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# Arsenic and Mercury Concentrations, Ecological and Health Risk Assessment in Freshwater Sediment and *Oreochromis niloticus* (Linnaeus, 1758) in a River Nile Canal, Egypt

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## ABSTRACT

Arsenic (As) and mercury (Hg) concentrations in the sediment and tissues of *Oreochromis niloticus* fish from a Nile River canal (Muweis Canal), Egypt, were subjected to an investigation between May and July 2022 at six stations along the canal. Concentrations of As and Hg were determined via an atomic absorption spectrophotometer. The results showed that the concentrations of metals in the liver, muscle and sediment varied significantly among the different sampling sites. The contamination factor (CF) and potential ecological risk index (RI) indicated a considerable risk for aquatic life. For *O. niloticus* consumption, the estimated daily intake (EDI) of Hg was less than the permissible daily intake. However, the target hazard quotient (THQ) and target cancer risk (CR) values for As exceed the acceptable value range, suggesting a risk of cancer for consumers. Therefore, the continuous monitoring for heavy metals in Muweis Canal and similar localities in Egypt should be improved to preserve ecological and human health.

## INTRODUCTION

Environmental pollution is one of the major problems facing the human society today. Rapid industrialization coupled with urbanization has contaminated the aquatic ecosystems through heavy metals **(Islam & Tanaka, 2004; Mwanamoki *et al.*, 2015; Ali *et al.*, 2019)**. Due to their persistence, heavy metals pose a serious risk on living organisms and the aquatic ecosystems **(Ullah *et al.*, 2017, Fuentes-Gandara *et al.*, 2018; Ogbomida *et al.*, 2018)**. In addition, their bioaccumulation and magnification through the water, sediments and food chain **(Omar *et al.*, 2013; Liu *et al.*, 2018; Kumari &Maiti, 2020)** have given heavy metals the potential to pose delitrious threat.

Arsenic and mercury are contaminants of a particular concern attributed to their wide distribution in the environment and their high potential for bioaccumulation and biomagnification **(Lavoie *et al.*, 2013; Qiu *et al.*, 2018; Marziali & Valsecchi, 2021)**. In freshwater systems, the accumulation of As and Hg has been detected in sediment originated from anthropogenic inputs; sediment can act as a potential secondary source of the contaminant for overlaying waters and aquatic organisms **(Amos *et al.*, 2014; Marziali & Valsecchi, 2021)**. According to public health guidelines, As and Hg are among the most toxic chemicals **(WHO, 2017)**. A daily intake of 1.0mg inorganic arsenic may cause skin lesions within a few years. However, Hg is a teratogenic element, and even low levels of exposure can have irreversible effects on the central nervous system **(Crespo-Lpes *et al*., 2021)**.

Compared to water, analysis of sediment gives accurate estimations for contaminants, which are absorbed by particulates tending to sink on bottoms **(Ibrahim & Omar, 2013)**. Heavy metals in sediment can accumulate in benthic organisms and then transfer to higher levels in the food chain **(Shirneshan *et al.*, 2013; Varol & Sunbul, 2019)**. Therefore, sediment monitoring is primary to identify harmful metals in the aquatic ecosystem. Furthermore, due to their location at the top of the food chain, fish can accumulate metals from water, sediments, their food and pollution residues **(Zhao *et al.*, 2012; Varol & Sunbul, 2019)**. Thus, the metals' concentration in their tissues may be significantly higher, compared to their concentration in the water and sediment **(Goodwin *et al.*, 2003)**. For this reason, fish have been considered as a good bioindicator for water bodies contamination **(Mansour & Sidky, 2002; Markert *et al.*, 2008)**. Additionally, monitoring of metal concentrations in fish tissues helps ensuring the safety the aquatic organisms and the health of their consumers **(Ali *et al.*, 2019; Pinzon-Bedoya *et al.*, 2020)**.

Muweis Canal in the Egyptian Delta is affected by agricultural drains, domestic wastes, as well as wastes from the Miser Oil & Soap Factory **(APRP, 2002; Abdel-Satar *et al.*, 2017)**. This canal is regarded as a source of water for drinking, agricultural, industrial and fisheries. Therefore, regular monitoring of metals in different environmental segments such as sediment and biota is necessary for pollution assessment and control as well as to assess the risks threatening wildlife and human health **(Lin *et al.*, 2019)**. One of the most popular species in Egypt is the Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758). Due to the limited information on arsenic and mercuric contaminations in this fish species until now and the toxicity of these elements to human health, this study aimed to assess As and Hg concentrations in liver and muscle tissues of *O. niloticus* and evaluate the human health hazards in relation to fish consumption. In addition, the levels of As and Hg in sediment samples were assessed to evaluate the degree of soil contamination that could adversely affect benthic organisms.

## MATERIALS AND METHODS

### Study area

Muweis Canal is considered as a natural source of irrigation, drinking and fishery. The canal arises from Al-Raiyah Al-Tawfky and runs through Sharkia Province, Egypt. The governorate is located in the east of the Nile Delta between latitudes 30° 34′ 0″ N & longitudes 31° 30′ 0″ E. Six stations were chosen along this canal for approximately 42.52 kilometres; namely, Al-Azizeyah (S1), Minya El Qamh (S2), Zagazig (S3), Kafr-Elhosr (S4), Hehya (S5) and Abou Kabir (S6) (Fig. 1).These sites are impacted by different anthropogenic activities. They receive domestic, industrial and agricultural wastes. Samples were collected between May and July 2022.

