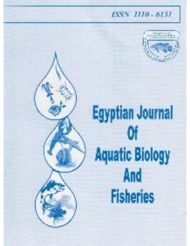
Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(5): 137 – 147 (2022)
www.ejabf.journals.ekb.eg



Assessment of heavy metal concentration in water and the Nile tilapia of Lake Manzala, EL-Kapoty, Egypt

Ahmed, I. Abd El-kader[1], Mohamed Bahnasawy[2], Mahmoud Zaky[3], Marwa A. El-Serafy[4]*

1. Department of Environmental Sciences, Faculty of Science, Port Said University, Egypt.
2. Department of Zoology, Damietta Faculty of Science, Damietta, Egypt.
3. Department of Botany, Faculty of Science, Port Said University, Port Said, Egypt.
4. Analytical Specialist, Faculty of Pharmacy, University of Port Said, Egypt.

*__Corresponding author:__elserafy.marwa@yahoo.com

ARTICLE INFO

Article History:
Received: Aug. 14, 2022
Accepted: Aug. 27, 2022
Online: Sept. 9, 2022

Keywords:
Lake Manzala,
EL-Kapoty,
Heavy metals,
Nile tilapia

ABSTRACT

Heavy metal levels (Copper, zinc, lead, and cadmium) in water and fish (Nile tilapia) have been evaluated in three different locations in (EL-Kapoty) Lake Manzala. Metals' quantities in both fish tissues and water were measured. Fish samples with weights ranging between 78.7 and 42.3gm varied significantly by area and season. All metals under study peaked in summer and dropped in winter. The levels of different metals in fish tissues and water were ordered in the correct sequence: Copper > zinc > Lead > cadmium. In water, the mean concentrations of metals were as follows: Cd is 0.006 mg/L, Pb is 0.007mg/L, Zn is 0.032mg/L, and Cu is 0.007mg/L. The water's cadmium amount was higher than the limit allowed for drinking water. The mineral concentration in fish organs was much higher than in water. The gills of the tested fish had the greatest mineral concentration, while the muscles showed the lowest. Despite the fact that Lake Manzala was polluted with heavy metals, the amount of minerals in the fish's muscles did not overpass the limits allowed, making the fish safe.

INTRODUCTION

Metals are typically introduced into the aquatic environment through atmospheric deposition, geological matrix erosion, or anthropogenic activities such as industrial effluents, domestic sewage, and mining wastes **(Tarvainen *et al*., 1997; Jewett *et al*., 2000)**. Heavy metals have received a lot of attention in aquatic systems due to their accumulation and toxicity levels in flora and fauna (biota) **(Mason, 1992)**. Whilst some metals such as zinc and copper, which are biologically necessary and exist in the natural composition of aquatic ecosystems, are believed to be toxic at enormously high concentrations. Whereas, other metals such as cadmium and lead are toxic to the living organisms even if these metals were in small quantities. In human body, zinc performs a wide range of biological functions. It is not only a fundamental component of more than one hundred enzymes, involved in a wide range of essential metabolic reactions but also participates in the synthesis of various hormones. However, excess zinc consumption is believed to cause violent vomiting, abdominal pain, collapse, and liver degeneration. Remarkably, copper is almost certainly a necessary component of all cells. Nevertheless, the excessive consumption of copper causes gastrointestinal disruption, headache, hepatic necrosis and hepatic failure. On the other hand, cadmium is strongly believed to be the most dangerous component to public health. It is worth mentioning that, it is responsible for causing itai-itai, which is a rickets-like bone disease. It can also be a reason behind cardiac enlargement, iron deficiency, pulmonary emphysema, renal failure, and gonadal atrophy. In addition, Pb is a chemical metal of high toxicity that is harmful to both humans and animals. Iron deficiency anemia , encephalopathy, mass and coordination damage, stomach pain, vomiting , stomach pain, and insomnia are all symptoms of lead poisoning **(Khallaf *et al.*, 2018)**. Metals, like many organic contaminants, are not degradable and can be collected throughout the food chain, causing harmful effects far from the point of pollution **(Fernández *et al*., 2000)**. Biomagnification is counted as one of the reasons for the accumulation of high concentrations of heavy metals in the food web. The surrounding media such as water and sediment can also be a source of these metals in the food chains **(Tulonen *et al*., 2006)**. Scientific studies have widely used aquatic organisms to monitor and assess the risk of heavy metals' levels in contaminants. Lake Manzala, with a surface estimated area of 52,611ha, is Egypt's largest lake as well as the most productive for fisheries. Unfortunately, several agricultural drains discharge significant amounts of various pollutants into the environment lake **(Badawy *et al*., 1995)**. Thus, accurate data on their density in aquatic ecosystems are required **(Janssen *et al*., 2000)**. As a result, this study's objective was to assess the level of pollutants in the area of EL-Kapoty, where this study determined the copper, zinc, lead and cadmium concentrations, not only in water but also in some fish organs, gills and muscles.

