007) in water sample is measured in terms of Bq/m$^3$. Determination of gross alpha concentration $C_w$ and the standard deviation σ (S.D.) in a sample of water using nuclear track detector is done by the following Eq. (1).

$$C_w\left(\frac{Bq}{m^3}\right) = \left(\frac{C_R T_R}{\rho_R}\right)\left(\frac{\rho_w}{Tw}\right) \quad (1)$$

$$\sigma_n(S.D.) = \sqrt{\frac{\sum_k^n (X_k - \bar{X})^2}{n-1}} \quad (2)$$

where $C_w$, Concentration of activity of $^{222}$Rn in a water sample; $C_R$, Concentration of activity of $^{226}$Ra (solid radon source) equal 800 Bq/m$^3$; $\rho_R$, Track density (number of tracks/m$^2$) in detectors exposed to $^{226}$Ra; $T_R$, Exposure time (in days) of detectors exposed to $^{226}$Ra, equal 72 days; $\rho_w$, Track density (number of tracks/m$^2$) in detectors exposed to water samples; $T_w$, Exposure time (in days) of detectors exposed to in water samples, equal 74 days; $X_K$, Activity concentration of a sample; $X$, Mean activity concentration of n samples; $N$, number of samples and $\sigma_n$ (S.D.): standard déviation.

## 4. Calibration of CR-39 detectors

Two detectors were exposed to a known activity of $^{226}$Ra (solid radon source) for a determined period of time. Then these detectors were treated by chemical etching. The average numbers of tracks/cm$^2$ were calculated. These detectors were inserted in the same volume (plastic cup) of the investigated sample, so they considered as a calibration standard. (El-Ghossain and Abusaleh, 2007; Raed M. Abusaleh 2005; Mahmoud Rasas, 2003; Nabil Hamed, 2005). Similar method is also used for detector technique as in (El-Ghossain and Abusaleh, 2007) to determine the calibration constant (factor) K. This is derived by dividing the track density by the total exposure of radon source as in Eq. (3).

$$K = \left(\frac{C_R T_R}{\rho_R}\right), \quad (3)$$

Then Eq. (1) for radon concentration becomes as follows.

$$C_w\left(\frac{Bq}{m^3}\right) = K_{1,2}\left(\frac{\rho_w}{T_w}\right) \quad (4)$$

where

$$k_{1,2} = (k_1 + k_2)/2$$

The calibration factor ($K$) is determined, where two CR-39 detectors are exposed to $^{226}$Ra (Radium Source) of activity concentration 800 Bq/m$^3$ (from factory) for 72 days. The calibration process for detectors used in this survey was carried out at the nuclear laboratory at physics department in The Islamic University of Gaza (IUG). The density of tracks for the two detectors equals $19.6 \times 10^6$ tracks/m$^2$ and $18.6 \times 10^6$ tracks/m$^2$, and the average calibration factor $K$ is $3.06 \times 10^{-3}$ [Bq/m$^3$ day/tracks/m$^2$], and the standard deviation is 10.5%. Substituting calibration constant in equation, the activity concentration of alpha particles in water becomes:

$$C_w\left(\frac{Bq}{m^3}\right) = 3.06 \times 10^{-3}\left(\frac{\rho_w}{T_w}\right) \quad (5)$$

Where 1 pci/L = 37 Bq/m$^3$ is used as conversion unit. E in the Table 1 is the average concentration and (S.D.) is the standard deviation.

### 4.1. Results from CR-39 detector and other detectors

Gross alpha concentration in water samples were calculated using Eq. (5) for various locations. The minimum and the maximum gross alpha concentration in tap water samples measured in Bq/m$^3$ units are tabulated in the Table 1 as well as the mean value of gross alpha concentration (E) and Standard Deviation (S.D.) for each location in this study which is mentioned (El-Ghossain and Abusaleh, 2007).

