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# Analytical Studies on the Radionuclide Levels of Sediment and Water in an Agricultural Environment in the Egyptian Delta

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**ABSTRACT**

This paper is an environmental investigation of the concentration values of radioisotopes and hazardous elements, aimed to shed light on industrial pollution and the effect of using fertilizers in the period of irrigation water drainage from cultivated lands, especially in the River Nile, irrigated, and draining channels in the middle portion of the Egyptian river delta. Different samples were analyzed, both for water and sediment. Many physical and chemical characteristics of samples were investigated. Among them are the quantitative measure of the acidity or basicity of aqueous or other liquid solutions (pH), grain size, and the total organic matter content (TOM) have been determined for sediments. pH and TDS, beside other types of pollutants, were determined for water samples. The water and sediment samples pH are slightly alkaline. The mean value of TDS for water samples is 488 mg/l, while he usual TDS value in river is 500 mg/l. The TOM values show that the sediment samples are poor in organic matter content. The bicarbonate range in the water samples is smaller than the same range in river water. The levels of Ra-226, Th-232, and K-40 activity in sediments are highly correlated. Natural radionuclides seem to correlate with the artificial Cs-137 in sediment. For this peruse, a 240 $cm^3$ high-purity germanium reagent Type-B was used to quantify the levels in each sample with a relative accuracy of 50 %. The radioactive element K-40 is having a typical value of 12.5 Bq/kg. The concentrations of both Cu beside Zn in water samples is smaller if compared with values that quoted by the WHO, the US-EPA, and the EC. It was also found that the average levels for both Cd and Mn are found to be close to the internationally recommended levels. The water and sediments in the southern part of the canal contain higher concentrations of heavy metals and radioactive isotopes than in the rest of the canal.



## INTRODUCTION

The two main types of radioactivity are recognized to be natural, as well as background radiation and artificial radiation [1]. The radiation level and environmental issues related to uranium mining have garnered attention on a global scale [2-6]. Due to the release of hazardous pollutants and domestic trash into Egypt's rivers, the country's surface and groundwater are deteriorating at an increasing rate. Water contamination issues in agriculture are also caused by overuse of pesticides and fertilizers. Water contamination brought on by various effluent emissions may be dangerous to human health [7]. Heavy metals in water are the subject of several research nowadays, because they precipitate fast and tend to collect in sediments [8]. Due to their toxicity, persistence, and bioaccumulation, hazardous trace metal pollution of the aquatic system is a global issue [9,10]. Examination of the geographical distribution of the toxic substances Cr, Mn, Ni, Cu, Zn, As, Cd, and Pb in deposits from Longhu Lake to determine their pollutant levels and associated environmental dangers was performed. Zn, Cd, and Pb are

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moderately to highly polluted in lake sediments, according to the GI (The Geo-accumulation Index), and these elements may be more harmful than some other materials [11]. The results of this study will give important new information on the possible environmental effects of farming activities on the delta region's water quality. Furthermore, knowing the amounts of these toxins can assist guide Egypt's sustainable irrigation and land management policies.

## EXPERIMENTAL

### Sampling and sampling preparation

#### *Study area*

The investigated area is in the Nile Delta region, Tanta, Egypt. This area lies between 30° 47' to 30° 49' E longitudes and 30° 45' to 30° 47' N latitude. It is divided into two areas. The first one is the cultivated area shown as a box in Fig. 1. The second part is an open agriculture irrigation canal 5 km long with 2 m in width, branching from the main irrigation canal with a width of 5 m (see Fig. 1).

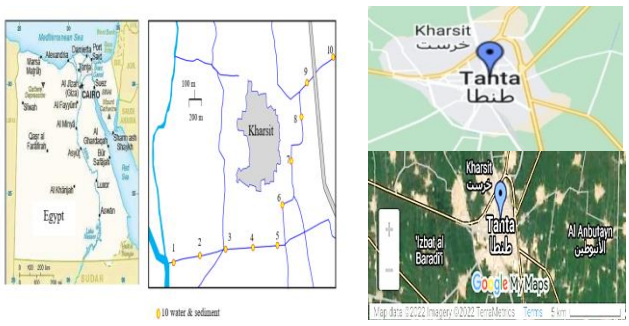


**Fig. 1.** Study area map in Nile Delta region, Tanta, Egypt. The sediment and water sample's locations are shown as an open circle.