MATERIALS AND METHODS

Fig. (1) presents a map of Lake Manzala bounded by the Mediterranean Sea, the Suez Canal, and the Nile's Damietta section on the north, the east and the west, respectively. The lake was previously brackish, but due to increased water resource and sewage discharged through seven major drains, it has been changed to an eutrophic freshwater lagoon **(Abdel-Baky *et al*., 1998)**. During winter, spring, summer, and autumn seasons, samples of water and tilapia fish were collected from three locations (31°25'06.0000"N latitude and 32°25'60.0000"E longitude) (Fig. 1). The sites (L1, L2, and L3) chosen are the far northeastern (EL-Kaboty) regions. They are heavily polluted and different levels of pollution can be represented. Two polyethylene bottles, which were acidified with HNO_3 were used to take water samples on a monthly basis from a depth of fifty centimeters, and then saved for analysis.

Fig.1. Lake Manzala geographical location

Each fish had its gills, skin, and dorsal muscle dissected, weighed, and placed in small conical flasks. The flasks were put in an oven at a temperature of 105^0C to be dried for approximately one day. The flasks were then put for acid digestion on a hot plate with $HNO_3 + HClO_4$ at a ratio of 2:1 until a clear solution was obtained. Using an atomic absorption spectrophotometer, the extraction method of **APHA (1998)** was used to determine the concentrations of the four heavy metals (copper, zinc, cadmium and lead) in water (AAS, Perkin Elmer 2380). In order to estimate the substantial differences in the four heavy metals studied in fish organs and water based on location and season, the two-way ANOVA method was used **(Flora, 1982)**. The significance level also known as alpha level was set at 0.05.

RESULTS

Table (1) displays the average concentrations of the four heavy metals in Lake Manzala. The following values are the mean concentrations of the four heavy metals under study in the water samples collected from the study site; the measured values in mg/L were as follows: Cu (0.007), Zn (0.032), Pb (0.007), and Cd (0.006).

The sequential order of the values of heavy metals is similar to those recorded in previous studies on Lake Manzala **(Abdel-Baky *et al*., 1998**;

Ibrahim *et al.*, 1999a). The concentration of metals under study were extensively focused at location L3. Due to industrial and farming activities, enormous quantities of wastes coming from factories and agricultural fields, such as water drained from farms, sewage and other types of wastes are delivered to this area through Bahr Al-Baqar region. **Badawy and Wahaab (1997)** investigated this location and recorded a high accumulation of organic carbon. **Radwan *et al.* (1990)**, **Abdel-Baky *et al.* (1998)** and **Dheina (2007)** detected a link between the huge quantity of organic matter and the concentration of heavy metals in water. This order of occurrence preceded the studies on Lake Manzala **(Abdel-Baky *et al.*, 1998; Ibrahim *et al.*, 1999a)**. At L3, all metals were generally more concentrated. Through the region of Bahr Al-Baqar, this area is plagued by enormous quantities of farming wastes and water drained from the fields, in addition to the factories' chemical wastes. **Badawy and Wahaab (1997)** illustrated that, humans are not welcome in the Bahr Al-Bakar area. This site has a high concentration of organic carbon **(Dheina., 2007)**. Many authors discovered a link between the huge quantities of organic matter and heavy metals' concentrations in water **(Radwan *et al.*, 1990; Abdel-Baky *et al.*, 1998)**. The discharge of heavy metals from the soil particles to the overlying water as a result of both high temp and a fermentation process induced by organic substances degradation results in an increase in metal levels of contamination throughout warm climates (spring and summer). Metal concentrations in water have been reported to change seasonally **(Zyadah, 1995; Elewa *et al* ., 2007)**. Several studies refer to different water bodies suh as the River Nile **(Abdel-Baky *et al.*, 1998; Ibrahim *et al.*, 1999a; Zahran *et al.*, 2015; Abu-Zaid *et al.*, 2020)**. A low density of Cu **(Abdel-Mohsien & Mahmoud, 2015)** was recorded (0.01-0.02 mg/L); lower levels of cadmium and higher levels of lead **(Zahran *et al.*, 2015)** were detected. In addition, higher levels of copper, zinc, cadmium and lead **(Abdel-Baky *et al.*, 1998)** (0.08, 7.94, 0.11 and 0.64 mg/L, respectively) were reported. Additionally, compared to Lake Piaseczno in Poland (**Radwan *et al.*, 1990)**, **Ibrahim *et al.* (1999a)** noted that, Lake Manzala contains higher levels of copper, zinc, lead and cadmium (0.01, 0.05, 0.001, 0.01 mg/L, including both).

