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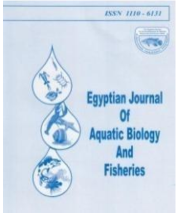

Water Quality Indices and Risk Assessment of Consumption of Nile Tilapia Tissues from Ismailia Canal, Egypt

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ABSTRACT

Ismailia Canal is considered one of the most important sources of fresh water for a large number of citizens, yet it is exposed to many sources of pollution. Water and fish samples were collected to study the quality of water as well as the concentration of metals in water, fish tissue, and its effect on humans. Several indices were used to evaluate the water and fish quality of Ismailia Canal water. Based on the weighted arithmetic water quality index (WAWQI) results, the canal water was classified as excellent for drinking, aquatic life and irrigation. While the study of Metal Index (MI) showed that the water of the Ismailia Canal is polluted for drinking water and aquatic life while it is not polluted for Irrigation water, as well as the resultant contamination index (Cd) values ranged between low ($Cd < 1$) to high ($Cd > 3$) in the station (1) due to the effluent of drainage water treatment plants which throwing waste water rich with Aluminum, Iron and Manganese. Aquatic Toxicity Index (ATI) results indicate the suitability of the canal's water for different fish species. Hazard Index (HI) and Hazard Quotient (HQ) indicate that no risk ($HQ < 1$) on the other hand (HI) is 1.538. This result revealed the moderate risks from the consumption of edible tissue of the Nile Tilapia *(O. niloticus)*. For improvement of water quality in Ismailia canal, the dumping of pollutants of all kinds, industrial, agricultural and domestic, into the waters of the Ismailia Canal must be prohibited and criminalized.

INTRODUCTION

Environmental pollution problems are one of the most serious national issues that requires great efforts at all levels; individual, groups, national and international. This is especially true with respect to pollution of rivers because they serve as the recipient of urban and rural wastewater. Water quality issues have become of major concern to all agencies dealing with water resources management and planning. This requires data collection, analysis and interpretation. One major goal of surface water quality data collection may be the estimation of magnitude of changes in the concentration of various constituents **(Yehia *et al.*, 2011)**. Water quality state of a water body depends on a large number of physical, chemical and biological indicators. An evaluation approach, such as water quality index that can be used to indicate the overall water quality condition, is essential **(Elshemy & Meon, 2011)**. Water quality index is a mathematical mechanism for summarizing water quality data into simple terms (e.g., excellent, good, bad, etc…); it reflects the level of water quality in rivers, streams and lakes **(Al-Shujairi, 2013)**. Moreover, the metal quality indices have been applied for assessing the drinking water resources with respect to metals **(Backman *et al.*, 1997)**. Recent years have witnessed significant attention being paid to the problems of environmental contamination by a wide variety of chemical pollutants, including the heavy metal ions. Trace elements may exert beneficial or harmful effects on plant, fish and human life, depending on their concentration. In Egypt, the pollution by trace metal ions is one of our most serious environmental problems. Effluents resulting from daily domestic and industrial activities may induce considerable changes in the physical and chemical properties of the Nile water. These changes may greatly alter the environmental characteristics of river reaches **(El Sayed, 2011)**.

Unlike many organic wastes, heavy metals cannot be degraded biologically into harmless products. As a result, heavy metals tended to accumulate in the food chain and environment **(Goher, 2018)**. Discharge of heavy metals into river or any aquatic environment can change both aquatic species diversity and ecosystems due to their toxicity, persistence and accumulative behavior **(Al-Weher, 2008)**. Fish are one of the most important bio-monitoring devices in aquatic systems for estimating the level of mineral contamination **(Authman, 2008)**. They can be accumulated in fish tissues by direct consumption of water across permeable membranes of gills and the digestive tract **(Ribeiro *et al.*, 2005)**. Which can be transferred to humans through fish ingestion **(Imam *et al.*, 2020)**. This leads to serious health problems in humans **(Alinnor & Obiji, 2010)**. Some of the heavy metals do not perform essential functions in living organisms. Therefore, these metals are very toxic even at very low concentrations for all life forms including human health **(Goher *et al.*, 2019)**. The most critical heavy metals are Cd, Hg and Pb from a water pollution viewpoint. Some metals (Cu, Co, Fe, Ni, and Zn) are essential trace metals for living organisms but become toxic at higher concentrations **(Igiri *et al.*, 2018)**. Field and laboratory studies have shown that the accumulation of heavy metals in tissues depends mainly on water concentrations of metals and the period of exposure. Although some other environmental factors such as water temperature, oxygen concentration, pH, hardness, salinity, alkalinity and dissolved organic carbon may influence and play an important role in mineral accumulation and fish toxicity **(Linbo *et al.*, 2009)**. The concentration of heavy metals in fish tissues reflects previous exposure via water and/or food. The assessment of heavy metal contamination in the aquatic environment is determined by measuring their concentrations in water and living organisms. Biological monitoring of heavy metal accumulation in body parts (muscles) is a representative measure of exposure **(Mustafa & Guluzar, 2003)**. No one can deny that the Nile is the main source of life in Egypt. The Nile River is the soul of Egypt, providing more than 95% of its freshwater demand. However, it receives different pollutants discharged into the water body along its stretch from Aswan (downstream of the High Dam) to Cairo, which is approximately 950 km **(Goher *et al.*, 2021)**. Ismailia Canal is the most vital canal arise from the Egyptian River Nile to supply water for several governorates in the east of the Nile Delta. It provides water for irrigation, navigation, and drinking, industrial and local purposes to the largest populated eastern governorates of Egypt **(Abu-Zaid *et al.*, 2020)**. Ismailia Canal is considered as a sink for all contaminants discharged into the River Nile for being one of the main distal downstream of the Nile. In addition, the upper part of the Ismailia Canal from Al-Mazalat to Bilbeis is threatened from uncontrolled, direct and indirect activities in the surrounding area such as petroleum, iron and steel and detergent industries. Besides, agriculture effluent and power station, which causes dramatic changes in its water quality is considered **(Youssef *et al.*, 2010)**. In addition to the afore- mentioned factors, water treatment plants causing dramatic changes in its water quality by throwing wastewater rich with aluminum, iron and manganese is another factor **(Goher *et al.*, 2014)**. Therefore, this study aimed to address water quality indices to study the possibility of this water for different uses, as well as the concentration of heavy metals in water and the accumulation of these elements in the Nile tilapia and the effects of consuming these fish on humans.

MATERIALS AND METHODS

1. Study area

Ismailia Canal extends eastward for about 125km from the Nile River in the Al-Mazalat region north of Cairo to the city of Ismailia on the Suez Canal. In Ismailia, it was divided into two branches: one in the north to supply the city of Port Said and the second in the south to supply the city of Suez.

The upper part of the Ismailia Canal (from Cairo to Abu Zaabal, the western side) receives a large amount of pollutants from the industrial zone (Shubra al-Khaimah, Mustrad, Abu Zaabal industrial areas), which includes the activities of petroleum and petroleum gas, iron and steel, Abu Zaabal Fertilizers Company , Alum (aluminum sulfate), detergent industries and electric power plant as well as water treatment plants that have made drastic changes in water quality by dumping wastewater rich in aluminum, iron and manganese. In addition to waste disposal, seepage from villages and septic tanks, distributed near the canal stream and agricultural effluents. The details of surface water sampling from the study sites are presented in Table (1) and Fig. (1).