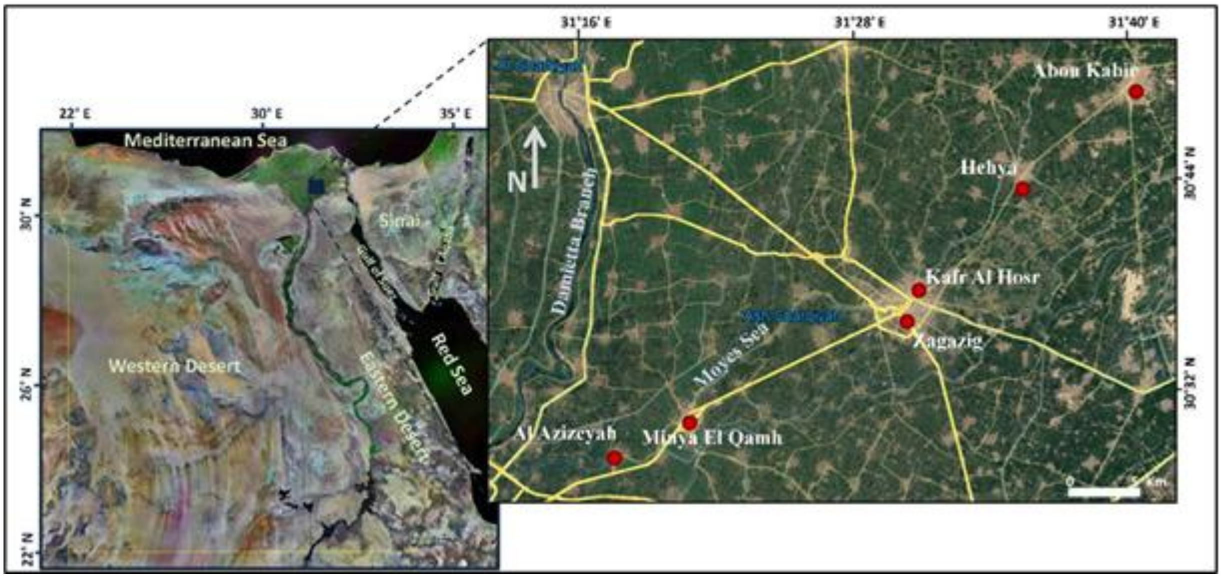


**Fig. 1.** Map of the studied sites located in Muweis Canal Al-Sharkia governorate, Egypt

## Sample collection, preparation and metal analysis

### Sediment samples

Sediment samples were gathered from the bottoms using an Ekman grab sampler (n=18, three from each sampling site). Sediment samples were preserved in tightly sealed and labeled plastic bags before being taken to the lab. The sediments were air-dried, sieved to separate coarse particles and ground in the lab. The samples were dried in an oven for 48 hours at 70°C to a constant weight. Then, 0.5g of the fine powdered sediment sample was digested using 10ml of concentrated $HNO_3$ (65%): $HClO_4$ (60%): HF (40%), with heating for 3 hours on a hot plate at 70°C for complete digestion **(Kouadio & Trefry, 1987)**. The digest was cooled to room temperature, filtered using whatman filter paper (No. 42) and diluted to a volume of 25ml, and then stored until analysis. An atomic absorption spectrophotometer "Buck Scientific USA 210 VGP", with an oxidizing air acetylene flame, was used to measure element concentrations (As and Hg) (Norwalk, CT, USA). Values for metals were given as g/g dry weight.

### *Oreochromis niloticus* fish samples

The Nile tilapia, *Oreochromis niloticus* specimens with an average body length (21.2 ± 0.44cm) and an average body weight (165.8 ± 7.35g) were caught by fishermen using fishing nets from the sampling station during the same period of sediment collection (n = 108, six individual/ month/ station). The specimens were cleaned to remove any debris, sealed in bags and transported in an icebox to the lab. In the lab, each *O. niloticus* fish sample was dissected by using sterile stainless steel tools to bring out liver and muscle tissue samples (dorsal muscle, with its covered skin). Fish tissues were then rinsed twice with distilled water, placed in labeled bags and immediately deep frozen at -20$^0$C until analysis. For each month, fish specimens (especially, liver) were pooled and blended together to form a composite homogenized sample, which was then analyzed in this study. About 0.5g of wet tissue samples was digested according to **Akubugwo *et al.* (2007)**. Metal values were given as µg/g wet weight.

Digestion of samples and metal analysis were made at the central laboratory in the Faculty of Veterinary Medicine, Zagazig University, Egypt. A quality control of the analysis was assessed by the routine examination of the standard reference materials (dogfish liver DOLT-4) for the studied metals (As and Hg) to ensure the precision and accuracy of the results. Recovery percentages from the spiked samples were 97.6 %, 96.2 % for mercury and 106.8 %, 106.2 % for arsenic for sediment and fish samples, respectively. Analysis was replicated three times for each sample.

**Assessment of sediment contamination**

To assess the possible environmental risks associated with the abnormal levels of metals in sediment, indices were used to indicate sediment contamination.

**Contamination factor (CF)**

The contamination factor was calculated using the following equation of **Hakanson, (1980)**:

$$CF = \frac{Ci}{Cb}$$

Where, Ci= content of the metal in the analyzed sediment, and Cb is the background concentration of metal. Due to the lack of local background values for Muweis Canal sediment, background concentrations of 0.25 and 8 µg $g^{-1}$ for Hg and As in crustal shale, respectively, were considered for the calculation **(Turekian & Wedepohl, 1961)**. **Hakanson (1980)** identified four categories of contamination: CF< 1 for low contamination; 1≤ CF ≤ 3 for moderate contamination; 3≤ CF≤ 6 for considerable contamination, and CF ≥ 6 for very high contamination.

**Potential ecological risk index (RI)**

In order to assess the level of metal pollution in sediments, the potential ecological risk factor (Er) of a single metal and the RI of multi metals were calculated by using the following equations:

$$Er = T \ x \ CF$$

$$\text{RI} = \sum Er$$

Where, RI = sum of all risk factors for metals in sediments; Er = the potential ecological risk of a single metal; CF: is the contamination factor of an individual element, and T: is the toxic response factor (Hg= 40 & As=10) **(Hakanson, 1980)**. According to **Hakanson (1980)**, the following terms were suggested for RI values: low risk (RI<150), moderate risk (RI>150 to >300), considerable risk (RI> 300 to <600) and high risk (RI>600).

**Sediment quality guidelines (SQGs)**

SQGs help in predicting the toxicity of metals in sediments on aquatic biota. Two toxicological reference values referred to as TEL (Threshold Effect Level) and PEL (Probable Effect Level) were used in order to evaluate sediment quality **(JFDEP; MacDonald, 1994)**. Additionally, **Long *et al.* (1995)** have mentioned ERL (effects range low), and ERM (effect range medium) references. Concentration ranges are as follows; < ERL for rarely effect; > ERL < ERM for occasionally effect, and > ERM for frequently effect.