According to the EPA **(Hamza-Chaffai *et al.*, 1996)**, copper, zinc, and lead levels in Lake Manzala are within the allowable limits suggested for drinking and irrigation purposes, while Cd was found in greater quantities than those strongly suggested. The levels of heavy metals in the muscle and gills of the Nile tilapia are seen in Tables (2- 5). The following metal concentrations were found in fish organs: copper > zinc > lead > cadmium, Increased amounts of Zn and Cu can be due to their biological role in fish metabolic processes, which leads to an active uptake and storage mechanism. Differences have been discovered between locations, seasons, and members of the fish. Cu, Zn, Pb, and Cd concentrations were higher in the tissues of L3 fish due to the continuous discharge of different pollutants. The mineral content in water at this site was at its highest due to its proximity to industrial drainage and sewage.

This is in line with the observations of **Abdel-Satar and Yacoub (2005)** who determined that, the accumulation of pollutants in various organs of fish takes into account the levels of water pollution in the environment ecosystems in which these fish live. According to **Ravera (2001)**, when an environment is exposed to international contaminants (for example, metals), its inhabitants may accumulate pollutants from the water or/and food, which are then focused in their bodies. Metal contamination was found in fish organs in the following order: gills > muscles. Zn (48.6-388.7) was the maximum in gills, followed by Cu (5.8-21.9), Pb (36.5-345.4), and Cd (0.7-0), all were evaluated in µg/g dry weight tested.

The increased metal concentration in gill tissues can be credited to fish gills' essential factor in metal uptake from the environment. Gills have the thinnest epithelium of any organ and are in direct contact with an infected medium (water) due to their respiratory function **(Kotze *et al*., 2006)**. These findings are consistent with those of other scientists who have discovered that gills have a high proclivity to collect heavy metals (**Wong *et al*., 2001; Coetzee *et al* ., 2002).** Gills in this study contained more Copper, Zn, Lead and CD than Mugil cephalus from the northeastern Mediterranean Sea **(Canli and Atli, 2003)**. Following minerals accumulate in lower concentrations in both gills, on the skin and this is due to the mucous layer on the outer surface of the skin and gill tissues .This mucus acts as a barrier to the spread of water pollutants throughout the fish epidermis **(Varanasi and Markey, 1978; Yilmaz, 2003).** Muscles contained the least amount of the metals tested. This finding was similar to the findings of many other investigators who discovered that fish muscles have a small ability to accumulate heavy metals when exposed to them **(Canli *et al.*, 1998; Ibrahim *et al*.,1999a; Canli and Atli, 2003; Khlaif *et al*., 2021).**