#### *Sampling*

Measurements of the water and sediments were taken throughout the summertime from an open irrigation canal used for farming. For the purposes of measuring the radioactive concentration, samples were collected (24 liters each) from every location in pristine containers. Moreover, 0.5 liters of water specimens were taken to assess various properties. In order to prevent radioactive particles from adhering to the water container, water samples were acidified with 10 ml of hydrochloric acid (11M) per liter. The same places where water samples were taken also yielded samples of sediment. It weighs roughly 2 kg for each sample. Each of these plastic bags held the specimens that were collected. All of the obtained samples were shipped to the Radio-analysis Research Laboratory (RRL), located in Tanta University, Egypt's College of Science.

#### *Sampling procedures*

The physical state in which specimens are presented in the laboratory may not be appropriate to be analyzed. Before assessment, they need to be dried, homogenized, or reduced in size. The sediment specimens were hand-cleaned to remove stones, leaves, and other foreign objects before being air-dried for many days at room temperatures. The collected samples were homogenized, filtered through a 2 mm sieve, then oven-dried at 90 °C until they attained a consistent mass. Using a hot plate, each water sample was evaporated until it had a volume of approximately 0.5 liters. After that, the water was permitted to cool. 500 $cm^3$ of the produced samples were put into a PVC cylindrical container with a diameter of 12.6 cm and a height of 6.5 cm. The collected samples were kept in storage for no less than four weeks to enable radiometric equilibria between Ra-226, Rn-222, and their progenies. The test specimens were carefully packed with strong adhesive tape around their necks to minimize any gas leaks as much as possible. The activity of Ra-226 should be then determined using the appeared radioactivity lines of daughters, namely Pb-214 and Bi-214.

#### *Determination of sampling characteristics*

Samples can have a variety of physical and chemical properties that can be studied. The pH, total organic matter (TOM), and particle size of sediment cores were among the parameters that were assessed. Also, for water samples, the content of bicarbonate, pH, and total dissolved solids (TDS) were assessed. The pH of a solution is important because it affects a variety of variables. As the pH changes, several chemicals' solubility or reactivity also changes. The pH will be somewhat impacted by almost anything that dissolves in water, and we shall take those impacts into account when we investigate various substances. 240 $cm^3$ of high-purity germanium reagent Type-B was used to quantify the activity levels in the specimens with an efficiency of 50 %, by taking advantage of energy analysis of 1.92 keV per 1332 keV for cobalt-60 line. The radioactive background is protected by a lead shielding, and the detection is covered with a 10 cm layer (Canberra 747electron). A multichannel

analysis tool and an analog/digital conversion provided the 8K magnified outputs for collection (Oxford BSA3). To check for stability and adjust the actual radioactivity count rate of the chosen X-ray impulses, the gamma-ray background spectrum was periodically examined. The measuring period lasted for at least 18,000. The exact peak has a random error of 3-5 %. The performance calibrating method was utilized using potassium chloride and standardized point sources. Using Soil-6, 326, and 327, IAEA-rated references, efficient calibrated hub and gas from containerized and leak-tight samples were examined. To use a testing reliability device, the activity of the various radioactive elements found within those current rating substances has been determined. Following that, it was compared to the values provided by the International Atomic Energy Agency, with a maximum deviation rate of 3 % [4]. This involves Ra-226 activity, which is confirmed by the specimen containers' effective sealing. The most popular radioactive hazard index, Radium equivalent activity, or $Ra_{eq}$, was used to evaluate the risks from -ray radiation posed by the radionuclides Ra-226, Th-232, and K-40 as shown in Eq. (1) [12].

$$Ra_{eq} = C_{Ra} + 1.43\ C_{Th} + 0.077\ C_K \quad (1)$$

For which $C_{Ra}$, $C_{Th}$, and $C_K$ represent the activity levels of Ra-226, Th-232, and K-40, respectively, in $Bq.kg^{-1}$. The $R_{eq}$ is used to compare the behaviors of sediment with various radioactive isotope concentrations as a result of NORM in the collected samples. This presumption remains that the -ray dosage rates will be identical for 1 $Bq.kg^{-1}$ of Ra-226, 0.7 $Bq.kg^{-1}$ of Th-232, or 13 $Bq.kg^{-1}$ of K-40, while the $Ra_{eq}$ should not be more than 370 $Bq.kg^{-1}$ [13].

The specific absorption rates in outdoor air ($nGy.h^{-1}$) at an elevation of 1 m above the ground level had also been calculated using the obtained activity levels. The dosage conversion coefficients are 0.462, 0.604, and 0.0417, accordingly, for translating the activity quantities of U-238, Th-232, and K-40 into doses ($nGy.h^{-1}$ per $Bq.kg^{-1}$) [10]. Thus, the formula utilized for this purpose is provided by Eq. (2).

$$D = 0.462\ C_U + 0.604\ C_{Th} + 0.0417\ C_K. \quad (2)$$

At which $C_U$ represents U-238 activity in $Bq.kg^{-1}$. The globally averaged dosage rate that is accepted is 0.5 (0.16-0.82) $mGy.a^{-1}$ [12,13].