**Health risk assessment**

***Estimated daily intake of metals***

The estimated daily intake (EDI) of Hg and As was calculated via the following equation of **USEPA (1989)** and **Christophoridis *et al*. (2019)**:

$$EDI = \frac{C * IR}{BW}$$

EDI was represented as µg/ kg bw/day; C = metal levels in edible tissue of the fish (µg/g ww); IR= the daily consumption of fish, which is 62.25 g/person/ day based on the **Ministry of Agriculture and Land Reclamation, Egypt (2017)**, and BW represents the weight of body (70 kg for adults).

***Evaluation of the target hazard quotients***

Target hazard quotient (THQ) was calculated to assess the risk for non-carcinogenic diseases due to exposure to metals, according to following equation expressed by **US EPA (2012)**. If THQ values were lower than 1.0, the potential risk would not likely occur. However, if the values were higher than 1.0, there would be a risk that hazardous effects occur **(US EPA, 2019)**. The following formula was determined to calculate THQ:

$$THQ = \frac{EF * ED * IR * C}{RFD * BW * AT} * 10^{-3}$$

Where, Ef= exposure frequency (365 days per year); C = metal concentrations in fish (µg/g w.w); Ed= exposure duration (70 years); IR= ingestion rate g/person/day; AT= average exposure time (365 days/year × ED), and Rfd= oral reference dose for As and Hg are 0.0003 and 0.0001 µg/g /day, respectively **(USEPA, 2019)**.

***Evaluation of target cancer risk***

Target cancer risk (CR) was calculated according to **USEPA (2000)**, using the following equation. Carcinogenic risk between $10^{-6}$ and $10^{-4}$ indicates a range of potential risks associated with cancer causes, while CR higher than $10^{-4}$ is unacceptable **(USEPA, 2011)**

$$CR = \frac{EF * ED * IR * 10^{-3} * C * CSF}{BW * AT}$$

Where, EF= the frequency of exposure days/year; ED= the exposure duration years; IR= the ingestion rate g/person/day; CSF= the cancer slope factor (As= 1.5mg/ kg/ day) **(USEPA, 2019)**; BW: the body weight (kg), and AT= the average exposure time (365 days × 70 years).

**Statistical analysis**

The data were statistically analyzed by using the SPSS statistic version 16.0. One-way analysis of variance (ANOVA), followed by Duncan's multiple range tests were performed to determine the significant differences and comparison of the means among groups. Pearson correlation test was applied to evaluate the correlation coefficient of heavy metals of the liver and muscle tissues and sediment.

## RESULTS

**Arsenic and mercury concentrations in sediment**

Arsenic and mercury levels in the sediments at the different sites along the Muweis Canal are shown in Table (1).The ranges of mean concentrations were 8.47 – 14.54 µg/g for As, and 1.81 – 2.6 µg/g for Hg. The highest content of As was recorded at S5, while S3 had the highest levels of mercury. The mean concentration of As showed significant difference between the sampling sites (*P*<0.01).

**Table 1. Concentrations of As and Hg (µg/g) in sediment and tissues of *O. niloticus* at different stations**

| **Station** | **Sediment** | | **Muscles** | | **Liver** | |
|---|---|---|---|---|---|---|
| | As | Hg | As | Hg | As | Hg |
| **S1** | $9.71 \pm 0.99^{ab}$ | $1.97 \pm 0.03^{ab}$ | $4.67 \pm 0.17^{c}$ | <DL | $5.02 \pm 0.51^{a}$ | $0.09 \pm 0.007^{a}$ |
| **S2** | $11.91 \pm 1.0^{bc}$ | $1.81 \pm 0.25^{a}$ | $3.08 \pm 0.08^{a}$ | <DL | $6.87 \pm 1.07^{ab}$ | $0.31 \pm 0.007^{b}$ |
| **S3** | $8.47 \pm 0.89^{a}$ | $2.6 \pm 0.35^{b}$ | $4.81 \pm 0.15^{c}$ | $0.02 \pm 0.006^{a}$ | $5.48 \pm 0.48^{a}$ | $0.07 \pm 0.009^{a}$ |
| **S4** | $9.06 \pm 0.59^{ab}$ | $2.19 \pm 0.16^{ab}$ | $3.92 \pm 0.09^{b}$ | <DL | $5.50 \pm 0.52^{a}$ | $0.06 \pm 0.007^{a}$ |
| **S5** | $14.54 \pm 0.65^{c}$ | $2.12 \pm 0.04^{ab}$ | $5.26 \pm 0.44^{c}$ | $0.03 \pm 0.003^{a}$ | $8.40 \pm 0.35^{b}$ | $0.54 \pm 0.03^{c}$ |
| **S6** | $13.67 \pm 0.58^{c}$ | $1.93 \pm 0.12^{a}$ | $3.74 \pm 0.29^{ab}$ | <DL | $6.66 \pm 0.11^{ab}$ | $0.31 \pm 0.009^{b}$ |
| ***F*-value** | 9.77 | 1.9 | 11.12 | 20.2 | 4.62 | 152.3 |
| ***P*-value** | 0.008 | 0.16 | 0.0001 | 0.00001 | 0.01 | 0.00001 |

-The data are presented as means ± SE. Means with different letters in the same column are statistically significant at *P*<0.05 (one-way ANOVA and subsequent post-hoc multiple comparison with Duncan's multiple range tests); <DL: below detection limit.

**Assessment of sediment contamination**

The contamination factor, the potential ecological risk factor and the risk index of As and Hg in sediments of Muweis Canal are presented in Table (2). CF values ranged from 1.06 to 1.82 for As and 7.24 to 10.4 for Hg. The Er values ranged from 10.6 to 18.2 for As, and 289.6 to 416 for Hg. The calculated RI values for the sediments ranged from 306.5 to 432.6, following the orders of S3> S4> S5> S1> S6> S2.

Data from Muweis Canal were compared with the sediment quality guidelines of **MacDonald, (1994)** and **Long *et al.*, (1995)** in order to take into account the ecotoxicological significance of As and Hg concentrations (Table 3). The mean As content was above the threshold effect level (TEL) and effect range low (ERL); the mean content of Hg was three orders of magnitude higher than ERM and PEL.