The National Health and Medical Research Council says (NHMRC) **(Ibrahim *et al*., 1999a)**, according to the suggested acceptable limit of heavy metals in fish tissue for human food, the muscle of Nile tilapia in the current study is safe for human consumption. Metal concentrations in fish organs differed seasonally, with all of the discovered metals peaking in the summer and dropping in the winter. These seasonal changes were related to climatic variations caused by changes in the quantity of drainage water released into the lake (**Abdel-Baky *et al.*, 1998)**. In comparison to other research findings (**Hülya Karadede *et al.*, 2004)**, Liza aurata from Tunisia's Middle Eastern coast accumulated greater densities of Cu (4.7 µg/g dry weight) and Zn (45.0 µg/g dry weight) but decreased rates of Cd (0.07 µg/g dry weight) in its muscles Cu and Zn densities was significantly elevated (23.16 and 27.26 µg/g dry weight, in both) in the muscle of Liza abu from Turkey's Tigri .In the muscle of Liza aurata from Cadiz Bay, Spain **(Yilmaz, 2005)** found an unusually high accumulation of Copper, Zinc, Lead and cadmium levels were also observed to be higher in the muscle of Liza ramada from Lake Manzala (**Bahnasawy *et al.*, 2009)** and the Damietta Nile estuary (**Ibrahim *et al.*, 1999a)**.

Table 1. Seasonal and site variations in levels of heavy metals (mg/L) in Lake Manzala waters (mean standard deviation).

Elements	**Site**	**Seasons**					**ANOVA**		
		Winter	**Spring**	**Summer**	**Autumn**	**Mean**	**Factor**	**F-value**	**Sig.**
Copper	**L1**	**0.008±0.00015**	**0.008±0.0006**	**0.005±0.0002**	**0.009±0.0002**	**0.0075±0.001**	**Site**	**0.048**	**0.953**
	L2	**0.008±0.0003**	**0.009±0.0004**	**0.0057±0.0002**	**0.009±0.0007**	**0.008±0.0004**	**Season**	**160.976**	**0.000**
	L3	**0.008±0.0002**	**0.009±0.0002**	**0.005±0.0002**	**0.0095±0.0003**	**0.008±0.0002**			
Zinc	**L1**	**0.018±0.001**	**0.042±0.002**	**0.042±0.001**	**0.025±0.0005**	**0.03±0.00**	**Site**	**0.002**	**0.998**
	L2	**0.018±0.0005**	**0.042±0.002**	**0.04±0.001**	**0.025±0.0020**	**0.03±0.00**	**Season**	**769.580**	**0.000**
	L3	**0.018±0.0005**	**0.043±0.001**	**0.042±0.001**	**0.025±4.24919 E-18**	**0.03±0.00**			
Cadmium	**L1**	**0.005±0.00001**	**0.0084±0.0004**	**0.003±0.0005**	**0.0096±0.0001**	**0.006±0.0002**	**Site**	**0.004**	**0.996**
	L2	**0.005±4.16333 E-05**	**0.0083±0.0002**	**0.003±0.0005**	**0.009±0.0002**	**0.006±0.0002**	**Season**	**693.519**	**0.000**
	L3	**0.005±2.08167 E-05**	**0.008±0.0002**	**0.003±0.0005**	**0.0096±0.0003**	**0.006±0.0002**			
Lead	**L1**	**0.008±5.7735E-05**	**0.009±5.7735 E-05**	**0.008±0.0001**	**0.005±0.0001**	**0.008±2.44017E-05**	**Site**	**0.013**	**0.987**
	L2	**0.008±0.0005**	**0.009±0.0005**	**0.0082±0.0006**	**0.0052±1E-04**	**0.007±0.0002**	**Season**	**338.585**	**0.000**
	L3	**0.008±0.0005**	**0.009±0.0005**	**0.008±0.0001**	**0.005±0.0001**	**0.007±0.0002**			

N.D. stands for not detected (0.001).

Table 2. Seasonal and sampling site variations in **Copper** densities (µg/g dry wt.) in Nile tilapia organs from Lake Manzala (mean standard deviation).

Organ	Seasons					ANOVA		
	Winter	Spring	Summer	Autumn	Mean	Factor	F-value	Sig
Gills	22.276±2.506	18.335±3.274	22.45±1.939	24.646±1.183	21.927±3.196	Season	7.470	.002
Muscles	7.1083±1.389	6.428±0.5144	5.163±1.903	4.823±1.824	5.880±1.282		7.995	.001

Table 3. seasonal and sampling site variations.in **Zinc** densities (µg/g dry wt.) in Nile tilapia organs from Lake Manzala (mean standard deviation).