The recommended standard equivalent dose was then computed [9] using the following assumptions: indoor and outdoor occupation factor (OF) of 0.8 and 0.2, accordingly, and a conversion coefficient (DCC) of 0.72 $Sv.Gy^{-1}$ for the absorption in the air (D) to the dosage in the internal organs ($(D_{Eff})_{eq}$). The Eq. (3) was used to compute the yearly effective dose equivalents ($(D_{Eff})_{eq}$) [13].

$$(D_{Eff})_{eq} = D \times DCC \times OF \times T. \quad (3)$$

Where T is the total amount of time in a year (8766 h).

This same soil coating which contributes most to outer irradiation beneath the ground is thought to be the top ten cm. Outdoor terrestrial gamma radiation has an effective dose equivalent to 0.070 mSv [13].

Equations 4 and 5 were used to determine the exterior and interior hazard indices ($H_{ex}$ and $H_{in}$, including both).

$$H_{ex} = (0.0027C_{Ra} + 0.00386C_{Th} + 0.0002079\ C_K) \quad (4)$$

$$H_{in} = (0.0054C_{Ra} + 0.00386C_{Th} + 0.0002079\ C_K) \quad (5)$$

Where $H_{in}$ and $H_{in}$ should not be more than 1.

Equation 6 was used to determine the gradiation level index:

$$I_{gr} = (0.0067C_{Ra} + 0.01C_{Th} + 0.00067\ C_K) \quad (6)$$

Where the value should not be larger than 1.

The atomic absorption spectrophotometer method was used to examine the samples prepared for the measurements of the concentration of heavy metals (Perkin-Elmer 2380).

The lowest measurable emission rate is dependent on the sample content, radiated energy, source-to-detector distances, detecting accuracy, backgrounds, and the measuring period. The MDA for a measurement device for each radioisotope may be calculated using a variety of techniques. Equation 7 has been employed to compute it.

$$MDA = (L_D/t_m) / \varepsilon \quad (7)$$

In which ε is the photo-peak efficiencies of such analyzed -ray energies, $t_m$ is the measurement period, and $L_D$ is the detectable limits. [3] $L_D$ was defined using Eq. (8).

$$L_D = 5.4 + 3.3\ \sqrt{2N_{bg}} \quad (8)$$

Where in $N_{bg}$ indicates the total amount of background counts for the area of greatest interest for γ-ray energy under consideration at measurement time $t_m$.

## RESULTS AND DISCUSSION

### Sample characteristics

Total dissolved solids (TDS), pH, and bicarbonate of the collected samples are listed in Table 1. With an average of 488 mg/l, the TDS of water samples ranged from 461 to 504 mg/l. TDS typically varies from 500 to 30,000 mg/l in saltwater, while the normal value of TDS is 500 mg/l in river water [14,15].

**Table 1.** Characteristics of the water samples; pH, TDS and Bicarbonate.

| Sample code | TDS (mg/l) | pH | Bicarbonate (mg/l) |
|---|---|---|---|
| W01 | 498 | 7.5 | 35.2 |
| W02 | 491 | 7.4 | 42.3 |
| W03 | 480 | 7.4 | 19.1 |
| W04 | 496 | 7.4 | 22.1 |
| W05 | 504 | 7.3 | 73.1 |
| W06 | 461 | 7.3 | 26.3 |
| W07 | 488 | 7.3 | 37.4 |
| W08 | 474 | 7.3 | 54.4 |
| W09 | 496 | 7.3 | 63.4 |
| W010 | 490 | 7.3 | 58.3 |
| Mean | 488 | 7.4 | 43.2 |
| Range | (461–504) | (7.3–7.5) | (19.1–73.1) |

The overall pH of the water samples ranges from 7.3 to 7.5 with an average of 7.4, making them somewhat alkaline but also with agree with the actual condition. For the Northern Delta Region in Egypt, an average pH range of 7.1 to 8.7 is determined [16]. The water samples were taken from several locations anywhere along the Nile River, and Tala Drin's mean total pH was around 8 [17]. The bicarbonate concentrations range from 19.1 to 73.1 mg/l, with a mean of 43.2 mg/l. The bicarbonate range in the samples collected is significantly less than the ranges for river water (133-596 mg/l) [18]. The sediment specimen parameters, including pH and TOM, are listed in Table 2.

