African Journal of Advanced Pure and Applied Sciences (AJAPAS)

Online ISSN: 2957-644X

Volume 2, Issue 3, July-September 2023, Page No: 44-52

Website: *https://aaasjournals.com/index.php/ajapas/index*

||Arab Impact factor 2022: 0.87|| SJIFactor 2023: 5.689|| ISI 2022-2023: 0.557

Bioaccumulation and Health Risk Assessment of Lead and Cadmium in Some Organs of Fish *Siganus Rivulatus* from Lake Timsah and Bitter Lakes, Suez Canal, Egypt

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Received: May 22, 2023	Accepted: July 08, 2023	Published: July 14, 2023

Abstract

Seawater pollution is the serious environmental problems and possess a major threat to the human health and global ecosystems. This study aimed to estimate the concentration of Pb and Cd in the muscles, liver and gills of fish *Siganus rivulatus* caught by commercial fisheries from Lake Timsah and Bitter Lakes (Suez Canal) during winter and summer 2020. Fish muscles recorded the lowest concentration of Pb and Cd among the studied organs with the values of 0.216 - 0.424 and 0.091-0.112 µg/g, respectively. While gills accumulated the highest concentrations of the investigated two metals. Moreover, Pb showed concentrations in the fish organs higher than Cd. Finally, by comparing the present concentrations of metals in fish muscles with the maximum permissible limit (MPL) recommended by the international organizations, in addition to calculate the estimated daily intake (EDI); it can be concluded that muscles of the present fish are safe for human consumption.

Keywords: Lead, Cadmium, Bioaccumulation, fish *Siganus rivulatus*, Suez Canal

Cite this article as: A. O. Balq, K. M. El-Moselhy, "Bioaccumulation and Health Risk Assessment of Lead and Cadmium in Some Organs of Fish Siganus Rivulatus from Lake Timsah and Bitter Lakes, Suez Canal, Egypt," *African Journal of Advanced Pure and Applied Sciences (AJAPAS)*, vol. 2, no. 3, pp. 44–52, July-September 2023.

دراسة التراكم الحيوي وتقييم المخاطر الصحية للرصاص والكادميوم في بعض أعضاء سمكة السيجان من بحيرة التمساح والبحيرات المرة، قناة السويس، مصر

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الملخص

يعد تلوث مياه البحر من المشكلات البيئية الخطيرة ويمثل تهديدًا كبيرًا لصحة الإنسان والنظم البيئية العالمية. هدفت هذه الدراسة إلى تقدير تركيز الرصاص والكادميوم في العضلات والكبد والخياشيم لأسماك Siganus rivulatus التي يتم صيدها من المصايد التجارية من بحيرة التمساح والبحيرات المرة (قناة السويس) خلال فصلي الشتاء والصيف 2020.

سجلت عضلات الأسماك أدنى تركيز للرصاص والكادميوم بين الأعضاء المدروسة بقيم 0.216 - 0.424 و0.091 - 1.112 ميكروغرام / غرام على التوالي. بينما تراكمت الخياشيم أعلى تراكيز للمعدنين اللذين تم فحصهما. علاوة على ذلك، أظهر الرصاص تراكيز أعلى من الكادميوم في أعضاء الأسماك. أخيرًا، بمقارنة التركيزات الحالية للمعادن في عضلات الأسماك مع الحد الأقصى المسموح به (MPL) الذي أوصت به المنظمات الدولية، بالإضافة إلى حساب الاستهلاك اليومي المقدر (EDI)؛ يمكن الاستنتاج أن عضلات الأسماك الحالية آمنة للاستهلاك البشري.

الكلمات المفتاحية: الرصاص، الكادميوم، التراكم الحيوي، سمك Siganus rivulatus، قناة السويس

Introduction

Pollution is the most serious of all-environmental problems and possess a major threat to the health and well-being of millions of people and global ecosystems. In recent years, pollution becomes a paramount problem with increasing the human activities (Hamed et al., 2012). Other major environmental problems are also partly caused by pollution; these include global warming, climatic change and the loss of biodiversity through the extinction of many species. The harmful substances were introduced into the environment show many adverse effects on the human health, agriculture productivity and natural ecosystem (Alloways and Ayres, 1993). Living organisms require trace amounts of some heavy metals, including cobalt, copper, iron, manganese, molybdenum, vanadium, strontium and zinc. Excessive levels of essential metals, however, can be detrimental to the organism. Non-essential heavy metals of particular concern to surface water systems are cadmium, chromium, mercury, lead, arsenic and antimony (Kennish, 1992). Metals are the natural constituents of the earth's crust. Within the marine environment, metals occur in various chemical forms (Garcia-Rico et al., 2001).