Organ	Seasons					ANOVA		
	Winter	Spring	Summer	Autumn	Mean	Factor	F-value	Sig
Gills	308.59±14.80	412.89±52.31	472.65±33.89	360.85±102.46	388.74±83.91	Season	8.121	.001
Muscles	40.56±2.99	40.53±5.361	55.03±14.43	58.30±15.28	48.60±9.57		20.431	.000

Table 4. seasonal and sampling site variations in **Cadmium** densities (µg/g dry wt.) in Nile tilapia organs from Lake Manzala (mean standard deviation).

Organ	Seasons					ANOVA		
	Winter	Spring	Summer	Autumn	Mean	Factor	F-value	Sig
Gills	0	0	0	0	0	Season	-------	------
Muscles	1.42±0.610	0.715±0.136	0.40±0.56	0.61±0.49	0.78±0.52		7.897	.001

Table 5. seasonal and sampling site variations in **Lead** densities (µg/g dry wt.) in Nile tilapia organs from Lake Manzala (mean standard deviation).

Organ	Seasons					ANOVA		
	Winter	Spring	Summer	Autumn	Mean	Factor	F-value	Sig
Gills	285.54±43.67	333.13±24.73	437.09±62.09	326.16±43.27	345.48±71.11	Season	12.136	.000
Muscles	46.69±7.39	29.70±2.95	30.13±12.32	39.75±11.80	36.57±8.48		17.952	.000

CONCLUSION

Lake Manzala is a significant wetland in Egypt, both in terms of size and commercial growth. The current report's findings clearly show that Lake Manzala is heavily polluted with copper, zinc, Cadmium, and lead because of discharge of various pollutants into it. Metal pollution in fish and water parts of the body happened in the right order: Copper > zinc > Lead > cadmium was found in water at amounts high than the drinking and irrigation measured value. Metal contamination in the following order: Gills came first, followed by muscles. The toxic metals levels were measured in the fish. Tissues from the most polluted area, demonstrating Nile tilapia metal concentrations show the degree of water pollution, supplied important information on metal levels. Outstanding efforts and collaboration among various authorities are required to clean up Lake Manzala. Treatment can be used to keep the lake clean and decrease pollution risks to the environment. It is also vital to conduct regular pollutant evaluations in the lake of agricultural, industrial, and sewage effluent.

REFERENCES

Abdel-Baky, T.E.; Hagras, A.E.; Hassan, S.H. and Zyadah, M.A. (1998). Environmental impact assessment of pollution in Lake Manzalah, 1-Distribution of some heavy metals in water and sediment, J. Egypt. Ger. Soc. Zool, Cited by 67.

Abdel-Mohsien, H. S. and Mahmoud, M. A. M. (2015). Accumulation of Some Heavy Metals in <i>Oreochromis niloticus</i> from the Nile in Egypt: Potential Hazards to Fish and Consumers. Journal of Environmental Protection, 06(09): 1003–1013. doi.org/10.4236/jep.2015.69089.

Abdel-Satar, A. and Yacoub, A. (2005). Heavy metals and macronutrients concentration in oreochromis njloticus and tilapia zilliifish species inhabiting some egyptian lakes and el-salam canal. Egyptian Journal of Aquatic Biology and Fisheries, 9(1): 97–116. doi.org/10.21608/ejabf.2005.1818

Abu-Zaid, A.; El-Sherbieny, A.; Dahdouh, S. and Sherif, M. (2020). ASSESSMENT OF SOME HEAVY METAL POLLUTION IN WATER AND SEDIMENTS OF ISMAILIA CANAL, EGYPT. Zagazig Journal of Agricultural Research, 47(1): 145–151.doi.org/10.21608/zjar.2020.70233

APHA. (1998).Standard methods for the examination of water and wastewater, 20th edition. American Public Health Association, Baltimore.