Sediments' pH levels are comparatively consistent, with an average value of 7.4 as in the case of water. With an average value of 0.6 %, the sediments specimens showed modest TOM readings ranging from 0.1 to 1.2 %. The sediment samples had little organic matter, as seen by the TOM readings. Table 3 provides measurements of pH and TOM from sediment samples taken from several sites around Egypt, along with the survey's current site. Whereas the pH values of the sediment samples in the current research are greater than that of the contamination region adjacent to the orthophosphate company and less than those of the samples from the Burullus Lake, Tala Drin, and different sites along, respectively, other locations in Egypt, the TOM values of the sediment samples in the study are lower than the two other locations.

**Table 2.** Characteristics of the soil and sediment samples; pH and TOM content.

| Sediment samples | pH | TOM % |
|---|---|---|
| D01 | 7.2 | 0.2 |
| D02 | 7.5 | 1.1 |
| D03 | 7.5 | 0.9 |
| D04 | 7.4 | 0.7 |
| D05 | 7.4 | 0.5 |
| D06 | 7.4 | 1.2 |
| D07 | 7.4 | 0.6 |
| D08 | 7.4 | 0.1 |
| D09 | 7.3 | 0.2 |
| D10 | 7.3 | 0.6 |
| Mean | 7.4 | 0.6 |
| *Range* | (7.2–7.5) | (0. l–1.2) |

Table 3 lists the measured pH and TOM from sediments samples from different locations in Egypt including the present study.

**Table 3.** The pH and TOM content of Egyptian sediment.

| Sediment | pH | TOM (%) |
|---|---|---|
| Study area | 7.4 (7.2–7.5) | 0.6 (0. l–1.2) |
| Close to phosphate fertilizer company | 6.5 | 2.9 |
| Nile Delta [19] | (5.1–6.8) | (2.0–4.1) |
| Burullus Lake [20] | 8.1 | 8.1 |

Small particle sizes are abundant as in sediment samples (as seen in Table 4). Well over 60 % of the specimens have particulates smaller than 0.5 mm. Throughout the current research, the proportion of silt and clay (0.0625 mm) in sediments is 18 %, whereas the portion of sands (0.063-2 mm) is 82 %.

**Table 4.** The fraction of the grain size of sediment samples.

| Sample | > 2mm | 1-2 | 0.5-1 | 0.25-0.5 | 0.125-0.25 | 0.0625-0.125 | <0.0625 |
|---|---|---|---|---|---|---|---|
| Sediment samples | | | | | | | |
| D01 | 1 | 15 | 22 | 19 | 30 | 5 | 7 |
| D02 | - | - | 5 | 21 | 32 | 18 | 24 |
| D03 | 6 | 20 | 18 | 13 | 30 | 4 | 8 |
| D04 | 2 | 21 | 39 | 14 | 4 | 6 | 10 |
| D05 | - | 23 | 21 | 21 | 14 | 10 | 11 |
| D06 | - | 10 | 15 | 18 | 6 | 19 | 32 |
| D07 | 3 | 11 | 22 | 18 | 17 | 11 | 18 |
| D08 | - | 18 | 9 | 12 | 20 | 16 | 25 |
| D09 | 4 | 14 | 25 | 11 | 14 | 11 | 21 |
| D10 | 4 | 20 | 12 | 10 | 14 | 18 | 22 |
| Mean | 3 | 15 | 19 | 16 | 18 | 12 | 18 |

### Heavy metals concentrations in examined samples

Due to their resistance to physical deterioration and prolonged persistence, metals are one of the primary causes of environmental contamination. Those who interfere with biogeochemical cycles develop inside living things before finally finding their way through the food system to individuals, where they can disrupt biological relationships and permanently harm essential organs [21,22].

The three major paths that humans are exposed to soil contaminants are by ingestion, inhalation, and dermal contact. Since sediment samples serve as the main repositories for airborne metals, it is helpful to evaluate the amounts of these metals in these media in order to identify changes in abundance and their effects. The canal used in this study is used extensively for agriculture and is sometimes used to collect wastewater and runoff from cities. Mn, Cu, Zn, and Cd were among the four main heavy metals analyzed in water samples. Tables 3-5 provide a brief overview of the information. Water contains varying amounts of Mn, Cu, Zn, and Cd, with values of 0.16 to 5.13 mg.l$^{-1}$, 0.15 mg.l$^{-1}$, and 0.02 mg.l$^{-1}$, correspondingly. W02, 4, 7, and 8 have the greatest Mn as well as Zn levels, whereas W06, 8, and 9 have such lower Mn and Zn amounts (see also Fig. 2). Two or more specimens were used to detect Cd. The whole first five sites (W01-W05) have average concentrated amounts of Mn, Cu, and Zn that look to be above the average concentrations found in the remaining five locations (W06-W10).