The gross alpha concentration for each location was calculated by summing individual gross alpha concentration values of each detector, and the sums of the values were divided by the total number of detectors, results shown in Table 2. The standard deviation was also (El-Ghossain and Abusaleh, 2007) calculated by Eq. (2). Fig. 3 shows the average gross alpha concentration for C and B locations found higher than D. The results indicate the range: from minimum 24.20 Bq/m$^3$ to maximum 64.67 Bq/m$^3$ in gross alpha concentration in each location which is very low level radiation, if to compare with the world average of 10 kBq/m$^3$. This variation in gross alpha concentration inside the locations is mainly due to the different places, and different contamination level of tap water from environment.

The results obtained from field space mentioned above showed the relation between the gamma activity in water sample in unit of (n Sv/h) as in Fig. 4, the minimum, maximum gamma concentration in tap water, mean value concentration and standard deviation, we see that, gamma activity in all Naser having the same values due mainly to the same exposed background radiation.

Results of the alpha activities in water sample in unit of (CPS) (which can be converted CPM) obtained from Electra

**Table 2** All results calculated from CR-39 for (A), (B), (C) and (D) regions.

| Cw Bq/m$^3$ | No. of tracks 1 cm$^2$ | Slides no. | Regions |
|---|---|---|---|
| 24.19 | 59 | 1 | Part "A" (Nasser West) |
| 39.77 | 97 | 2 | |
| 27.06 | 66 | 3 | |
| 38.13 | 93 | 4 | |
| 31.98 | 78 | 5 | |
| 21.32 | 52 | 6 | |
| 31.98 | 78 | 7 | |
| 33.21 | 81 | 8 | |
| 46.33 | 113 | 9 | |
| 31.98 | 78 | 10 | |
| 31.16 | 76 | 11 | Part "B" (Nasser East) |
| 24.19 | 59 | 12 | |
| 25.42 | 62 | 13 | |
| 71.34 | 174 | 14 | |
| 27.88 | 68 | 15 | |
| 24.19 | 59 | 16 | |
| 25.42 | 62 | 17 | |
| 38.13 | 93 | 18 | |
| 38.13 | 93 | 19 | |
| 25.01 | 61 | 20 | |
| 31.98 | 78 | 21 | Part "C" (Nasser South) |
| 74.21 | 181 | 22 | |
| 27.88 | 68 | 23 | |
| 27.47 | 67 | 24 | |
| 37.72 | 92 | 25 | |
| 27.06 | 66 | 26 | |
| 24.19 | 59 | 27 | |
| 27.88 | 68 | 28 | |
| 103.73 | 253 | 29 | |
| 73.80 | 180 | 30 | |
| 38.95 | 95 | 31 | Part "D" |
| 24.19 | 59 | 32 | (Nasser Shakhradwan) |
| 27.06 | 66 | 33 | |
| 30.75 | 75 | 34 | |
| 24.19 | 59 | 35 | |
| 37.31 | 91 | 36 | |
| 35.67 | 87 | 37 | |
| 28.29 | 69 | 38 | |
| 27.06 | 66 | 39 | |
| 31.16 | 79 | 40 | |
| 35.50 | 86.50 | Mean value "*E*" | |
| 3.45 | 7.19 | Standard deviation | |