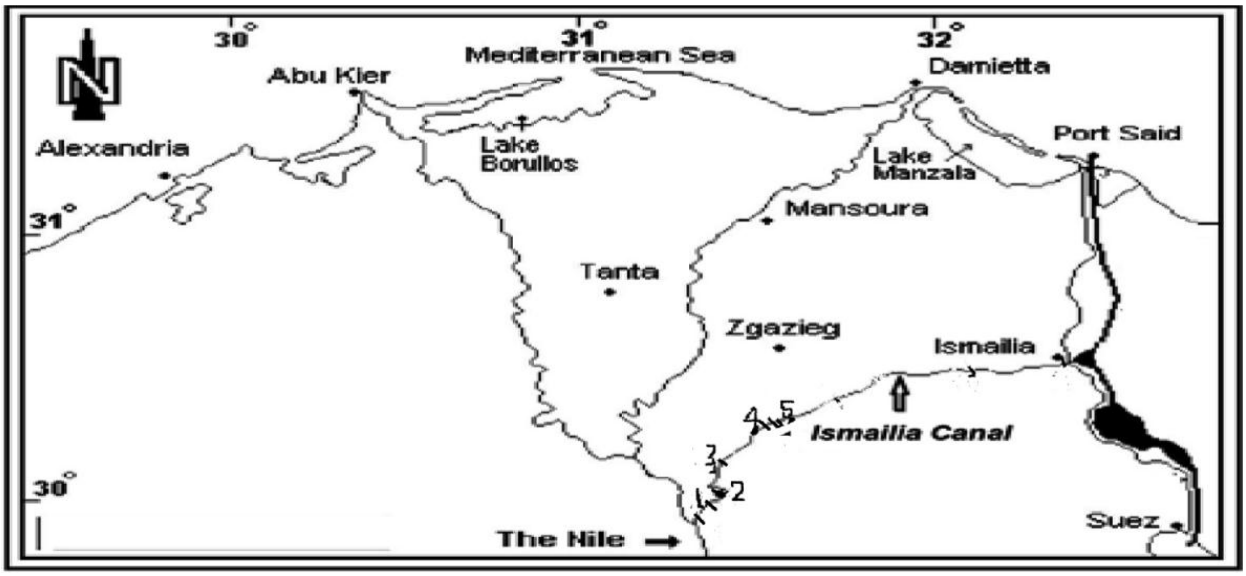

Fig. 1. Sample locations at Ismailia Canal, Egypt during 2021

Table 1. Details of surface water sampling location of Ismailia Canal

Station No.	Station	latitude	longitude
1	In front of Al-Amiria drinking water purification station	**30 06n 41nn**	**31 16n 22nn**
2	Mostourd	**30 09n 55nn**	**31 17n 36nn**
3	Ring Road	**30 10n 09nn**	**31 18n 20n**
4	after Abu Zabaal fertilizer Company by 2km	**30 16n 46nn**	**31 23n 06n**
5	Bilbeis	**30 24n 57nn**	**31 34n 33nn**

2. Methodology of water parameters evaluation

The subsurface (about 30 cm) water samples were collected in polyvinyl chloride Van Dorn plastic bottles (2 L) from 5 sites on two sampling occasions to provide 10 water samples in total. A Ruttner Water Sampler with the capacity of 2L was used to collect the samples which were kept in the well-cleaned plastic bottles. The methods of the American Public Health Association **(APHA, 2012)** were used for the determination of most physicochemical parameters, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), NO_2–N, NO_3–N, NH_4–N, PO_4–P, total phosphorus (TP), SiO_2, CO_3^{-2}, HCO_3^-, chloride, sulfate, calcium & magnesium. Water temperature (°C), pH and conductivity (EC, µS cm^{-1}) were measured *in situ* using a Hydrolab model (Multi Set 340i WTW, Weilheim, Germany) after previous calibration. Transparency was measured using a white/black Secchi disk (25 cm in diameter) and expressed as the Secchi disk depth (SDD). Heavy metals were measured after digestion by conc. HNO_3 using Atomic Absorption (I.C.P. plasma 400).

3. Water quality index (WQI)

WQI was estimated according to **Al- Mohammed and Mutasher (2013)**. **The Weighed Arithmetic Water quality index (WAQI) formula of this method is given by**

$$WAQI = \sum_{i=1}^{n} QiWi \,/\, \sum_{i=1}^{n} Wi \qquad (1)$$

Where, Qi is the sub quality index of ith parameter (or Qi is the quality rating scale of each parameter); Wi = unit weight of each parameter, and
n = number of parameters.

4. Aquatic toxicity index (ATI)

The index was developed by **Wepener *et al.* (1992)** to assess the health of aquatic ecosystems. Since an extensive toxicity database is available for fish, toxic effects of varying water quality on fish have been employed as health indicators of the aquatic ecosystem. In the case of the ATI, the Solway Modified Unweight Additive Aggregation function **(Wepener *et al.*, 1992; Sarkar and Abbasi 2006)** was employed as an aggregation technique, applying the following formula:

$$ATI = \frac{1}{100}\left(\frac{1}{n}\sum_{i=1}^{n} qi\right)^2 \qquad (2)$$

Where, ATI is the final index score; *qi* is the quality of the *i*th parameter (a value between 0–100), and *n* is the number of determinants in the indexing system.

Table 2. Water rating according to ATI and WAWQI methods

ATI		WAWQI	
WQI	**Rating**	**WQI**	**Rating**
60–100	**Suitable for all fish species**	**0–25**	**Excellent**
51–59	**Suitable only for hardy fish species**	**26–50**	**Good**
0–50	**Totally unsuitable for normal fish life**	**51–75**	**Poor**
		76–100	**Very poor**
		>100	**Unsuitable**

5. Metal quality indices

Three different quality indices were used to determine the metal contamination of Ismailia Canal water.

A. *The contamination index (Cd)*

The contamination index measures the relative contamination of different metals separately and manifests the combined effects of all metals. It was computed as follows **(Backman *et al.*, 1997):**

$$Cd = \sum_{i=1}^{n} C\,fi \qquad (3)$$

Where, C_{fi} was calculated as the following equation: $Cfi = \frac{CAi}{CNi} - 1$

Cfi is the factor of contamination for ith metal; C_{Ai} is the measured value for ith metal, and C_{Ni} is the upper allowable value of ith metal (N refers to the normative value). The resultant Cd values are grouped into three classes: medium (Cd = 1–3) and low (Cd < 1). C_{Ni} is considered as the standard permissible value.

B. Pollution index (PI)

It is based on individual metal calculations and categorized to 5 classes according to the following equation **(Caerio *et al*., 2005)**.

$$PI = \frac{\sqrt{\left[\left(\frac{Ci}{Si}\right)^2_{max} + \left(\frac{Ci}{Si}\right)^2_{Min}\right]}}{2} \qquad (4)$$

C_i: the concentration of each element.
S_i: metal level according to national water quality criterion.

C. Metal index (MI)

It is based on a total trend evaluation of the present grade. The higher the concentration of a metal compared to its respective MAC value, the worse the quality of water. MI value > 1 is a threshold of warning **(Bakan *et al.*, 2010)**. According to **Tamasi and Cini (2004)**, the MI is calculated by using the following formula:

$$MI = \sum_{i=1}^{n} \frac{Ci}{(MAC)_i} \qquad (5)$$

C_i: the concentration of each element.
MAC: maximum allowable concentration.