Table 5 lists the mean heavy metal concentrations in water samples taken from an open irrigation canal together with the global average, according to the World Health Organization [23], US EPA [23], as well as European Communities [24] standards. Whereas the average Cd content is close to such criteria, the amounts of both Zn and Cu are below WHO, EPA, and EC guidelines. Mn exhibits amounts that exceed those limits. All results of the detected concentration remain lower in comparison to the global mean. The sedimentary specimens include a substantial quantity of heavy metals that, in accordance with the surrounding environment, might be migrated. They are indeed rich in clay minerals, feldspar, and quartz. Heavy metals (Mn, Cu, Zn, and Cd) were examined as a result. Mn, Cu, Zn, and Cd element concentrations in sediment samples varied from 3.99 to 17.06 mg.g$^{-1}$, 0.45 to 1.12 mg.g$^{-1}$, 1.21 to 4.16 mg.g$^{-1}$, and 0.21 to 0.30 mg.g$^{-1}$, accordingly. This same canal's Cd quantities remain uniform. Mn, Zn, and Cu have the greatest levels in D03, D04, and D05, respectively (as seen in Fig. 3). The average amount of Mn, Cu, and Zn are 12.20, 0.95, and 3.37 mg.g$^{-1}$ for the five sites from D01 to D05, correspondingly, and 6.80, 0.58, and 2.03 mg.g$^{-1}$ for the five locations from D06 to D10. There is a strong indicator that perhaps the southern portion of the channel has larger amount of those three components.

Water yields the identical result as well. Table 6 displays the average heavy metal concentrations in sediment from the open irrigation canal in conjunction with the worldwide mean as well as other sites. Whereas the concentrations of Mn, Cu, and Zn are well under the global average's lower threshold, the level of Cd is very closely at the higher limit. Mn, Cu, and Zn measured levels in several rivers in India, Turkey, and the USA are significantly greater than those found in the current analysis.

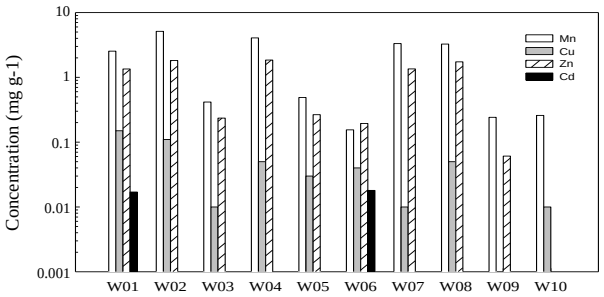


**Fig. 2.** The concentrations of significant metallic elements (Mn, Cu, Zn, and Cd) found in water specimens.

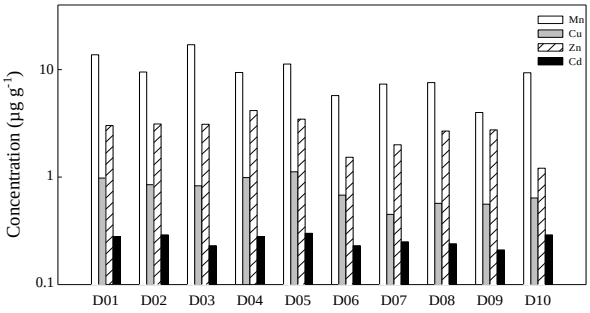


**Fig. 3.** The concentrations of significant metallic elements (Mn, Cu, Zn and Cd) measured in sediment specimens.

**Table 5.** Comparison between the levels of significant metallic elements in water specimens (mg.l$^{-1}$) of open irrigation canal and other locations. WHO, EPA, and EC limits are also given.