Commonly, the levels of contaminants accumulate in the organisms' tissues has been used to indicate the degree of chemical contamination in the environment (Khaniki et al., 2005). Heavy metals are considered among the most serious contaminants of aquatic ecosystems, due to their high potential to enter and accumulate in food chain (Tam and Wong, 2000; Erdoğrul and Erbilir, 2007). There are many biological and environmental factors affecting the accumulation of heavy metals in the marine fish such as water temperature, sexual state of the fish and metals concentration in the surrounding medium (Dallinger et al., 1987; Nicoletto and Hendricks, 1988). Many studies were conducted to discuss the relationships between metals level and factors affecting their accumulation in the fish tissues (El-Moselhy, 1993, 1996 and 2000, Kock et al., 1996; Lemus and Chung, 1999 and EL-Moselhy and EL-Boray, 2004).

Fish is a commodity of potential public health concern because it can be contaminated by a range of environmentally persistent chemicals, including heavy metals (Soliman, 2006). The consumption of fish containing elevated levels of metals is a concern because chronic exposure to heavy metals can cause health problems. Chronic cadmium exposure has been linked to renal failure, bone fragility and as a cancer–causing agent in humans (Hellstrom et al., 2001; Staessen et al., 1999; Honda et al., 2003 and WHO, 1993). The need for increasing fish production is important; thus, efforts have been made to increase fish production and to maintain the present level of consumption in view of the rapid population increase. Therefore, the main goal of the present study was to determine the concentrations of non-essential heavy metals (Pb and Cd) in muscles, gills and liver of fish Siganus rivulatus gathered from Lake Timsah and Bitter Lakes of the Suez Canal. In addition to assess the present environmental situation and health influence by comparing its levels against the recommended maximum permissible limit (MPL) and comparing with estimated daily intake (EDI).

Material and methods

1. Study area

The Suez Canal is located in Egypt between 29º 55′ N at Suez on the Gulf of Suez and 31º 15′ N at Port Said on the Mediterranean Sea, and stretches between 32º 17′ E and 32º 35′ E, with an average main length along the major axis of 164 km (101 mile) which extending between north of Port Said and south of Port Tawfiq through a series of lakes with different ecological conditions (Saad *et al.,* 2016). Lake Timsah covers about 15 km^2 between 30°32' and 30˚36' N and 32˚16' and 32˚21' E, and is located near the middle of the Suez Canal at a point 80 km South of Port Said. It receives agricultural, industrial fishing, employ local citizen and domestic wastes. The Bitter Lakes are located between Ismailia and Suez Cities (30°20 N, 32°23 E), and are the largest water bodies along the Suez Canal; it is made up of two lakes "the Great and the Little Bitter Lake" with a total surface area of about 250 km^2, with saline water. It affected by ship passaging and agricultural wastes (Fig. 1).

Figure (1): Map showing Suez Canal and sampling locations (Lake Timsah and Bitter Lakes)

2. Sampling and metals analysis

Samples of fish *Siganus rivulatus* were collected by local fishermen from Lake Timsah and Bitter Lakes during winter and summer 2020. The samples were packed in labeled polyethylene bags, and transported in an icebox to the lab at the National Institute of Oceanography and fisheries, Suez, Egypt. Then, the organs (muscles, gills and liver) were separated, weighed and digested in Teflon vessels with conc. HNO_3 and $HClO_4$ (Denton and Burdon-Jones, 1986; AOAC, 2005; Kaya and Turkoglu, 2017). Complete digestion was observed when an initial yellowish vapor ceased. The digested samples were allowed to cool, filtered and solutions were then made up to 10 mL with double distilled water and stored at 4°C until metals analysis. Then the extracts were analyzed by atomic absorption spectrophotometer Perkin Elmer model Analyst 100; concentrations of Pb and Cd were expressed in µg/g wet weight.

Metal Pollution Index (MPI) was calculated to indicate and examine the total metal accumulation (metal load) in the different organs, it was estimated using the following equation (Omar et al., 2015)

$$MPI = (M_1 \, x \, M_2 \, x \, M_3 \, x \, \ldots . M_n)^{1/n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where, M and n are the metal concentration (µg/g wet wt.) in the fish organs and number of metals, respectively.