**Table 2.** Contamination factor, Potential ecological risk (Er) and potential ecological risk index (RI) of As and Hg in the sediment of the Muweis Canal, Egypt

| **Station** | **As** | | **Hg** | | |
|---|---|---|---|---|---|
| | CF | Er | CF | Er | RI |
| **S1** | 1.21 | 12.1 | 7.88 | 315.2 | 327.3 |
| **S2** | 1.49 | 14.9 | 7.24 | 289.6 | 304.5 |
| **S3** | 1.06 | 10.6 | 10.4 | 416 | 426.6 |
| **S4** | 1.13 | 11.3 | 8.76 | 350.4 | 361.7 |
| **S5** | 1.82 | 18.2 | 8.48 | 339.2 | 357.4 |
| **S6** | 1.71 | 17.1 | 7.72 | 308.8 | 325.9 |

**Table 3.** Comparison of metal concentrations (μg/g d.w) in sediments in this study and other Egyptian localities

| **Location** | **As** | **Hg** | **References** |
|---|---|---|---|
| **Muweis Canal, Egypt** | 8.47 - 14.54 | 1.81 - 2.6 | This study |
| **The Northern lakes, Egypt** | - | 0.015 – 0.171 | Shreadah *et al*., 2012 |
| **The River Nile, Assiut** | - | 2.02 - 5.67 | Ibrahim & Omar, 2013 |
| **Lake Manzala** | 4.6 - 22 | - | El-Badry & Khalifa, 2017 |
| **El-Rahawy Drain** | 5.63 - 7.43 | - | Abd El-Aziz *et al*., 2022 |
| **El-Kanater** | 0.32 - 0.44 | - | Abd El-Aziz *et al*., 2022 |
| **SQGs** | | | |
| **ERL** | 8.2 | 0.15 | Long *et al*., 1995 |
| **ERM** | 70 | 0.71 | Long et al., 1995 |
| **TEL** | 7.24 | 0.13 | MacDonald et al., 2000 |
| **PEL** | 41.6 | 0.7 | MacDonald et al., 2000 |

- SQGs: Sediment quality guidelines; TEL: Threshold effect level, PEL: Probable effect level, ERM: Effect range medium, ERL: Effects range low.

## Arsenic and Hg concentrations in fish tissues

Table (1) represents the mean As and Hg concentrations in the *O. niloticus* liver and muscle at the different sampling sites. Arsenic recorded the highest concentration in muscle and liver tissues for all the analyzed samples. The mean As and Hg values in liver tissue were 5.02 - 8.40 and 0.06 -0.54g/ g, respectively. As was recorded at all sampling sites; the highest content of As in *O. niloticus* muscles was detected at station "5", while the lowest content was recorded at site "2". It was noticed that, Hg in fish muscles was detected only at stations "3 and 5".

Table (4) displays the findings of correlation test between heavy metals levels in muscle and liver tissues and sediment. The results showed that As and Hg in the sediment and muscle, sediment and liver and muscle and liver all had positive, non-significant ($P$> 0.05) correlations. However, Hg between the liver and sediment recorded a negative association.

**Table 4.** Person correlation coefficient (r) of metal concentrations between sediment and fish tissues

| Trace element | Sediment × Muscle | Sediment × Liver | Muscle × Liver |
|---|---|---|---|
| **As** | 0.186 | 0.187 | 0.082 |
| **Hg** | 0.418 | - 0.261 | 0.425 |

### Health risk assessment

Table (5) presents the EDI values compared with permissible tolerable daily intake (PTDI). The findings showed that the estimated daily intake for As from the consumption of *O. niloticus* ranged from 2.74 to 4.67µg/ kg bw/ day. This was higher than PTDI value. However, Hg values ranged from <DL to 0.03µg/ kg bw/ day, and this was below the PTDI value. The THQ values for As were higher than 1.0 at the sampling sites, with a range from 9.13 to 15.57. However, THQ values for Hg were lower than 1.0. The calculated target cancer risk for As was marked as unacceptable (higher than $10^{-4}$) at all sampling sites (Table 5).

**Table 5.** Estimated daily intake (µg/kg bw/day), target hazard quotient (THQ) and target cancer risk (CR) for As and Hg in *O. niloticus* at different stations

| Station | EDI | | THQ | | CR |
|---|---|---|---|---|---|
| | As | Hg | As | Hg | As |
| **S1** | 4.23 | - | 14.1 | - | 0.0063 |
| **S2** | 2.74 | - | 9.13 | - | 0.0041 |
| **S3** | 4.28 | 0.017 | 14.27 | 0.178 | 0.0022 |
| **S4** | 3.49 | - | 11.63 | - | 0.0052 |
| **S5** | 4.67 | 0.027 | 15.57 | 0.267 | 0.0070 |
| **S6** | 3.32 | - | 11.07 | - | 0.0049 |
| **PTDI** | 2.14 | 0.20 | | | |

-PTDI: Permissible tolerable daily intake (µg /kg bw/day) **(JECFA, 1989, 2009)**.

## DISCUSSION

Sediments usually act as both a non-point source and a sink for contaminants that can affect water quality and adversely affecting the aquatic food web **(Fernandes & Nayak, 2012; Tiquio *et al.*, 2017)**. Therefore, maintaining a healthy aquatic ecosystem and ensuring effective protection for both human health and aquatic life need attaining a good sediment quality **(Osman & Kloas, 2010)**.

Arsenic and mercury in sediments in this study showed a significant difference ($P<0.05$) between the sampling sites. As registered the highest levels for all sampling stations, with mean concentrations ranging from 8.47 to 14.54µg/ g. These results concur with those of **El-Badry and Khalifa (2017)**. However, the present data exceed those of **Abd El-Aziz *et al.* (2022)** addressing the Nile River branches; El-Rahawy Drain, and El-Kanater (Table 3). Comparison of Hg concentrations in the Muweis Canal sediment with previous researches from other Egyptian sites (Table 3) indicate that Hg levels are consistent with the values reported in the study of **Ibrahim and Omar (2013)** on the River Nile at Assiut governorate. On the other hand, these values are higher than those of **Shreadah *et al.* (2012)** who examined different northern lakes in Egypt. The excessive use of pesticides and fertilizers by farmers and discharges from agricultural and industrial sources may be the primary source for the high levels of As and Hg in sediments of Muweis Canal in this study. The highest metal concentrations in sediment, according to **Goher *et al.*, (2014)**, may have considerable anthropogenic causes.