Badawy, M. I. and Wahaab, R. A. (1997). Environmental impact of some chemical pollutants on Lake Manzala. International Journal of Environmental Health Research, 7(2): 161–170. doi.org/10.1080/09603129773968

Badawy, M. I.; Wahaab, R. A. and Abou Waly, H. F. (1995). Petroleum and chlorinated hydrocarbons in water from Lake Manzala and associated canals. Bulletin of Environmental Contamination and Toxicology, 55(2):doi.org/ 10.1007/BF00203018

Bahnasawy, M.; Khidr, A. A. and Dheina, N. (2009). Seasonal variations of heavy metals concentrations in mullet, Mugil cephalus and Liza ramada (Mugilidae) from Lake Manzala , Egypt. Egyptian Journal of Aquatic Biology and Fisheries, 13(2): 81–100. doi.org/10.21608/ejabf.2009.2034

Biology of freshwater pollution. (2nd Ed), C.F. Mason, Longman Scientific & Technical, (1992 -1991). xiii + 351 pp. Price £18.95. ISBN 0–582–06191–1 - Hellawell - Aquatic Conservation: Marine and Freshwater Ecosystems - Wiley Online Library: doi:10.1002/aqc.3270020310.

Canli, M. and Atli, G. (2003). The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environmental Pollution, 121(1): 129–136. doi.org/10.1016/S0269-7491(02)00194-X

Canli, M.; Ay, Ö.; and Kalay, M. (n.d.). (1998).Levels of Heavy Metals (Cd, Pb, Cu, Cr and Ni) in Tissue of Cyprinus carpio,Barbus capitoand Chondrostoma regiumfrom the Seyhan River, Turkey. p. 10. M, Turk. J. Zool. 22: 149-157. doi: 10.13140/RG.2.2.35097.88169.

Coetzee, L;Preez, H. D. and Vuren, J. V. (2002). Metal concentrations in Clarias gariepinus and Labeo umbratus from the Olifants and Klein Olifants River, Mpumalanga, South Africa: Zinc, copper, manganese, lead, chromium, nickel, aluminium and iron. Water SA, 28(4): 433–448. doi.org/10.4314/wsa.v28i4.4917

Dheina, N.A. (2007), Biological and ecological studies on some species of family Mugilidae from different habitats in relation to their parasitic fauna, Ph.D. Dissertation. Damietta Faculty of Science, Mansoura University, Egypt.

Elewa, A.-S.; Ghallab, M.; Shehata, M. and Saad, E. (2007). STUDIES ON THE EFFECT OF DRAIN EFFLUENTS ON THE WATER QUALITY OF LAKE MANZALA,EGYPT. Egyptian Journal of Aquatic Biology and Fisheries, 11(2): 65–78. doi.org/10.21608/ejabf.2007.1934 .

Fernández, M.; Cuesta, S.;Jiménez, O.; García, M. A.;Hernández, L. M.; Marina, M. L. and González, M. J. (2000). Organochlorine and heavy metal residues in the water/sediment system of the Southeast Regional Park in Madrid, Spain. Chemosphere, 41(6):801–812. doi.org/10.1016/S0045-6535(00)00004-7.

Flora, J. D. (1982). Statistical methods in biology: Norman T.J. Bailey, 2nd ed., Halsted Press John Wiley & Co., New York, 216 pp. index, $12.95 paperback. Mathematical Biosciences, 58(2):309–310. doi.org/10.1016/0025-5564(82)90078-5

Hamza-Chaffai, A.; Roméo, M. and El Abed, A. (1996). Heavy Metals in Different Fishes from the Middle Eastern Coast of Tunisia. Bulletin of Environmental Contamination and Toxicology, 56(5):766–773. https://doi.org/10.1007/s0012899 00112

Hülya Karadede.; Seyit Ahmet Oymak and Unlü, E. (2004). Heavy metals in mullet, Liza abu, and catfish, Silurus triostegus, from the Atatürk Dam Lake (Euphrates), Turkey. Environment International, 30(2): 183–188. doi.org/10.1016/S0160-4120(03)00169-7

Ibrahim, A.M.;Bahnasawy, M.H.; Mansy, S.E. and El-Fayomy, R.I..(1999a). Heavy metal accumulation in water, sediment and some fishes in Lake Manzala, Egypt. J. Egypt. Ger. Soc. Zool, R.I, 29: 43- 58.

Janssen, C. R.;Schamphelaere, K. D.; Heijerick, D.; Muyssen, B.; Lock, K.; Bossuyt, B.;Vangheluwe, M.and Sprang, P. V. (2000). Uncertainties in the Environmental Risk Assessment of Metals. Human and Ecological Risk Assessment: An International Journal, 6(6): 1003–1018. doi.org/10.1080/ 10807030091124257.