| | Mn | Cu | Zn | Cd |
|---|---|---|---|---|
| **Egypt** | | | | |
| Study area | 1.99 (0.16–5.13) | 0.05 (< 0.15) | 0.05 (< 1.81) | 0.004 (< 0.02) |
| Lake Nasser [25] | - | 0.0008-0.0067 | 0.00713-0.0118 | 0.000025-0.000065 |
| Borollus lake [26] | (0.012-0.144) | - | (0.086-0.176) | (0.0017-0.0058) |
| Lake Manzala [27] | 8.96-13.67 | 2.6-4.67 | 6.73-10.86 | 1.13-2.45 |
| **Greece [28]** | | | | |
| Aliakmonas River | 0.0002–0.0296 | 0.0009–0.0151 | 0.0011–0.2248 | – |
| Pinios River | 0.0002–0.0151 | 0.0009–0.0108 | 0.0018–0.0579 | – |
| Kalamas River | 0.0003–0.0071 | 0.0001–0.0099 | 0.0006–0.0204 | – |
| Louros River | 0.0001–0.0126 | 0.0004–0.0069 | 0.0007–0.2186 | – |
| Aoos River | 0.0002–0.0094 | 0.0006–0.0067 | 0.0003–0.0137 | – |
| **Others** | | | | |
| Bangladesh [29] | – | 0.6-0.81 | 0.12-042 | 0.0012-0.0023 |
| Baikal Lake, Russia [30] | 0.001-0.026 | 0.007 | 0.001-0.005 | 0.001 |
| Vemband Lake,India [25] | – | 0.00163 | 0.07493 | 0.00731 |
| Lake Victoria,Kenya [25] | – | 0.00007 | 0.144 | 0.001568 |
| Kosovo [31] | 0.096 | 0.031 | 0.002 | <0.001 |
| **Limits** | | | | |
| WHO [23] | 0.4 | 2 | - | 0.003 |
| EPA [1] | 0.05 | 1 | 5 | 0.005 |
| EC [24] | 0.05 | 2 | - | 0.005 |
| FAO [32] | 0.2 | 0.2 | 0.2 | 0.01 |

**Table 6.** Comparison between the levels of significant metallic elements in water specimens ($\mu g.g^{-1}$) for the open irrigation canal and other locations.

| | Mn | Cu | Zn | Cd |
|---|---|---|---|---|
| Study area | 9.50±3.82<br>3.99–17.07 | 0.77±0.22<br>0.45–1.12 | 2.70±0.90<br>1.21–4.16 | 0.26±0.03<br>0.21–0.30 |
| Damietta [10] | 490-1360 | 20-60 | 60-1100 | 0.2-0.5 |
| Lake Nasser [25] | – | 13-21.8 | 19-45 | 0.165-0.350 |
| Lake Manzala [33] | 233.0–1152 | 8.49–128.63 | 9.21–310.0 | – |
| Lake Bafa, Turkey [34] | 247.00–584.00 | 8.10–35.20 | 20.70–44.30 | 0.400–3.92 |
| Kosovo [31] | 660 | 61.2 | 122 | <1 |
| China [35] | 39.76 - 1884 | 2.13- 520.42 | 12.76 - | 0.06 - 40 |
| South China [36] | – | 20.54 | 1737.35 58.24 | 2.1 |
| World average [37] | 50-500 | 6-40 | 10-50 | 0.03-0.3 |

## Activity concentrations of radionuclides

### *Radioactivity concentrations in sediment and water*

Table 7 shows the activity concentrations of U-235, U-238, Ra-226, Th-232, K-40, and Cs-137 in sediment samples for the ten locations along the irrigation canal. The concentration level of U-238 was determined from the 185.7 keV photo-peak assuming a U-238/U-235 activity ratio of 21.6. At D04, D08, and D10, the quantity or concentration of U-238 is seen to be greater than the other samples. Similarly, for heavy metals, the southern portion of the channel (D01-D05) has greater concentrations of U-238, Ra-226, Th-232, and K-40 if compared with other sediment samples. Table 8 displays the average concentrations of heavy metals in sediments and water samples taken from the open irrigation canal. The average concentrations of heavy metals in sediments and water samples were measured at regular intervals using γ-ray energy under consideration at measurement time $t_m$. The results from Table 8 provide valuable insights into the pollution levels in the open irrigation canal, helping to assess the potential environmental risks associated with heavy metal contamination. Table 9 provides a comparison between radiological activity in sediment from the study location and other environmental zones. Whereas concentration levels for K-40 fall within the top half of the national range for Egyptian sediment, those for Ra-226 and Th-232 are in the lower half. While the lower threshold of the concentration level of K-40 is larger than the upper limit in the Nile delta, the observed activities of Ra-226 and Th-232 mainly accord with those from the region nearest to the research topic (the Nile Delta). All these times, fertilizers are used on the sediments. The Red Sea deposits have the greatest levels of Ra-226. Table 10 presents a comparison of the radiological activity in the average concentration beside the ranges of Ra-226, Th-232, K-40, and Cs-137 for water samples in Egypt, Iran and Sudan. The concentration levels of Cs-137 fall within the range for Iranian concentration values [43], whereas those for K-40 and Ra-228 the concentration values are lower than that for Egypt, Iran and Sudan [42-44]. Referring to values of concentration for Ra-226 the calculated values are in the lower values as for Egypt, Iran and higher than that for Sudan [42-44]. For all considered values the reported values are lower than the world average values [45].