Contamination factor, potential ecological risk index and sediment quality guidelines were utilized in this study to assess the potential ecological risks of As and Hg pollution in the sediments of Muweis Canal. In the current study, CF values of As at all the stations are higher than 1.0, reflecting moderately polluted sediments. However, the highest CF values of Hg was > 6, reflecting very high polluted sediments. Based on Er values, it was found that As had low risk while a high risk was assessed for Hg at all stations. In this respect, **Hakanson (1980)** classified the potential risk index reporting that, the surficial sediments of Muweis Canal represent a considerable ecological risk for aquatic life.

The sediment quality guidelines' values were considered as resulting from the toxicities of heavy metals. The results of comparison of As and Hg concentrations in Muweis Canal sediment with the SQGs in this study (Table 3) showed that the concentrations of Hg are higher than ERM and PEL at all sampling sites, whereas the As concentrations are higher than TEL and lower than PEL at all stations. According to these findings, occasional biological effect would occur due to As and frequently adverse effect due to Hg. Heavy metals in sediments could cause negative impacts on fish, and the benthic biota. **Raeisi *et al.*, (2014)** stated that, some polluted sediments can kill sediment dwelling organisms, and hence, the availability of food for larger fauna like fishes was decreased, and the biodiversity in the aquatic environment was declined. In addition, the bioaccumulation of sediment contaminants in the tissues of fish consumed by human causes health risks to human **(Mulligan *et al.*, 2001)**.

A variety of freshwater fish species have been shown to contain arsenic and mercury worldwide. A study in the Thigithe River, Tanzania detected As and Hg in muscle and liver of *Labeo victoriamus*, with As levels in muscles ranging from 0.25 to 2.5, while Hg ranged from 0.1 to 0.7 mg $kg^{-1}$ ; in liver, As level varied from 1.0 to 7.8 and Hg from <DL to 0.3mg $kg^{-1}$ **(Mataba *et al.*, 2016)**. In the muscles of the Nile tilapia (*O. niloticus*) in the present study, concentrations of As at all the sampling sites (Table 1) recorded higher levels, compared to other studies. Arsenic levels of 1.70, 1.55 and 1.50 µg/g were reported in the study of **Abdel-Kader and Mourad (2020)** in the muscles of *T. zillii, O. aureus* and *S. galilaeus*, respectively, from Burullus Lake, Egypt. However, As concentrations in the muscle of *O. niloticus* from Cempaka Lake in Malaysia ranged from 1.10 to 3.12mg $kg^{-1}$ dry weight **(Taweel *et al.*, 2013)**. According to **FSANZ (2011)**,

As levels in muscles of *O. niloticus* from the studied sites along Muweis Canal exceed the permissible limits set for human fish consumption (2.0µg/ g). Mercury level in *O. niloticus* muscles in this study ranged from <DL to 0.03µg/ g; this value seems to be similar to Hg concentration in muscle of the same fish species (0.045 µg/g) caught from the Manzala Lake, Egypt **(Sallam *et al.*, 2019)**. Whereas, a much higher mean level of 0.72, 0.65 and 0.55µg/ g for Hg has been reported for *O. aureus*, *T. zilliia* and *S. galilaeus*, respectively, from Lake Manzala, Egypt **(Abdel-Kader & Mourad, 2022)**. Mercury levels detected in this study are below WHO acceptable levels (0.5µg/ g).

Since *O. niloticus* are inshore fish, their feeding habit may be the reason of high metal accumulation in tissues. The As and Hg levels in the liver in this study were higher than those recorded in the muscle tissues at all stations ($P < 0.05$). In this context, **Phillips (1980)** explained that, benthic fishes can accumulate heavy metals more than fish that live in the water column, and this is dependent on the high metal levels in sediment compared to the water column. Furthermore, the high metabolic rate of liver rate may explain why it accumulates metals at a higher rate than other organs **(Aytekin *et al.*, 2019; Sadeghi *et al.*, 2019)**. The non-significant correlation coefficient between As and Hg concentrations in sediment and fish tissues found in this study suggests that the source of these metals in *O. niloticus* tissues could be the water or food rather than sediments **(Rashed, 2001)**.

Metal levels in fish muscles were utilized to determine human health risks by computing EDI, THQ and CR values **(Sharafi *et al.*, 2019; Abd-Elghany *et al.*, 2020)**. The high EDI values for As in this study, when compared to the acceptable daily intake stated by the joint FAO/WHO Expert Committee on Food Additive **(JECFA, 2009)**, suggested that the consumption of *O. niloticus* poses serious concerns to human health in regard to As. On the other hand, the lowest EDI and THQ values for Hg indicate no health hazards. While, THQ of more than unity (1.0) indicates the presence of health risks **(USEPA, 2011; Yi *et al.*, 2017)**. THQ values for As are greater than one at all stations in this study, and this suggests health risks for consumers. Likewise, THQ of As and Hg were reported to be unsafe for human consumption in all fish species in the Persian Gulf (**Keshavarzi *et al.*, 2018)**. Thus, the target cancer risk (CR) should be monitored. The **USEPA (2011)** states that CR values between $10^{-4} – 10^{-6}$ indicate an acceptable range of potential risks associated with cancer causes, and values higher than $10^{-4}$ are unacceptable. The findings of this study demonstrated that at all sites, the CR for As was extremely above the permissible value range. Therefore, the potential cancer risk associated with consuming this fish for long period of time can be concerned.

## CONCLUSION

This study would provide valuable information on arsenic and mercury concentrations in sediment and *O. niloticus* tissues along Muweis Canal, Sharkia Province, Egypt. The levels of metals in the liver, muscle and sediment varied significantly between the different sampling sites. According to sediment pollution indices, Muweis Canal's sediments are categorized as moderately to very high polluted. Therefore, there is a considerable risk for the ecosystem. Furthermore, As and Hg concentrations in the liver tissues of *O. niloticus* are more than those recorded in muscles. Concerning arsenic levels in fish muscles, the EDI, THQ and CR values were found to be higher than the acceptable value range, forming alarming signs to consumer health. As a result, regular monitoring of the metal concentrations in several fish species in the Muweis Canal is necessary.