6. Human health risk

The human health risk assessment associated with the fish consumption was established using Hazard Quotient (HQ) and Hazard Index (HI) developed by the United States Environmental Protection Agency using the following equation.

$$HQ = 10^{-3}\, x\, \frac{EF\ x\ ED\ x\ FI\ x\ MC_f}{RFD_0\ x\ BW\ x\ AT} \qquad \textbf{(6)}$$

Where, EF is the exposure frequency (365 days/year); ED is the life time exposure duration (70 years); FI is the mass of the fish ingested by person per day (57 mg in Egypt, the per capita consumption of fish in Egypt for human food is averaged 20.8 Kg; MC_f is the metal concentration in fish (in milligrams per kilogram, ww); BW = body weight (A body weight of 70 kg is used as a default value for the adult as suggested by USEPA; AT is averaging time for non-carcinogens (365 days/year x number of exposure years), and 10^{-3} is the unit conversion factor. It was assumed that cooking has no effect on metals toxicity in seafood.

7. Hazard index (HI)

The hazard index (HI) was obtained using the following equation:

$$\mathbf{HI} = \sum_{i=1}^{n} \mathbf{HQ_i} \qquad (7)$$

Where, *i* is the individual heavy metal.

8. Fish samples and measurement of heavy metals in fish muscles

The samples of *O.niloticus* fish were collected from all sites during winter and summer 2021. The yield of each site was 15 fish, with an average length (23±3 cm) and weight (180± 7g). About 1g from previously oven dried muscle tissues was ignited and digested with concentrated HNO_3 and HCl according to procedures recommended by **AOAC (2005)**. The concentrations of heavy metals in the fish muscle were measured via Atomic Absorption (I.C.P. plasma 400). Results were expressed in µg /g dry weight of the tissue and as maximum and minimum of the all sites of collection.

9. Statistical analysis

The one-way ANOVA test was used to determine spatial and temporal significant differences for the obtained data **(Leščešen *et al.*, 2015)** using Excel-Stat software. In addition, standard deviation and pair coefficients of correlations (r) were calculated.

RESULTS AND DISCUSSION

The result of the physicochemical characteristics of water in Ismailia canal is presented in Table (3). Temperature ranged between 15.8 & 31°C, with a mean value of 23.38°C, and a highly significant difference was recorded between seasons ($P < 0.01$). The Ismailia Canal water was within the best range for fish and aquatic organisms in winter while exceeding the ideal value in summer. Temperature is positively correlated with Cr (r= +0.58), Ni (r=+0.66), Cd (r=+0.49) n=21 P <0.01. This result agrees with that of **Goher *et al.* (2014**) who reported that, the increase of heavy metal in hot seasons may be attributed to the liberation of heavy metals from the sediment to the overlying water under the effect of both high temperature and organic matter decomposition. On the other hand, temperature is high negatively correlated with HCO_3^- (r=-=0.92), Ca (r=--0.99), n=21 P <0.01, confirming that the decrease of water temperature increases the solubility of CO_2 and subsequently increases bicarbonate ions and Ca^{2+}, which exist in water as hydrogen carbonate; this result coincides with that of **Abdel-Satar *et al.* (2017)** and **El Sayed *et al.* *(*2020).**

Water transparency ranged between the lowest value (40Cm) during winter and the highest one (100Cm) during summer. Transparency is positively correlated with DO (r=+0.48) and pH (r=+0.55). While transparency is negatively correlated with TS, COD, NH_4^+, HCO_3^-, Cl, Al, Mn and Cr with r= (-0.53, -0.82, -0.61, -.49, -0.44, -0.56, -0.52 and-0.44), respectively. This result concurs with that of **Goher *et al.* (2014)** and **El Sayed *et al.* (2020)** who deduced that, water transparency is affected by particulate content of river water from suspended matter and floating substances.

EC recorded the highest value 339-424 µs cm^{-1} in winter due to drought period and the lowest value 312-316 µs cm^{-1} in summer due to flood period (dilution effect), with a highly temporal significant difference, where EC and the water level are inversely related **(Islam *et al.*, 2015)**. As expected, a high positive correlation exists between EC and TDS (r= 0.99), also TS, BOD, COD with (r= 0.44, 0.94 and 0.66), as well as nutrient, cation, anions and heavy metals. Whereas, EC negatively correlated with DO (r= -0.42). Total dissolved solid has the same manner as EC confirmed by the high positive correlation (r= 0.99). TSS and TDS were varied in the range of 44 - 75 mg/l and 206.4 – 275.6 mg/l, respectively, with a highly temporal significant difference. While, the highest value was recorded in front of Al-Amiria drinking water purification station; this may be attributed to effluents discharged into the water bodies. According to TSS value, Ismailia Canal water is classified as cloudy. **Kidd (2011)** reported that, water with TSS concentration less than 20 mg/l tends to be clear. Water with TSS levels between 40 and 80 mg/l tends to appear cloudy, while water with concentrations over 150 mg/l usually appears dirty.

The pH of the Ismailia Canal lies in the alkaline side, where the lowest value 7.9 recorded at the conflicting of Al-Amiria drinking water purification station and the maximum value 8.43 recorded at station (3). pH highly positive correlation with DO (r=0.36) conformed the effect of photosynthetic activity on the elevation of pH value **(Shehata & Badr, 2010)** & CO3 (r=0.65), while it is negatively correlated with Mn, Cr, Ni, Zn and Cd with (r= -0.67, -0.63, -0.5,-0.45 and -0.47). This approved the precipitation of these metals to the bottom sediment with the increase of water pH **(Moustafa *et al.*, 2010)**. Ismailia Canal water was completely oxygenated within the year with a maximum value of 7.12mg/ l and minimum value of 5.48mg/ l, the decreases of DO is related to different wastewaters, which enter the canal as sewage, urban runoff and industrial **(Stahl & Ramadan, 2008)**.

Table 3. Physical and chemical characteristics of water in the Ismailia Canal in 2021, compared to guidelines used in WQI, PI and MI computations