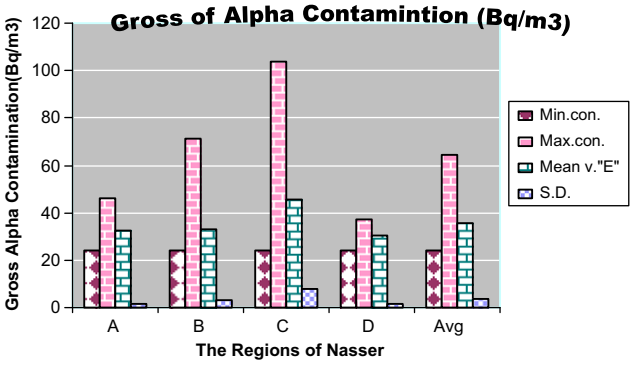


**Figure 3** Gross alpha concentration in each location and S.D.

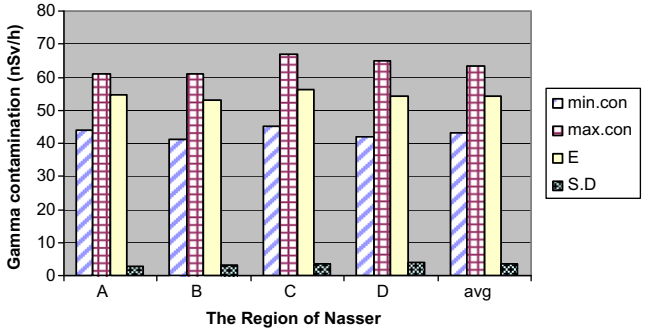


**Figure 4** Gamma concentration (nSv/h) in each location and S.

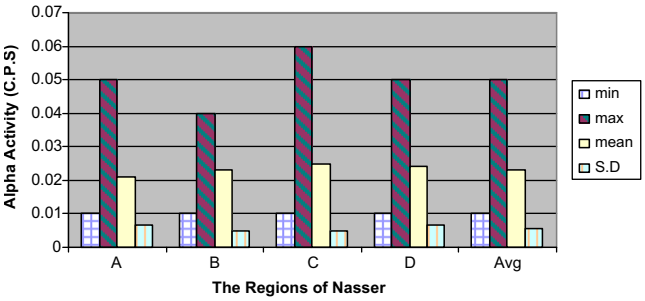


**Figure 5** Alpha activity in Nasser regions (Electra Plus).

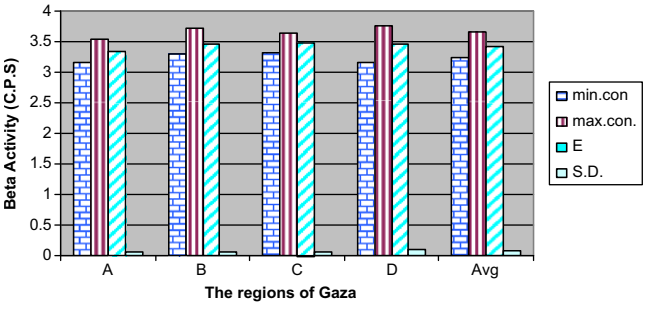


**Figure 6** Beta activity in Nasser regions (from Electra Plus).

Plus and the relation among regions are shown in the Fig. 5. We can see that the alpha activity in Nasser Shakhradwan (C) is greater than in other regions and in Nasser East (B) – lower than in other region in activity values and the difference is still less than the standard deviation.

Fig. 6 shows results of the beta activity in water samples in unit of (CPS) obtained from Electra Plus and the relation among regions. The results obtained from Electra Plus show that the beta radiation level in these regions is very low if to compare with other regions.

The results obtained from Geiger counter showed the relation between the radiation activities in water in unit of (CPM) and (kBq) calibrated. (The 37 kBq of Cesium radioactive source is used for calibration by multiplying by $X$ (0.102) kBq).

The results from all detectors indicate that, there is low level radiation in the studied area, because it is below 10 kBq/m$^3$. Fig. 7 shows there is low level radiation in water samples in the studied area in comparison to each other. The activities