**Table 7.** The concentration levels of U-235, U-238, Ra-226, Th-232, K-40 and Cs-137 in sediment specimens.

| Isotope | U-235 | U-238 | Ra-226 | Th-232 | K-40 | Cs-137 |
|---|---|---|---|---|---|---|
| Sediments (Bq $kg^{-1}$) | 0.8–1.9 | 14.0–40.6 | 12.1-21.0 | 13.5 - 22.3 | 241–371 | 1.3–2.8 |
| Mean | 1.3±0.4 | 26.6±8.9 | 16.5 ± 2.9 | 17.7±2.8 | 316±42 | 2.0±0.5 |

**Table 8.** The calculated MDA of the activity concentration of each nuclide in a typical sediment sample (1 kg and 10 h counting time), and water sample (0.5 l and 10 h counting time) utilizing a 50 % HPGe detector in the experimental setup of the current study.

| Isotope | Ra-226 | Th-232 | K-40 | Cs-137 |
|---|---|---|---|---|
| Sediments (Bq $kg^{-1}$) | 0.20 | 0.33 | 0.51 | 0.03 |
| Water (Bq $l^{-1}$) | 0.02 | 0.02 | 0.04 | 0.06 |

**Table 9.** The average concentration beside the ranges of Ra-226, Th-232, K-40, and Cs-137 (Bq kg-1 DW) for sediments specimens from different areas.

| | U-238 (Ra-226) | Th-232(Ra-228) | K-40 | Cs-137 |
|---|---|---|---|---|
| Egypt [39] | 13.79 ± 0.75 | 14.57 ± 1.15 | 128.9 ± 4.15 | – |
| Oman [40] | 20.49 | 2.26 | 44.83 | – |
| Iran [41] | 22.5 ± 1.0<br>to 47.4 ± 2.2 | 6.5 ± 0.1<br>to 18.7 ± 0.7 | 559.9 ± 30.9<br>to 233.2 ± 19.4 | 2.7 ± 0.1 |
| World average [38] | 32 | 45 | 412 | – |

**Table 10**. The average concentration beside the ranges of Ra-226, Th-232, K-40, and Cs-137 (Bq l–1DW) for water samples in other locations.

| | $^{238}U(^{226}Ra)$ | $^{232}Th(^{228}Ra)$ | $^{40}K$ | $^{137}Cs$ |
|---|---|---|---|---|
| **Egypt** [42] | 0.27 | 0.06 | 1.61 | – |
| Iran **[43]** | 7.65±1.64<br>to 1.45±1.39 | 0.33±0.14 | 5.32±0.99 | 0.08±0.03 |
| Sudan [44] | 0.007-0.014 | 0.001-0.039 | – | – |
| South Africa [45] | 0. 5 | BDL* | 11 | – |

*BDL: Blow the detection level.

The reported values for the concentrations of heavy metals, namely Mn, Cu, Zn, and Cd, in water specimens taken from the open irrigation canal ($mg.l^{-1}$) for samples W1 to W10 in different sectors are statistically represented in Table 11. For samples D01 to D10, Table 12 displays the concentration of heavy metals in sediment specimens in ($mg.g^{-1}$) units together with the computed values' arithmetic mean (A.M.), standard deviation (S.D.), ranges, median, and geometrical mean (G.M.).Lastly, the radionuclides, g-ray energy (keV), and intensity (%) used to calculate the activity concentrations for Th-232, Ra-226, Th-234, K-40, and Cs-137 are shown in Table 13.

**Table 11.** Heavy metals concentration in water specimens collected from the open irrigation canal ($mg.l^{-1}$).

| | Mn | Cu | Zn | Cd |
|---|---|---|---|---|
| W01 | 2.54 | 0.15 | 1.35 | 0.02 |
| W02 | 5.13 | 0.11 | 1.81 | - |
| W03 | 0.42 | 0.01 | 0.24 | - |
| W04 | 4.06 | 0.05 | 1.85 | - |
| W05 | 0.49 | 0.03 | 0.27 | - |
| Mean W01–05 | 2.53±2.10 | 0.07±0.06 | 1.10±0.80 | |
| W06 | 0.16 | 0.04 | 0.19 | 0.02 |
| W07 | 3.32 | 0.01 | 1.35 | - |
| W08 | 3.27 | 0.05 | 1.74 | - |
| W09 | 0.24 | - | 0.06 | - |
| W10 | 0.26 | 0.01 | - | - |
| Mean W06–10 | 1.45±1.68 | 0.02±0.02 | 0.67±0.82 | |
| A.M.±S.D. | 1.99±1.88 | 0.05±0.05 | 0.89±0.79 | |
| G.M. | 1.02 | 0.03 | 0.39 | |
| Range | 0.16–5.13 | < 0.15 | < 1.85 | |
| Median | 1.51 | 0.04 | 0.81 | |