Seasons	winter		summer		Drinking EWQS 2007	Irrigation FAO**	Aquatic live CCME 2017
Parameter	Range	mean±SD	Range	mean±SD			
Trans (cm)	40-75	62±13.51	50-100	76±19.49		<35	8. - 28.
temp (°C)	15.8-16.7	16.22±0.41	30.1-31	30.54±0.35			
EC (µScm-1)	399-424	409 ± 9.97	312-316	315±1.73	2000	3000	
TDS (mg/l)	260.4-275.6	267.05±6.02	206.4-210.4	208.55±1.53	1000	2000	500
TSS (mg/l)	44- 75	57.2± 11.43	43-62	50 ± 7.19			
pH	7.98-8.43	8.19±0.16	7.90-8	8.13± 0.13	6.5- 8.5	8.5	6.5 - 9
DO (mg/l)	5.48-7.10	6.10±0.67	6.2- 7.12	6.55± 0.34	6		5
BOD (mg/l)	2.38-3.80	3.04±0.52	1.93-3.8	2.71± 0.82	3		
COD (mg/l)	6.32-12.1	8.30±2.31	4.12-7.81	5.56± 1.38	10		
PO_4 (µg/l)	15.7-40.0	26.67±11.51	10.27-34.89	16.94±10.25		2000	
NO_2 (µg/l)	6.90-8.55	7.71±0.73	1.68-5.57	3.00± 1.50	60		60
NO_3 (µg/l)	60.4-85.7	72.02±9.34	9.17-18.26	14.26± 3.61	10000	10000	2930
NH_4 (µg/l)	129.-234.	167.05±41.93	111.98-353.23	175±101.19	410	5000	1270 - 77
SiO_2 (mg/l)	2.91-3.90	3.44±0.43	0.56-0	0.67± 0.11			
SO_4 (mg/l)	21- 28.07	24.7± 2.73	11.00-13.30	12± 1.04	250	960	
CO_3 (mg/l)	0-6	1± 2.68	0-0	0± 0.00		30	
HCO_3 (mg/l)	143- 157	150± 4.99	133-135	134± 0.89		610	
Mg (mg/l)	15.7-18.1	16.54±0.98	10.7-10	10.70± 0.00	50	60	
Ca (mg/l)	29.8-32.2	31.24±0.94	22.4-22	22.44±0.00	75	400	
Cl (mg/l)	26.9-28.2	27.64±0.55	17.4-18	17.64± 0.45	250	1036	120
TP(µg/l)	44.5-65.3	54.52+9.45	33.76-56.49	40.88± 9.99	1000		
Al (µg/l)	996.6-3410	1713.96±980.5	282.6-1058.6	648.88±299.7	200	5000	100
Fe (µg/l)	212.4-541.6	327.12±138.4	208.2-318.2	255.64±53.06	300	5000	300
Mn (µg/l)	29.4-76.4	54.84±17.99	33.3-41.8	36.3±3.289	100	200	100
Cr (µg/l)	1-3.4	2.44±0.920	2.6-6.6	3.4 ±1	50	100	10
Ni (µg/l)	0.8-1.8	1.36±0.384	1.6-2.4	1.92±0.334	20	200	25
Zn (µg/l)	2.6-6.6	4.56±1.532	6-25.2	14.36±7.891	3000	2000	50
Cd (µg/l)	0-0.2	0.12±0.109	0.2-0.2	0.2 ±0	3	10	1
Pb (µg/l)	0.2-1	0.64±0.296	0.2-2.2	0.8 ±0.8	10	5000	7

These results are confirmed by the highly negative correlation between DO and BOD, COD, PO_4^{-3}, NH_4^+ and NO_2^- with (r= -0.41,-0.64, -0.51, -0.27 and -0.46, respectively), where the dissolved oxygen was consumed by the oxidation of nitrogenous compounds and organic matter **(El Sayed *et al.*, 2020)**.Concerning the current study, the levels of both BOD and COD in Ismailia Canal water were within the international permissible levels, showing narrow variations of BOD and COD values between different seasons and localities. They varied in the ranges of (1.45-3.8) and (4.12- 12.12) mg/l, respectively. BOD was highly positive correlation with BOD /COD r= 0.46, BOD / PO_4^{-3} r=0.5, BOD / NO_2^- (r= 0.9), BOD /NO_3^- (r=0.92).

The main components of alkalinity of surface water are carbonates and bicarbonates **(Hassouna *et al.*, 2019)**. Carbonates concentration depleted completely in all stations, except station 3 which recorded 6mg/ l in winter, whereas bicarbonates varied in the narrow range from maximum value 157.5 mg/l in winter to a minimum value of 133 mg/l in summer, with a highly significant difference between seasons. Bicarbonates are highly positive correlated with Mg, Ca, Cl and Al with r= 0.93, 0.88, 0.92 and 0.79; this result agrees with the finding of **El Sayed (2015**) for the same canal.

Chlorides and sulfates have the same manner, with a clear increase in winter due to drought period and a decrease in summer due to dilution effect. Chlorides and sulfates fluctuated in the range of 17.44–28.27 and 11– 28.7mg/l, respectively, with a highly temporal significant difference.

Calcium and magnesium values varied in the range of 22.44–32.27 and 10.7–18.9mg/ l, respectively, with a highly significant difference between seasons. The decrease in Ca and Mg concentrations in summer seasons may be attributed to the precipitation of $CaCO_3$ resulting from an increase in temperature **(Goher, 2021)**. It may be an outcome of the adsorption of $MgCO_3$ onto clay minerals and bottom deposition due to water temperature rise as reported in the study of **Chiu *et al.* (2010)**. This result is established by a high negative correlation between temperature with Ca and Mg (r= -0.99 and -0.97, respectively). The present result showed low Mg^{+2} concentration compared to Ca^{+2}; this is due to the behavior of dissolved CO_2 in water, which may affect the concentration of magnesium ion in solution since CO_2 reacts with calcium ion salts more than with magnesium ion, thus converting large quantities of calcium into soluble bicarbonate **(El-Sayed, 2011)**.

Nutrient salts (NO_2^- , NO_3^- , NH_3 , PO_4^{-3} , T.P and SiO_2) fluctuated in the following range (1.98-8.55, 9.17- 85.78, 111.98 – 353.23, 10.27-40.2, 34.2 – 65.32 µg/l and 0.56 – 3.9 mg/l), respectively; these values were lower than those recorded in previous studies (Table 4) **(Abdo, 1998; El-Haddad, 2005; El-Sayed, 2008; Stahl & Ramadan, 2008; Abdo & El-Nasharity, 2010; Abdo *et al.*, 2012; Goher *et al.*, 2014**; **Hamed, 2019)** for the same canal. This is mainly attributed to two reasons, the first is high dilution effect in the last years, which renews the water in the canal and the second is adjusting some factories to their conditions, which led to the reduction of pollutants such as Alum company as well as the degradation of the discharged pollutants by self-purification. On the other hand, nitrite value was lower than the corresponding value of nitrate; this may be attributed to oxidation of nitrite into nitrate. Nitrite and nitrate concentration was in low value in summer seasons; this may be attributed to its utilization by phytoplankton in surface water. Ammonia has no spatial and seasonal significant difference. **EWQS (2007)** has set a limit of 0.41 mg/L of nitrogen as a maximum admissible limit for ammonia and highly positive correlation with Mn, Cr, Ni and Zn (r = 0.92, 0.73, 0.45 and 0.41, respectively). The value of PO_4^{-3}& TP showed slight increase in winter this may be attributed to the increase of the decay of the phytoplankton by microbiological activity during the drought period (**Singh and Choudharyn, 2013)**. In different side silicate value showed the minimum value in summer seasons and may be attributed to its uptake by diatoms, bacteria and fishes as well as the sedimentation of SiO_2 - on clay or fine clay to the bottom **(El-Sharkawy, 2010),** this result is confirmed by the high positive correlation Temperature/SiO_2 (r=-0.98).

The concentrations of Al, Fe, Mn, Cr, Ni, Zn, Cd and Pb in Ismailia Canal water were found in the range of (282.6- 3410, 208.2- 548.6, 33.3-76.4, 1-6.6, 0.8 – 2.4, 2.6- 25.2, 0 – 0.2 and 0.2 -2.2 µg/l.