## REFERENCES

Abd El-Aziz, M.A.E.; Hassan, A.M.; El-Naggar, H.A.; Abbas, M.M.M. and Bashar, M.A E. (2022). Potential carcinogenic and non-carcinogenic health risks of heavy metals ingestion from consumption of the crayfish, *Procambarus clarkii* in El-Rahawy Drain and ElKanater in the River Nile, Egypt. Egyptian Journal of Aquatic Biology & Fisherie 26 (3): 667 – 686..

Abdel-Kader, H.H. and Mourad, M.H. (2022). Carcinogenic and Human Risk Assessments, Trace Element Concentrations, Proximate Composition, and Liver Antioxidants of Three Commercial Tilapia Fish Species from Manzalah Wetland, Egypt. Egyptian Journal of Aquatic Biology & Fisheries 26(4): 1 – 24
.

Abdel-Satar, A.M.; Ali, M.H. and Goher, M.E. (2017). Indices of water quality and metal pollution of Nile River, Egypt. Egypt. J. Aquat. Res 43: 1–29.

Akubugwo, I. E.; Ofoegbu, C. J.; Ukwuoma, C. U. (2007). Physicochemical studies on Uburu Salt Lake Ebonyi StasteNigeria.Pakistan Journal of Biological Sciences. 10(17): 3170-3174.

Ali, H.; Khan, E. and Ilahi, I. (2019). Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. Journal of Chemistry (4): 1-14. https://doi.org/10.1155/2019/673030.

Alvarado-Flores, J.; Rubio-Franchini, I.; Sánchez-Ávila, A.S.; Ramírez-Tlalolín, G.D. and Rico-Martínez, R. (2019). Arsenic toxicity, bioaccumulation and risk assessment: A case study in Tolimique Dam, Aguascalientes, Mexico. Cogent Environmental Science, 5: 1650630 https://doi.org/10.1080/23311843.2019.1650630.

Alves, R.I.S.; Sampaio, C.F.; Nada, l.M.; Schuhmacher, M.; Domingo, J.L. and Seguramuñoz, S.I.(2014). Metal concentration in surface water and sediments from Pardo River, Brazil: human health risks. Environmental Research, 133:149 –155. DOI10.1016/j.envres.2014.05.012.

Amos, H.M.; Jacob, D.J.; Kocman, D.; Horowitz, H.M.; Zhang, Y., Dutkiewicz, S.; Horvat, M. Corbitt, E.S.; Krabbenhoft, D.P. and Sunderland, E.M. (2014). Global biogeochemical implications of mercury discharges from rivers and sediment burial. Environ Sci Technol 48: 9514–9522.

APRP (Agricultural Policy Reform Program, Water Policy Program). Survey of Nile System Pollution Sources; Agricultural Policy Reform Program (APRP), Ministry of Water Resources and Irrigation: Cairo, Egypt; 2002, Volume 64, 84p.

ATSDR, (2007). Toxicological profile for arsenic. US Public Heal Serv Agency Toxic Subst Dis Regist. doi:https://doi.org/10.1155/2013/ 286524, Genomic structure and variation of nuclear factor (erythroid-derived 2)-like 2.

Aytekin, T.; Kargın, D.; Çoğun, H.Y.; Temiz, Ö; Varkal, H.S. and Kargın, F. (2019). Accumulation and health risk assessment of heavy metals in tissues of the shrimp and fish species from the Yumurtalik coast of Iskenderun Gulf. Turkey. Heliyon 5 (8): 2131. https://doi.org/10.1016/j.ecoenv.2018.04.035.

Christophoridis, C.; Kosma, A.; Evgenakis, E.; Bourliva, A. and Fytianos, K. (2019). Determination of heavy metals and health risk assessment of cheese products consumed in Greece. Journal of Food Composition and Analysis 82:103238. https://doi.org/10.1016/j.jfca.2019.103238

Crespo-Lopez, M.E.; Augusto-Oliveira, M.; Lopes-Araújo, A.; Santos-Sacramento, L.; Yuki Takeda, P.; Macchi, B.M. Nascimento, J.L.M.; Maia, C.S.F.; Lima, R.R. and Arrifano, G.P. (2021). Mercury: What can we learn from the Amazon? Environ Int. 146:106223. doi: 10.1016/j.envint.2020.106223. Epub 2020 Oct 27. PMID: 33120229.

Dallinger, R. (1993). Strategies of metal detoxification in terrestrial invertebrates. In: Ecotoxicology of metals in invertebrates, 276pp.

El-Badry, A.A. and Khalifa, M.M. (2017). Geochemical Assessment of Pollution at Manzala Lake, Egypt: Special Mention to Environmental and Health Effects of Arsenic, Selenium, Tin and Antimony. Journal of Applied Sciences 17 (2): 72-80.

Fernandes, L.L. and Nayak, G.N. (2012). Heavy metals contamination in mudflat and mangrove sediments (Mumbai, India). Chemistry and Ecology 28 (5):435–455.

Food Standards Australia New Zealand (FSANZ) (2011). Food Standards Australia and New Zealand Standard 1.4.1 — Contaminants and natural toxicants (F2011C00542).Retrieved from: https://www.legislation.gov.au/Details/F2011C00542

Fuentes-Gandara, F.; Herrera-Herrera, C.; Pinedo-Hernández, J.; Marrugo-Negrete, J.; Díez, S. (2018). Assessment of human health risk associated with methylmercury in the imported sh marketed. in the Caribbean. Environmental research 165:324–329. https://doi.org/10.1016/j.envres.2018.05.001.

Giesy, J.P. and Hoke, R.A. (1990). Freshwater sediment quality criteria: toxicity bioassessment. In: Baudo R, Giesy JP, Muntao M (eds) Sediments: Chemistry and toxicity of in-place pollutants. Lewis Publishers, Ann Arbor, MI, pp 265–348.

Goher, M.E.; Farhat, H.I.; Abdo, M.H. and Salem, S.G. (2014). Metal pollution assessment in the surface sediment of Lake Nasser, Egypt. Egypt J Aquat Res 40:213–224.