Jewett, Stephen C.; and A. Sathy Naidu. (2000). "Assessment of Heavy Metals in Red King Crabs Following Offshore Placer Gold Mining." Marine Pollution Bulletin 40(6): 478–90. doi: 10.1016/S0025-326X(00)00037-0.

Khallaf, E.A.; Authman ,M.M.N.; Galal ,M. and Zaid ,R.A. (2018)"A comparative biological study on Oreochromis niloticus from two Nilotic Canals in the Delta of Egypt," Egypt. J. Aquat. Biol. & Fish., 22 (5): (Special Issue): 39–63, Nov. doi: 10.21608/ejabf.2018.17953.

Khlaif, A. T. .;Mohammed, S. S. and Al-Sultany, D. A. A. (2021). Detection of contamination by some trace elements in the muscles of Carassius auratus (Linnaeus) collected from the Euphrates River / Central Iraq [Preprint]. In Reviewdoi.org/10.21203/rs.3.rs-1097301/v1

Kotze PJ,; HH du Preez and JHJ van Vuren.(2006). Bioaccumulation of copper and zinc in Oreochromis mossambicus and Clarias gariepinus, from the Olifants River, Mpumalanga, South Africa. 12.Department of Zoology, Rand Afrikaans University, PO Box 524, Auckland Park 2006, South Africa

Radwan, S.;Kowalik, W. and Kornijów, R. (1990). Accumulation of heavy metals in a lake ecosystem. Science of The Total Environment, 96(1):121–129. doi.org/10.1016/0048-9697(90)90012-J.

Ravera, O. (2001). Monitoring of the aquatic environment by species accumulator of pollutants: A review. Journal of Limnology: 60. doi.org/10.4081/jlimnol. 2001.s1.63

Tarvainen.; Timo.; Pertti Lahermo and Jaakko Mannio. (1997). "Sources of Trace Metals in Streams and Headwater Lakes in Finland." Water, Air, and Soil Pollution 94(1–2): 1–32. doi: 10.1007/BF02407090

Tulonen, T.; Pihlström, M.;Arvola, L. and Rask, M. (2006). Concentrations of heavy metals in food web components of small, boreal lakes. Boreal Env. Res, 11: 185–194.

Varanasi, U. and Markey, D. (1978). Uptake and release of lead and cadmium in skin and mucus of coho salmon (Oncorhynchus kisutch). Comparative Biochemistry and Physiology Part C: Comparative Pharmacology, 60(2):187–191. doi.org/10.1016/0306-4492(78)90092-8

Wong, C.;Wong, P. and Chu, L. (2001) “Heavy metal concentrations in marine fishes collected from fish culture sites in Hong Kong,” Arch Environ Contam Toxicol, vol. 40, no. 1: pp. 60–69, Jan. doi: 10.1007/s002440010148.

Yilmaz, A. B. (2003). Levels of heavy metals (Fe, Cu, Ni, Cr, Pb, and Zn) in tissue of Mugil cephalus and Trachurus mediterraneus from Iskenderun Bay, Turkey. Environmental Research, 92(3):277–281. doi.org/10.1016/S0013-9351(02)00082-8

Yilmaz, A. B. (2005).Comparison of heavy metal levels of grey mullet (Mugil cephalus L.) and sea bream (Sparus aurata L.) caught in Iskenderun Bay (Turkey). Turkish Journal of Veterinary and Animal Sciences, 29: 257-262.

Zahran, M. A. E.-K.; El-Amier, Y. A.; Elnaggar, A. A.; Mohamed, H. A. E.-A. and El-Alfy, M. A. E.-H. (2015). Assessment and Distribution of Heavy Metals Pollutants in Manzala Lake, Egypt. Journal of Geoscience and Environment Protection, 03(06): 107. doi.org/10.4236/gep.2015.36017.

Zyadah, M. 127 pp. (1995), Environmental impact assessment of pollution in Lake Manzalah and its effect on fishes. Ph.D. Dissertation, Zoology Department, Faculty of Science, Mansoura University, Egypt.