Table (4): Comparison of physicochemical parameter and heavy metals concentrations in Ismailia canal water with previous studies.

Parameters							
TDS (mg/l)		149.8-231			210–365	293	206.4-275.6
TSS (mg/l)		28.7-83.3			39–176	138.7	43-75
pH	7.4-8.1	8-8.47			7.09–8.46	8.27	7.9-8.43
DO (mg/l)		6.4-10	4.9 -8. 9	6 – 10	5.78–9.98	7.37	5.48 -7.12
BOD (mg/l)	2.4-5.46	2- 4.92		2.8 – 5.2	0.3–7.18	4.03	1.93-3.8
COD (mg/l)	2.8-4.46	6.0 – 19.2	<25	6 – 16)	3.68–15.08	9.17	4.12-12.1
PO_4 (µg/l)	23.7-157.7	11.24-91.96		23 – 165.5	8–399	150	10.27 -40
NO_2 (µg/l)	1.24 - 6.3	2.18-10.24		9 – 18,	2--27	61	1.68 - 8.55
NO_3 (µg/l)	17.6-116.9	10.04-51.21		20 – 52	31–584	354	9.17 -85.7
NH_4 (µg/l)	160-580	240-540		108 –500	88-598	245	111.98-353.2
SiO_2 (mg/l)	1.9-5.4	1.75-5.88		1.44 – 7.70	0.37 -878	6.47	0.56 -2.93
TP(µg/l)	86-300	82.77-380.41		109 – 1478	38-480	317	33.76-65.3
Al (µg/l)				100-800	55–45400	3821	282.6-3410
Fe (µg/l)	400- 6460	110 – 640		190- 300	109–2239	675	208.2-541.6
Mn (µg/l)	58.9-711.3	40 – 360	60	100- 180	20– 483	229	29.4-76.4
Cr (µg/l)			1				1- 6.6
Ni (µg/l)			2.5		0.0– 25		0.8-2.4
Zn (µg/l)	4.2-311	1.8 – 54.8,	100	40 -95	2– 127	39	2.6 -25.2
Cd (µg/l)			1	15 -29	0– 3	9	0 -0.2
Pb (µg/l)		7.5 – 35.7	5	1--3	11– 34	24	0.2 -2.2
References	Abdo, (1998)	El-Hadad, (2005)	Stahl and Ramadan, (2008)	Abdo and El-Nasharity, (2010)	Goher et al,2014	Hamed, 2019	present study

The heavy metal concentrations decreased in the sequence during winter and summer as Al> Fe>Mn> Zn>Pb>Cr> Ni >Cd in different sites. The result showed that the heavy metals Al, Fe and Mn at different sites were higher in winter seasons than in summer as well as Al, Fe and Mn increase in site (1) than all sites. The concentration of Al exceed detection limit in all station in study period reached to 17 fold the permissible limits in winter and 5 fold in summer in site (1) this attributed to water treatment plants which caused dramatic changes in its water quality by throwing waste water rich with Aluminum, Iron and Manganese **(El Sayed, 2015)** this result confirmed by high positive correlation Al/Fe (r= 0.86). Despite the high Al value in this study, it is less than that of **Stahl and Ramadan (2008)** and **Goher *et al.* (2014)** for the same canal (Table 4). Fe and Mn concentrations along the canal remained nearly constant below (detection limit) ~ 0.3 mg/l and 0.05 mg/ l, respectively, except station (1) which exceeds this value in winter seasons. The concentration of Cr, Ni, Zn, Cd and Pb were below the detection limit.

Water quality indices

Water quality index is a mathematical mechanism for summarizing water quality data into simple terms (e.g., excellent, good, bad, etc.); it reflects the level of water quality in rivers, streams and lakes **(Al-Shujairi, 2013).**

Two water quality indices were used to assess the water quality in Ismailia Canal including the (ATI) and (WAWQI). The ATI was developed to evaluate the aquatic ecosystem health and determine the suitability of aquatic environments for different fish species. Ten water parameters were selected to compute the ATI (PO_4-^{3}, TDS, DO, pH, NH_4^+, Mn, Cr, Zn, Ni, Pb). Table (6) shows the values of ATI, the score of which ranged from 60.75 to 62.99, with a mean value of 61.55 for the whole canal. These results indicate the suitability of the canal's water for different fish species.

Another index used to assess the water quality in Ismailia Canal for different purpose is WAWQI, which categorizes water quality according to the degree of purity by using the most measured water quality variables. To compute the WAWQI, a total of 21, 20 and 16 variables were selected to assess the suitability of water in the Ismailia Canal for drinking, irrigation and aquatic life, respectively, according to WAWQI modules. Egyptian standards were used for drinking water assessment. The selected parameters for drinking water include TDS, pH, DO, BOD, COD, NH_3-N, NO_3^- -N, TP, Cl, SO_4^{-2} , Ca^{+2}, Mg^{+2} , Al, Cd, Cr, Fe, Mn ,Ni, Pb and Zn, While, TDS, pH, NH_3-N, NO_3 -N, NO_2^--N, PO4 $^{-3}$, CO_3^{-2}, HCO_3^- , Cl, SO4 $^{-2}$, Ca^{+2}, Mg^{+2}, Al, Cd, Cr, Fe, Mn ,Ni, Pb and Zn were selected for irrigation. The selected variables for the aquatic life include TDS, pH, DO, COD, BOD, NH_3-N, NO_3^--N, Cl Al, Cd, Cr, Fe, Mn, Ni, Pb and Zn. Based on the WAWQI results, the canal water was classified as excellent for drinking, aquatic life and irrigation with WQI, 1.85, 1.4 and 0.13, respectively. The WAWQI indicated that the water in the Ismailia Canal is suitable for drinking, irrigation and aquatic life utilization.

Table 5. WQI and its categorization of Ismailia Canal water for drinking, irrigation and aquatic life utilization

Station	Drinking water		Aquatic life water		Irrigation water	
1	**1.93**	**Excellent**	**2.05**	**Excellent**	**0.15**	**Excellent**
2	**1.68**	**Excellent**	**0.94**	**Excellent**	**0.08**	**Excellent**
3	**1.70**	**Excellent**	**1.15**	**Excellent**	**0.10**	**Excellent**
4	**1.64**	**Excellent**	**1.36**	**Excellent**	**0.14**	**Excellent**
5	**2.32**	**Excellent**	**1.47**	**Excellent**	**0.13**	**Excellent**

Table 6. ATI and its categorization of Ismailia canal water

Station	Winter		Summer	
1	62.99	Suitable	61.20	Suitable
2	61.76	Suitable	62.13	Suitable
3	62.00	Suitable	62.10	Suitable
4	61.89	Suitable	61.73	Suitable
5	60.75	Suitable	61.68	Suitable

Metal quality indices

Different indices were calculated to assess the metal contamination of Ismailia canal water; the first one is the Pollution Index (PI), that is dependent on the effect of the individual metal. While the other index, Metal index (MI) and Cd based on the effect of the total metals level.