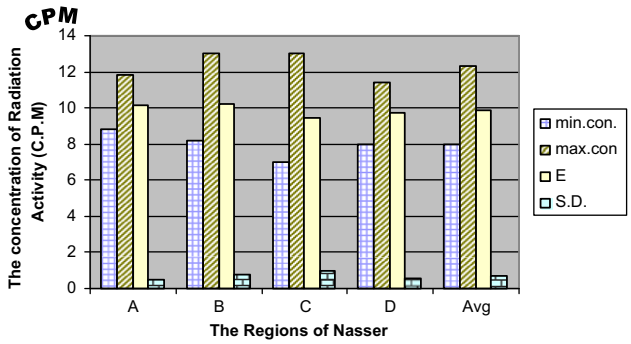


**Figure 7** Radiation activity in Nasser regions in CPM for comparison.

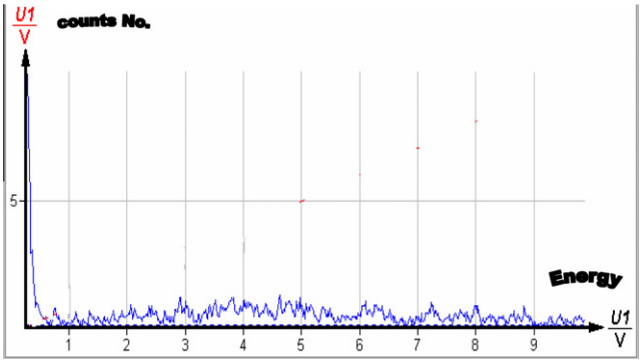


**Figure 8** Spectrum of water sample number-25 in Nasser Shakhradwan (C).

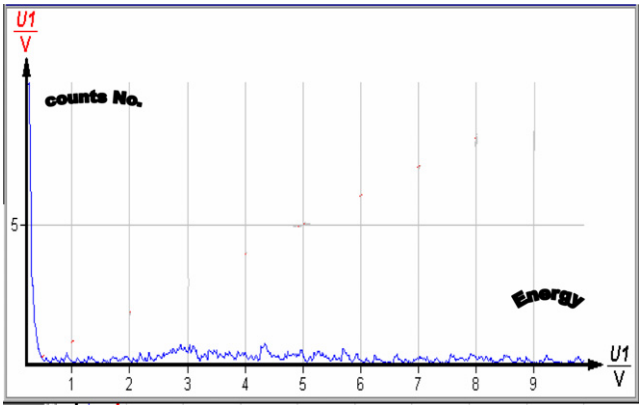


**Figure 9** Spectrum of background in surrounding air.

in these samples are very low because it is far away from rocks which contain Uranium and other radioactive material.

The results obtained from scintillation counter showed that there is low level radiation in the studied area. (Region, *y*-axis is the number of counts of radiation and *x*-axis is the channel number (energy), spectrum from background, sources were taken for calibration, $^{137}$Cs and $^{60}$Co)

In Fig. 8, the energy spectrum obtained for a water sample, each spectrum compared with each sample spectra and the calibration spectra, which showed no peaks appear in the sample spectra, that indicates that the water contain very low level of radiation.

The measurements of gamma rays made by means of the scintillation counter confirm that there is low level of radiation because the water sample level differs slightly from the background level, see Fig. 9.

## 5. Conclusion

The study purpose was to measure the radiation activity and to find out an approximate mean and range of radiation concentration in tap water at Nasser region in Gaza city. Only CR-39 determines concentration of alpha particles in terms of quantity in Bq/m$^3$, all other methods give the activity of radiation water samples in terms CPM.

Nasser region was divided into four areas, in our survey, included, Nasser west (A), Nasser east (B), Nasser shakhradwan (C), and Nasser south (D). We used five types of detectors. These detectors and their methods are already explained earlier: Solid State Nuclear Track Detectors (CR-39), Geiger counter, Portable Gamma Spectrometer, Scintillation counter and Portable Electra Plus.

In the present work all detector results indicate the low level of radiation activity in the Al-Nasser area. In general most water samples have very low levels of the natural radionuclides, and the average alpha concentration was 35.95 Bq/m$^3$ or 0.95 pci/L for Al-Nasser for the four regions of study, levels low enough to not be considered a public health concern as mentioned earlier in this reference. (''Risk Assessment of Radon in Drinking Water'', released September 15, 1998).

We are interested mainly in measuring alpha concentration which measured in Bq/m$^3$ using CR-39 accurately by counting alpha tracks, but in general way beta and gamma are measured for comparison purposes of samples with each other and with the calibration sources and not exactly like CR-39.

It is shown that the results of the measurements, the radiation concentration in water vary in the low level scale.

The main results of radiation measurements in water observed in the present study can be summarized as follows:

1. The radiation concentration in the tap water at Nasser is typically in values close to those normally found in other countries and much lower than the word average 10 kBq/m$^3$ (UNSCEAR, 1986).
2. The higher radiation concentration in water at Nasser south 103.75 Bq/m$^3$ or 2.8 pci/L, does not create any special environment and or health problem because it is less than the average of 10 k Bq/m$^3$ hopefully, and EPA of 15 pci/L for gross of all alpha standards, and 5 pci/L for alphas from combined radium 226/228.
3. We would like to do more specific measurements on some of naturally occurring radioactive isotopes like potassium, uranium, radium and others. This required more equipment which should be more accurate for this low level of radiation.

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