Goodwin, T.H.; Young, A.R.; Holmes, M.G.R.; Old, G.H.; Hewitt, N. Leeks, G.J.L.; Packman, J.C.and Smith, B.P.G. (2003). The temporal and spatial variability of sediment transport and yields within the Bradford Beck catchment, West Yorkshire. Sci Total Environ 314-316:475–494.

Hakanson, L, (1980.) An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res 14:975–1001.

Ibrahim, A.T.A. and Omar, H.M. (2013). Seasonal variation of heavy metals accumulation in muscles of the African Catfish Clarias gariepinus and in River Nile water and sediments at Assiut Governorate, Egypt. J Biol Earth Sci 3(2): 236-248.

Islam, S.M. and Tanak, M. (2004) Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach form anagement:areviewand synthesis. Mar Pollut Bull 48 (7): 624–649. https://doi.org/10.1016/j.marpolbul. 2003. 12.004.

JECFA (Joint FAO/WHO Expert Committee on Food Additives)(2010). Evaluation of certain food additives and contaminants: seventy third report of the Joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series 960: 149–177.

Khallaf, E.A.; Authman, M.M.N. and Al-Nenaei, A.A. (2018). Contamination and Ecological Hazard Assessment of Heavy Metals in Freshwater Sediments and Oreochromis niloticus (Linnaeus, 1758) Fish Muscles in a Nile River Canal in Egypt. Environmental Science and Pollution Research 25: 13796–13812.

Klavins, M.; Briede, A.; Parele, E.; Rodinov, V. and Klavina, I. (1998). Metal accumulation in sediments and benthic invertebrates in Lakes of Latvia. Chemosphere 36:3043–3053.

Kouadio, L. and Trefry, J.H. (1987). Saline trace metal contamination in the Ivory coast West Africa. Air Water Soil Pollut 32: 145–154.

Kumari, P. and Maiti, S.K. (2020). Metal(loid) contamination in water, sediment, epilithic periphyton and fish in three interconnected ecosystems and health risk assessment through intake of fish cooked in Indian style. Environmental Science and Pollution Research 27(33):41914-41927.. https://doi.org/10.1007/s11356-020-10023-8.

Lavoie, R.A.; Jardine, T.D.; Chumchal, M.M.; Kidd, K.A. and Campbell, L.M.(2013). Biomagnification of mercury in aquatic food webs: A worldwide meta-analysis. Environ. Sci. Technol 47:13385–13394.

Lin, W.; Wu, K.; Lao, Z.; Hu, W.; Lin, B.; Li, Y.; Fan, H. and Hu, J. (2019). Assessment of trace metal contamination and ecological risk in the forest ecosystem of Dexing mining area in Northeast Jiangxi Province, China. Ecotoxicol. Environ .Saf, 167: 76–82.

Liu, X.; Jiang, J.; Yan, Y.; Dai, Y. Y.; Deng, B.; Ding, S.; Gan, Z. (2018). Distribution and risk assessment of metals in water, sediments, and wild fish from Jinjiang River in Chengdu, China. Chemosphere, 196: 45–52. https://doi.org/10.1016/j. chemosphere. 2017.12.135.

Long, E.; MacDonald, D.D.; Smith, S.L. and Calder, F.D. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. J Environ Manag 19: 81–97.

Long, E.R.; Robertson, A.; Wolfe, D.A.; Hameedi, J. and Sloane, G.M. (1996). Estimates of the spatial extent of sediment toxicity in major US estuaries. Environmental Science& Technology 30 (12): 3585–3592. DOI 10.1021/es9602758.

MacDonald, D.D. (1994). Approach to the assessment of sediment quality in Florida coastal waters.Vol.1-Development and evaluation of sediment quality assessment guidelines, Florida: Florida Department of Environmental Protection Office of Water Policy.

MacDonald, D.D.; Ingersoll, C.G. and Berger, T.A. (2000). Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol 39:20–31.

MacDonald, D.D.; Ingersoll, C.G. and Berger, T.A. (2000), Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch Environ Contam Toxicol 39:20–31.

Mansour, S.A. and Sidky, M.M. (2002). Ecotoxicological Studies: 3. Heavy Metals Contaminating Water and Fish from Fayoum Governorate, Egypt. Food Chemistry 78: 15-22. http://dx.doi.org/10.1016/S0308-8146 (01) 00197-2

Markert, B.A.; Breure, A.M. and Zechmeister, H.G. (2003). Definitions, strategies and principles for bioindication/biomonitoring of the environment. In: Markert, B.A., Breure, A.M., Zechmeister, H.G. (Eds.), Bioindicators and Biomonitors. Elsevier Science Ltd, pp. 3–21.

Marziali, L. and Valsecchi, L. (2021). Mercury Bioavailability in Fluvial Sediments Estimated Using Chironomus riparius and Diffusive Gradients in Thin-Films (DGT). Environments 8: 7. https://doi.org/10.3390/ environments8020007.

Mataba, G.R.; Verhaert, V.; Blust, R. and Bervoets, L. (2016). Distribution of trace elements in the aquatic ecosystem of the Thigithe river and the fish Labeo victorianus in Tanzania and possible risks for human consumption. Science of The Total Environment 547:48-59.

Ministry of Agriculture and Land Reclamation, (2017). In Fish Statistics Year Book. Cairo, Egypt. General Authority for Fish Resources Development. https://www.gafrd.org (in Arabic)

Mwanamoki, P.M.; Devarajan, N.; Niane, B.; Ngelinkoto, P.; Thevenon, F. and Nlandu, J.W. (2015). Trace metal distributions in the sediments from river-reservoir systems: case of the Congo River and Lake Ma Vallee, Kinshasa (Democratic Republic of Congo). Environ Sci Pollut Res Int 22(1):586–597.

Ogbomida, E.T.; Nakayama, S.M.; Bortey-Sam, N.; Oroszlany, B.; Tongo, I.; Enuneku, A.A.; Ozekeke, O.; Ainerua, M.O.; Fasipe, I.p. and Ezemonye, L.I. (2018). Accumulation patterns and risk assessment of metals and metalloid in muscle and offal of free-range chickens, cattle and goat in Benin City, Nigeria. Ecotoxicology environmental safety 151:98–108. https://doi.org/10.1016/j.ecoenv.2017.12.069.