A.M.: stands for the arithmetic mean, S.D.: for the standard deviation, and G.M.: for geometrical mean**.**

**Table 12.** The amount of heavy metals present in sediment specimens ($\mu g.g^{-1}$).

| | Mn | Cu | Zn | Cd |
|---|---|---|---|---|
| D01 | 13.74 | 0.98 | 3.02 | 0.28 |
| D02 | 9.51 | 0.85 | 3.12 | 0.29 |
| D03 | 17.06 | 0.83 | 3.10 | 0.23 |
| D04 | 9.42 | 0.99 | 4.16 | 0.28 |
| D05 | 11.27 | 1.12 | 3.46 | 0.30 |
| Mean W01–05 | 12.20±3.23 | 0.95±0.12 | 3.37±0.47 | 0.28±0.03 |
| D06 | 5.74 | 0.68 | 1.53 | 0.23 |
| D07 | 7.34 | 0.45 | 2.00 | 0.25 |
| D08 | 7.58 | 0.57 | 2.68 | 0.24 |
| D09 | 3.99 | 0.56 | 2.75 | 0.21 |
| D10 | 9.36 | 0.64 | 1.21 | 0.29 |
| Mean W06–10 | 6.80±2.03 | 0.58±0.09 | 2.03±0.68 | 0.24±0.03 |
| A.M.±S.D. | 9.50±3.82 | 0.77±0.22 | 2.70±0.90 | 0.26±0.03 |
| G.M. | 8.81 | 0.74 | 2.55 | 0.26 |
| Range | 3.99–17.06 | 0.45–1.12 | 1.21–4.16 | 0.21–0.30 |
| Median | 9.39 | 0.76 | 2.89 | 0.27 |

A.M.: stands for the arithmetic mean, S.D.: for the standard deviation, and G.M.: for geometrical mean.

**Table 13.** The radionuclides and γ–ray energy employed for determining activity concentrations for Th-232, Ra-226, Th-234, K-40 and Cs-137.

| Isotope | Measured radionuclides | γ-ray energy (keV) and intensity (%) |
|---|---|---|
| Ra-**226** | Pb-**214** | 295.2(0.182), 351.9(0.351) |
| | Bi-**218** | 609.3(0.446), 1120.3(0.147), 1764.0(0.151) |
| Th-232 | Ac-228 | 911.2(0.266), 964.6(0.0505), 969.0(0.1623) |
| | Tl-208 | 538.2(0.3058), 860.6(0.045), 2614.5(0.3588) |
| | Bi-212 | 727.3(0.0664) |
| K-40 | | 1460.8(0.1067) |
| Cs-137 | | 661.7(0.852) |

## CONCLUSION

The specimens of water and sediment taken from the southern part of the canal were determined to contain greater concentrations of radioisotopes and heavy metals compared to the other specimens. The findings of this study are summarized as follows: for water samples, the amounts of Cu and Zn present within water samples are lower than those advised by the WHO, EPA, and EC. Also, it was discovered that the mean concentrations of Cd and Mn are greater than or very close to the values that are generally regarded as optimal. The only radioactive isotope found in water samples was K-40, which had an average concentration of 12.5 $Bq.kg^{-1}$. while for sediment samples it was discovered that Mn, Cu, and Zn contents are below the values observed globally, although Cd concentration is close to the upper limit. Indicating the presence of uranium pollution brought on through the use of phosphate fertilizers in nearby farming fields, the percentage of U-238 to Ra-226 went up significantly. The ratio of Th-232 to Ra-226 is relatively close. In general, the concentrations of heavy metals (Mn, Co, and Zn), NORM, and Cs-137 in the investigated area do not surpass the usual ranges.

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## AUTHOR CONTRIBUTION

R. Shady and A. E. A. Elzain are equally contributed as the main contributors of this paper. The authors read and approved the final version of the paper.

## COMPETING INTERESTS

The authors stated that they have no competing interests.

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