Pollution index (PI)

The pollution index (PI) was used in our study to determine the score of trace metals toxicity in water samples. It is based on individual metal calculations and categorized to five classes (Table 7) according to **(Caeiro *et al.*, 2005)**. The results indicate a various pollution degree of the studied metals for aquatic life in Ismailia Canal. Pollution index exhibited that Mn, Cd, Pb, Cr Ni, and Zn have not polluted effect for different usage PI **≤ 1**. On the other hand, Al showed moderately pollution affected (PI >**2-3)** to seriously affected PI >**5** at all station for drinking water. However, Al showed seriously affected for aquatic life water and no effect for irrigation water usage. Fe showed slightly pollution effect at stations (1) for drinking water and aquatic life water and no effect for irrigation water, (Fig. 2b).

Table 7. Categories of water pollution index

Class	PI value	Class
1	≤1	no effect
2	>1-2	slightly affected
3	>2-3	moderately affected
4	>3-5	strongly affected
5	>5	seriously affected

Table 8. Pollution index of the measured metals in Ismailia Canal water according to guideline levels of drinking, irrigation and aquatic life water

Station		**Drinking**	**Effect**	**Aquatic life**	**Effect**	**Irrigation**	**Effect**
Al	**1**	**8.926**	**seriously affected**	**17.853**	**seriously affected**	**0.357**	**no effect**
	2	**3.722**	**strongly affected**	**7.443**	**seriously affected**	**0.149**	**no effect**
	3	**4.511**	**strongly affected**	**9.022**	**seriously affected**	**0.180**	**no effect**
	4	**2.843**	**moderately affected**	**5.685**	**seriously affected**	**0.114**	**no effect**
	5	**3.046**	**strongly affected**	**6.093**	**seriously affected**	**0.122**	**no effect**
Fe	**1**	**1.047**	**slightly affected**	**1.047**	**slightly affected**	**0.063**	**no effect**
	2	**0.503**	**no effect**	**0.503**	**no effect**	**0.030**	**no effect**
	3	**0.751**	**no effect**	**0.751**	**no effect**	**0.045**	**no effect**
	4	**0.512**	**no effect**	**0.512**	**no effect**	**0.031**	**no effect**
	5	**0.680**	**no effect**	**0.680**	**no effect**	**0.041**	**no effect**
Mn	**1**	**0.833**	**no effect**	**0.833**	**no effect**	**0.208**	**no effect**
	2	**0.457**	**no effect**	**0.457**	**no effect**	**0.114**	**no effect**
	3	**0.639**	**no effect**	**0.639**	**no effect**	**0.160**	**no effect**
	4	**0.760**	**no effect**	**0.760**	**no effect**	**0.190**	**no effect**
	5	**0.638**	**no effect**	**0.638**	**no effect**	**0.160**	**no effect**
Cr	**1**	**0.074**	**no effect**	**0.371**	**no effect**	**0.037**	**no effect**
	2	**0.047**	**no effect**	**0.235**	**no effect**	**0.024**	**no effect**
	3	**0.040**	**no effect**	**0.202**	**no effect**	**0.020**	**no effect**
	4	**0.040**	**no effect**	**0.198**	**no effect**	**0.020**	**no effect**
	5	**0.040**	**no effect**	**0.198**	**no effect**	**0.020**	**no effect**
Ni	**1**	**0.075**	**no effect**	**0.060**	**no effect**	**0.008**	**no effect**
	2	**0.054**	**no effect**	**0.043**	**no effect**	**0.005**	**no effect**
	3	**0.061**	**no effect**	**0.049**	**no effect**	**0.006**	**no effect**
	4	**0.050**	**no effect**	**0.040**	**no effect**	**0.005**	**no effect**
	5	**0.057**	**no effect**	**0.045**	**no effect**	**0.006**	**no effect**
Zn	**1**	**0.002**	**no effect**	**0.128**	**no effect**	**0.003**	**no effect**
	2	**0.001**	**no effect**	**0.065**	**no effect**	**0.002**	**no effect**
	3	**0.003**	**no effect**	**0.204**	**no effect**	**0.005**	**no effect**
	4	**0.002**	**no effect**	**0.104**	**no effect**	**0.003**	**no effect**
	5	**0.004**	**no effect**	**0.257**	**no effect**	**0.006**	**no effect**
Cd	**1**	**0.047**	**no effect**	**0.141**	**no effect**	**0.014**	**no effect**
	2	**0.033**	**no effect**	**0.100**	**no effect**	**0.010**	**no effect**
	3	**0.033**	**no effect**	**0.100**	**no effect**	**0.010**	**no effect**
	4	**0.047**	**no effect**	**0.141**	**no effect**	**0.014**	**no effect**
	5	**0.047**	**no effect**	**0.141**	**no effect**	**0.014**	**no effect**
Pb	**1**	**0.042**	**no effect**	**0.061**	**no effect**	**0.000**	**no effect**
	2	**0.014**	**no effect**	**0.017**	**no effect**	**0.000**	**no effect**
	3	**0.042**	**no effect**	**0.052**	**no effect**	**0.000**	**no effect**
	4	**0.045**	**no effect**	**0.061**	**no effect**	**0.000**	**no effect**
	5	**0.121**	**no effect**	**0.131**	**no effect**	**0.000**	**no effect**

Metal index (MI)

It is based on a total trend evaluation of the present grade. By increasing the concentration of a metal compared to its respective maximum allowable value (MAC), the worse impact of the quality of the water appeared. MI value >1 is a threshold of a warning limit **(Cude, 2001)**. Eight heavy metals (Al, Cd, Cr, Fe, Mn, Ni, Pb, and Zn) were selected to assess the contamination of water in Ismailia Canal with metals, based on the Metal Index (MI). According to MI values, all selected sites in Ismailia canal water suffer from seriously metal pollution for the drinking water and aquatic life utilization. On the other hand, site 1 is the most polluted (MI = 13.888 & 26.686 for drinking water and aquatic life utilization, respectively); this may be attributed to the effluent of drainage water treatment plants which caused dramatic changes in its water quality by throwing waste water rich with aluminum, iron and manganese. This result was confirmed in the study of **Nour *et al*. (2022)** who reported that, the higher levels of metals in some samples might be originated mostly from anthropogenic sources related to industrial, agricultural and urbanization activities along the investigated canal. Whereas, according to MI, the water in Ismailia Canal is classified as not polluted for irrigation water.

Table 9. Pollution index of the measured metals in the Ismailia Canal water during 2021

Station	D water		Aq.Water		Irr. Water
1	13.888	polluted	26.686	polluted	0.892
2	5.798	polluted	10.912	polluted	0.425
3	8.011	polluted	15.291	polluted	0.576
4	5.437	polluted	10.611	polluted	0.515
5	6.063	polluted	11.504	polluted	0.510

The contamination index (Cd)

The contamination index measures the relative contamination of different metals separately and manifests the combined effects of all metals. The resultant Cd values in winter ranged between low (Cd < 1) at station 2,4 and 5, medium (Cd = 1–3) at station 3 and high (Cd > 3) in station (1) due to the effluent of drainage water treatment plants, which throws waste water rich with aluminum, iron and manganese. While, low Cd values (Cd < 1) were observed in summer at all stations, as shown in Fig. (2).