Omar, W.A.; Zaghloul, K.H.; Abdel-Khalek, A.A.and Abo-Hegab, S. (2013). Risk assessment and toxic effects of metal pollution in two cultured and wild fish species from highly degraded aquatic habitats. Arch Environ Contam Toxicol 65:753–764.

Osman, A.G.M. and Kloas, W. (2010). Water quality and heavy metal monitoring in water, sediments, and tissues of the African catfish Clarias gariepinus (Burchell, 1822) from the River Nile, Egypt. J Environ Prot 1:389–400.

Phillips, D.J.H. (1980), Quantitative aquatic biological indicators: their use to monitor trace metal and organochlorine pollution. Applied Science Publishers Ltd., London, 488p.

Pinzón-Bedoya, C.H.; Pinzón-Bedoya, M.L.; Pinedo-Hernández, J.; Urango-Cardenas, I. and Marrugo-Negrete, J. (2020). Assessment of Potential Health Risks Associated with the Intake of Heavy Metals in Fish Harvested from the Largest Estuary in Colombia. Int J Environ Res Public Health 17(8): 2921. doi: 10.3390/ijerph17082921. PMID: 32340229; PMCID: PMC7215908.

Raeisi, S.; Rad, J.S.; Rad, M.S.and Zakariaei, H. (2014). Analysis of heavy metals content in water, sediments and fish from the Gorgan bay, southeastern Caspian sea, Iran. Int J Adv Biol Biomed Res 2:2162–2172.

Rashed, M.N. (2001). Monitoring of environmental heavy metals in fish from Nasser Lake. Environ Int 27:27–33.

Sadeghi, P.; Loghmani, M. and Afsa, E. (2019). Trace element concentrations, ecological and health risk assessment in sediment and marine fish Otolithes ruber in Oman Sea, Iran. Marine Polution Bulletin 140: 248-254.

Sallam, K.I.; Abd-Elghany, S.M. and Mohammed, M.A. (2019). Heavy Metal Residues in Some Fishes from Manzala Lake, Egypt, and their health-risk assessment. Journal of Food Science 84 (7): 1957-1965.

Shirneshan, G.; Riahibakhtiari, A.; Sayfabadi, S.J. and Mortazavi, S. (2013). Environmental geochemistry of Cu, Zn and Pb in sediment from Qeshmis land, Persian gulf,Iran:acomparisonbetweenthenorthernandsoutherncoastandecologicalrisk. Geochemistry International 5(8):670–676. DOI10.1134/S0016702913050078.

Shreadah, M.A.; Abdel Ghani, S.A.; Taha, A.A.; Ahmed, A.M. and Hawash, H.B.I. (2012). Mercury and Methyl Mercury in Sediments of Northern Lakes, Egypt. Journal of Environmental Protection 3 (3): 254-261. doi: 10.4236/jep.2012.33032.

Taweel, A.; Shuhaimi-Othman. and Ahmad, A.K. (2013). Assessment of heavy metals in tilapia fish (Oreochromis niloticus) from the Langat River and Engineering Lake in Bangi, Malaysia, and evaluation of the health risk from tilapia consumption. Ecotoxicology and Environmental Safety 93: 45 –51.

Tiquio, M.G.J.; Hurel, C.; Marmier, N.; Taneez, M.; Andral, B.; Jordan, N. and Francour, P. (2017). Sediment-boundtracemetalsinGolfe-JuanBay,northwesternMediterranean: distribution, availability and toxicity. Mar Pollut Bull 118(1):427–436.https:// doi.org/10.1016/j.marpolbul.2017.02.065.

Turekian, K.K. and Wedepohl, K.H. (1961). Distribution of the elements in some major units of the Earth's crust. Geol Soc Am Bull 72: 175–192.

Ullah, A.A.; Maksud, M.; Khan, S.; Lutfa, L. and Quraishi, S.B. (2017). Dietary intake of heavy metals from eight highly consumed species of cultured sh and possible human health risk implications in Bangladesh. Toxicology Reports 4:574–579. https://doi.org/10.1016/j.toxrep.2017.10.002.

Uluturhan, E. and Kucuksezgin, F. (2007). Heavy metal contaminations in Red Pandora (*Pagellus erythrinus*) tissues from the Eastern Aegean Sea, Turkey. Water Res 41:1185–1192.

US EPA (1989). Risk assessment guidance for superfund, vol. I: Human Health Evaluation Manual. EPA/540/1-89/002. Office of Emergency and Remedial Response, United States Environmental Protection Agency, Washington.

US EPA (2011). Regional screening level (RSL) summary table. United States Environmental Protection Agency, Washington https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.

US EPA (2012). Regional Screening Level (RSL) Summary Table (TR=1E-06, HQ=1), United States Environmental Protection Agency: Washington, DC, USA, 2019. Available online: http://www.epa.gov/regshwmd/risk/human/Index.htm (accessed on 10 February 2002).

US EPA (2019). Risk based concentration table. United States Environmental Protection Agency, Philadelphia, Washington.

USEPA (United States Environmental Protection Agency) (2011) Risk Assessment Guidance for Superfund. Volume I: (Part A: Human Health Evaluation Manual; Part E, Supplemental Guidance for Dermal Risk Assessment; Part F, Supplemental Guidance for Inhalation Risk Assessment). US Environmental Protection Agency Washington, DC.

Varol, M. and Sunbul, M.R. (2019). Environmental contaminants in sh species from a large dam reservoir and their potential risks to human health. Ecotoxicol Environ Saf; 169:507–515. https://doi.org/10.1016/j.ecoenv.2018.11.060.

WHO (2017). Guidelines for Drinking-water Quality, fourth ed. incorporating the rs taddendum. Geneva. https://apps.who.int/iris/handle/10665/254637.

Yi, Y.; Tang, C.; Yi, T.; Yang, Z. an Zhang, S. (2017). Health Risk Assessment of Heavy Metals in Fish and Accumulation Patterns in Food Web in the Upper Yangtze River, China. Ecotoxicology and Environmental Safety 145: 295-302. https://doi.org/10.1016/j.ecoenv.2017.07.022

Zhao, S.; Feng, C.; Quan,, W.; Chen, X.; Niu, J. and Shen, Z. (2012). Role of living environments in the accumulation characteristics of heavy metals in fishes and crabs in the Yangtze River Estuary, China. Mar Pollut Bull 64:1163–1171.