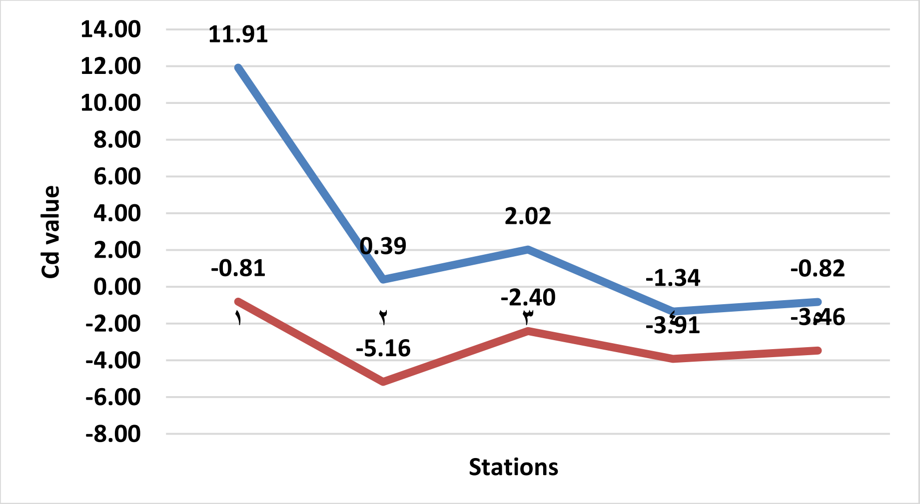

Fig. 2. Contamination index of the measured metals in the Ismailia Canal water during 2021

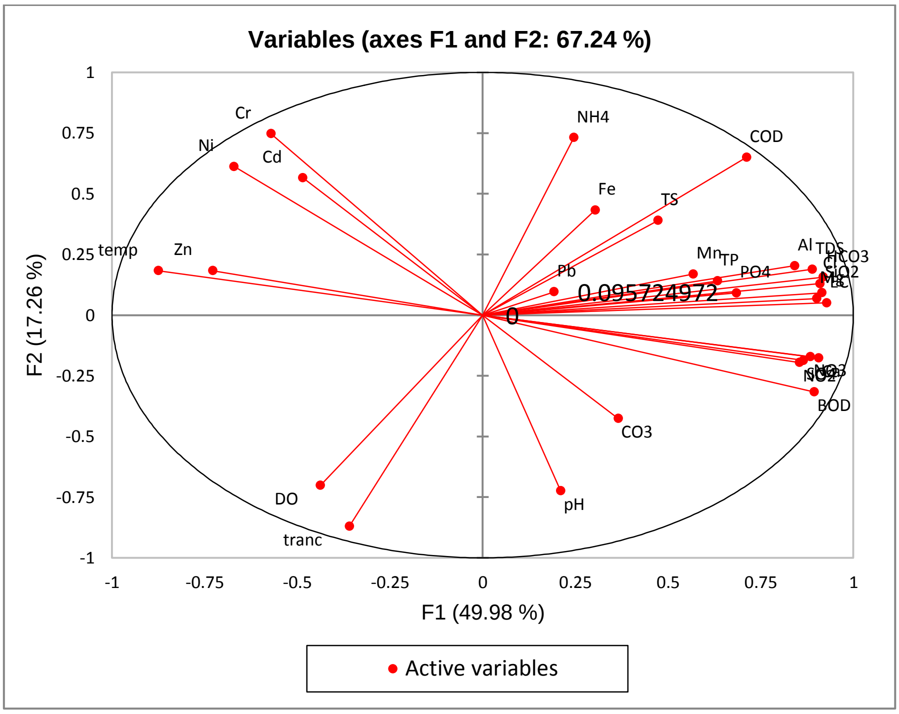

Fig. 3. Principal component analysis (PCA) (Axis I and II) for measured parameter of the Ismailia Canal water

According to Fig. (3), the principal component analysis (PCA), Al, Fe, Pb and Mn were positive significantly correlated with each other. This may be attributed to the same allochthonous sources of these metals, which increased during winter season (cold environment) and correlated by increase of variables NH_4, COD, TSS, TP, PO_4^{-3}, TDS, Cl, HCO_3^-, SiO_2, Mg, EC, Ca, SO_4^{-2}, $NO_2^{-,}$ $NO_3^-{}_,$ BOD, CO_3^{-2}, and pH on other side this element high correlated with decreased of variables temperature, dissolved oxygen and transparence. PCA showed that Cr, Ni, Zn and Cd were more positively affected by the temperature. The first axis explaining 49.98 % of the variables and it was primarily associated with the heavy metals, while axis 2 was explaining 17.26 % of the variance of some physicochemical variables.

Table (10) minimum, Maximum and mean values of heavy metals (µg/g dry wt.) in muscles of *O. niloticus* from Ismailia canal during winter and summer 2021.

Metals	Winter				Summer			
	minimum	max	mean	S.D.	minimum	max	mean	S.D.
Al-F	17.35	105.60	55.37	32.75	14	34	25	10
Fe-F	34.80	177.40	91.62	59.25	14	50	32	17
Mn-F	4.45	11.75	8.28	2.73	2	5	3	2
Cr-F	1.30	2.05	1.86	0.32	1	1	1	0
Ni-F	0.60	1.00	0.86	0.15	0	15	4	6
Zn-F	29.55	46.40	37.36	7.49	32	40	35	3
Cd-F	0.00	0.05	0.04	0.02	0	0	0	0
Pb-F	0.30	2.40	0.79	0.90	0	7	2	3

The results of different measured heavy metals were shown in table (10), the results were expressed as minimum and maximum for the all five collected sites. In winter season the metal ranged as follows: Al (17.35-105.60),Fe (34.80-177.40), Mn (4.45-11.75),Cr (1.30-2.05), Ni (0.60-1.00), Zn

(29.55-46.40), Cd (0.00-0.05)and Pb (0.30-2.40).The order of distribution for the all metals as shown in the mean values were Fe > Al > Zn >Mn> Cr >Pb> Ni >Cd.For summer season, the range of different metals were Al (14-34),Fe (14-50), Mn (2-5),Cr (1-1), Ni (0.00-15.00), Zn (32-40), Cd (0.00-0.00)and Pb (0.00-7.00).So the order of distribution were Zn >Fe > Al > Ni >Mn>Pb>Cr > Cd(not found).According to the maximum permissible limits of **FAO (1983)** and **WHO (1989)** which was(50,40,1,0.5,0.5 µg/g) for(Fe, Zn, Mn, Cd and Pb),the results revealed that , Mn and Pb exceed the permissible limit in both winter and summer seasons. While Fe exceed the limits only in winter season and was under the permissible limit in summer season. For Zn and Cd the results were under the limits in winter and summer. This study, which we are in agreement with some researchers in this field, such as both *(***Authman *et al.*, 2011),** where they found that metals concentration in fish organs exhibited seasonal variations and they attribute these variations to the increase or decrease of drainage water discharged into the drainage canal. **Tekin-Özan and Kir (2008)** described that bioavailability of metals may influenced by physiological activities of fish during different seasons. **Abdel-Khalek (2015)** in muscle tissues of Nile tilapia at southern part of river Nile at Shoubra El-Khaema. This also complies with **(Watanabe *et al.*, 2003; Masoud *et al.*, 2007)** who mentioned that, bioaccumulation of metals in tissues varies from metal to metal. Moreover, **Koca *et al.*, (2005)** postulated that the accumulation patterns of contaminants in fish and other aquatic organisms depend on both uptake and elimination rates of contaminants. **Jezierska and Witeska (2006)** concluded that the difference in the amounts of various metal ion accumulation in fish body result from different affinity of metals to fish tissues, different uptake, deposition, and excretion rates. Studies related to the bioaccumulation of metals in tissues demonstrated the variation of metal accumulations (**Younis *et al.*, 2015)**. Moreover, **Koca *et al.* (2005)** postulated that the accumulation patterns of contaminants in fish and other aquatic organisms depend on both uptake and elimination rates of contaminants. Bioaccumulation of metals may lead to high mortality rate or cause many biochemical and histological alterations in the survived fish **(Soltan *et al.*, 2005).** Table (11) shows some previous studies on different places of the Nile River and the effect of heavy metals on the muscles of Nile tilapia.

Table (11). Comparison of heavy metals concentrations in muscles of *Oreochromis niloticus* with previous studies in river Nile, Ismailia canal and lakes.

location	Fe	Ni	Zn	Cd	Pb	references
Aswan	**-**	**0.05 ± 0.04**	**1.31 ± 0.52**	**0.09 ± 0.9**	**0.34 ± 0.08**	***Ahmed et al.*, 2022**
Abbassa region	**-**	**0.99 ± 0.05**	**2.80 ± 0.30**	**0.7 ± 0.46**	**0.53 ± 0.10**	***Ahmed et al.*, 2022**
Mariout	**-**	**1.41 ± 0.18**	**3.9 ± 0.17**	**1.17 ± 0.15**	**2.7 ± 0.25**	***Ahmed et al.*, 2022**
Aswan	**26.08 ± 6.44**	**-**	**41.84 ± 7.62**	**0.67 ± 0.64**	**3.99 ± 2.64**	**Alaa and. Osman2012**
El-Zamalek district	**5.37±0.5**	**-**	**0.90±0.22**	**0.009±0.002**	**0.662±0.058**	***Abeer et al.*, 2014**
Abu Zaabal region	**-**	**-**	**-**	**1.96±0.18**	**1.43±0.17**	**Mohamed *et al.*, 2011**

Human health risk

The health risks resulting from the consumption of *O. niloticus* from Ismailia canal have been estimated based on Hazard Quotient (HQ). The HQ is a ratio of determined dose of a pollutant to a reference dose level. The interpretation of the HQ value is binary: HQ is either ≥ 1 or < 1, where HQ > 1 indicates a reason for health concern.

Figure (4) show the non-carcinogenic (Hazard Quotient) risks of heavy metals through edible tissue exposure route using the eight measured metals to calculate the HQ values. According to **USEPA (2012)** no health risk may occur as a result of ingestion of the fish at Hazard Quotient (HQ) or total Hazard Index (HI) below one, while the greater the value of (HQ) and (HI) above 1, the greater the level of risk associated with the fish consumption. Hence, HI < 1 means no hazard; 1 > HI < 10 means moderate hazard while greater than 10 means high hazard or risk **(Ukoha, 2014)**.

The present results indicated that the obtained HQ values was in the order Cr (HQ)=0.842>Pb (HQ=0.328)> Zn (HQ = 0.098)> Ni (HQ=0.095)> Fe (HQ =0.072)> Cd (HQ=0.037)>Mn (HQ=0.034)> Al (HQ=0.033) which indicate that no demonstrate risk (HQ < 1) associated with consumption of 57 g/day of ***O. niloticus***from Ismailia Canal. On the other hand the total non-carcinogenic hazard index (HI) for the analyzed heavy metals is 1.538. This result revealed that the risks from consumption of edible tissue of the Nile Tilapia (O. niloticus) 1.5 times higher than the threshold value of 1. The human health risk assessment for heavy metal contamination delineated low risk in edible tissues. The hazard index value (HI = 1.538) was classified as moderate risk level (10 > HI > 1) **(Ukoha, 2014).** This moderate value based mainly on the HQ values of Cr (HQ = 0.842) and Pb (HQ = 0.321).

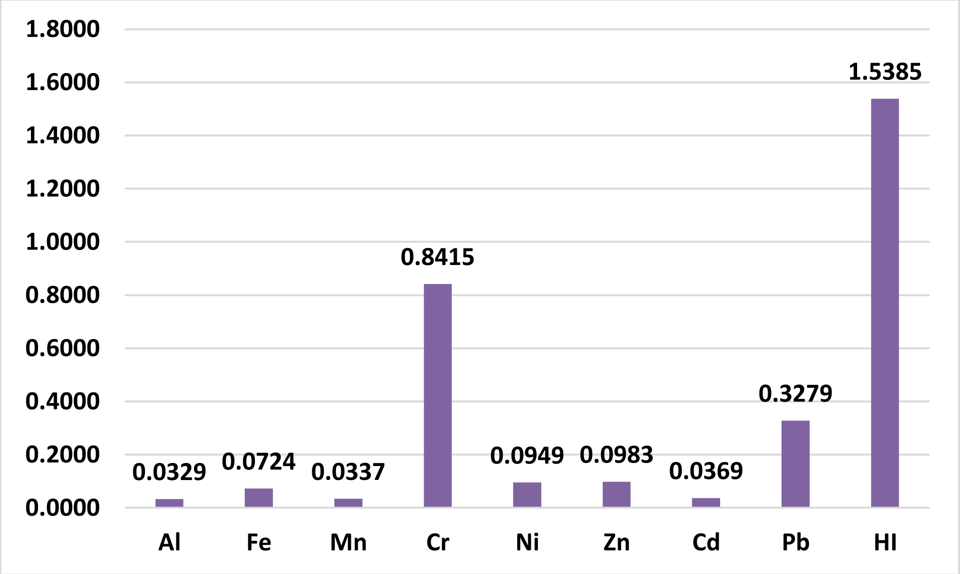

Figure (4): HQ and HI to human population from metals through *O. niloticus* from Ismailia canal.

CONCLUSION

The Ismailia Canal is considered one of the most important sources of drinking and irrigation water in Egypt. Despite this, it is exposed to many sources of pollution, including the activities of petroleum and petroleum gas, iron and steel, Abu Zaabal Fertilizers Company , Alum (aluminum sulfate), detergent industries and electric power plant as well as water treatment plants that have made drastic changes in water quality by dumping wastewater rich in aluminum, iron and manganese. Water and fish were collected from 5 different places of the Ismailia Canal from El- Amiriya to Belbeis to study the quality of water and fish as well as the concentration of metals in fish tissue. WAWQI was studied to study the suitability of this water for drinking, aquatic life and irrigation water while ATI was used to study the extent to which this water can be used for fish. The results of WQI showed that the water quality of the Ismailia canal is excellent for various uses as a result of severe dilution. While the study of MI, PI and Cd showed that the water of the Ismailia Canal is polluted for drinking water and aquatic life while it not polluted for Irrigation water. On The other hand the results indicated that, there were differences in places in some heavy metal accumulations in the muscle tissues of the studied fish. This study showed that consumption of fish from these places does not expect adverse health effects in most cases. However, the effects of the cumulative risks of the mineral gave a particular warning signal in higher fish consumption rates. The reason for improving the water quality in the Ismailia Canal is due to the severe mitigation at the time of the study, in addition to the modification of some factories to their conditions. For further improvement, the dumping of pollutants of all kinds, industrial, agricultural and domestic, into the waters of the Ismailia Canal must be prohibited and criminalized.

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