Estimated daily intake (EDI) was calculated to assess the health risk from consuming the edible parts of the current studying fish species. EDI is one method regularly used to recognize the number of contaminants consumed daily. EDI was estimated according to the equation described by USEPA (2010) and Bortey-Sam et al. (2015).

$$EDI = \frac{C_m \, x \, FDC}{B_W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where C_m is the heavy metal concentration in the investigated sample (µg/g wet/wt). FDC is the average food daily consumption of fish muscles (g/person/day), which ranged between (31.2, 38.13 and 64.0 g/day) for normal consumer and (142.4, 200 g/day) for high consumer (FAO, 2013; World Fish, 2015). B_W is the body weight of Egyptian adults and child (70 and 15 kg, respectively) and expressed as (µg/kg bw/day). It is essential to assess the daily intake of metals consumption and compare it with the tolerable daily intake (TDI) values determined by international organizations for health safety (FAO/WHO, 2015).

Results and discussion

Pb and Cd concentrations in Fish organs

Concentrations of lead (Pb) and cadmium (Cd) in the different organs (muscles, gills and liver) of the fish *Siganus rivulatus* collected from Lake Timsah and Bitter Lakes, Suez Canal, Egypt during winter and summer 2020 are presented in Table (1) and annual means are illustrated in Figure (2). Generally, levels of the studied metals in the fish organs showed the order of Pb > Cd. Furthermore, gills revealed the highest concentrations of Pb and Cd, while, muscles showed the lowest values of the studied two metals. In this context, Kojadinovic et al. (2007); El-Moselhy et al. (2014); Sadeghi et al. (2020) and Zaghloul et al, (2022) reported similar results for low metal levels in the muscles tissues in comparing to the internal organs of fish. The studied fish (*S. rivulatus*) tend to accumulate Pb and Cd in the gills and in some extent in the liver tissues. Gills are the main route of metal ion exchange from water as they have very large surface areas that facilitate rapid diffusion of toxic metals (Qadir and Malik, 2011; Dhaneesh et al., 2012). Therefore, it is suggested that metals accumulated in gills are mainly concentrated from water. This is in agreement with the findings of Moore and Ramamoorthy (1984). Similar results for high metal concentrations in gills were recorded by Kargin (1998), Avenant-Oldewage and Marx (2000), Abu Hilal and Ismail (2008), Eisler (2010) and Qadir and Malik (2011). On the other hand, the liver also showed high levels of non-essential metals such especially Cd; this finding could be explained by the ability of Cd to displace the normally MT-associated essential metals in hepatic tissues (Amiard et al., 2006; Dural et al., 2007; Eisler; 2010; Zhao et al. 2012).

Lead in muscles, gills and liver showed annual means of 0.261, 1.689 and 0.918 µg/g (in Lake Timsah fish) and 0.326, 2.099 and 1.287 µg/g (in Bitter Lakes fish), respectively; while, for cadmium were 0.105, 0.571 and 0.529 µg/g (in Lake Timsah fish) and 0.102, 1.063 and 0.866 µg/g (in Bitter Lakes fish). Statistically, variations of Pb and Cd mean concentrations between different organs from the two studied lakes showed very highly significant variance with p-values < 0.001 (Table 1). According to the local variation, fish from Bitter Lakes recorded high Pb and Cd in all fish organs (Fig. 2). Seasonally, winter reflected the highest values of Pb and Cd in all fish organs except Cd in muscles of fish from Lake Timsah with insignificant difference (p = 0.761), while most of the seasonal differences were significantly varied (p < 0.05 and < 0.001) (Table 1). Mahmoud (2017) indicated that difference in seasonal metals accumulation mainly attributed to the availability of such metals in the surrounding water and other environmental factors, in addition to biological factors such as age, feeding behavior and reproductive state.

Table (1): Mean values of Pb and Cd (µg/g wet wt.) in different organs of fish *S. rivulatus* from Lake Timsah and Bitter Lakes during winter and summer2020

Location	Organ	Lead		p-value	Cadmium		p-value
		Winter	Summer		Winter	Summer	
Lake Timsah	Muscles	0.305±0.068	0.216±0.079	0.091	0.103±0.015	0.106±0.013	0.761
	Gills	1.814±0.157	1.563±0.207	0.063	0.724±0.051	0.418±0.040	**<0.001**
	Liver	1.452±0.109	0.384±0.092	**<0.001**	0.782±0.058	0.275±0.079	**<0.001**
	p-value	**<0.001**	**<0.001**		**<0.001**	**<0.001**	
Bitter Lakes	Muscles	0.424±0.110	0.227±0.151	**0.047**	0.112±0.016	0.091±0.018	0.089
	Gills	2.470±1.075	1.727±0.739	0.239	1.539±0.439	0.586±0.084	**0.001**
	Liver	2.106±0.447	0.467±0.292	**<0.001**	1.348±0.315	0.383±0.070	**<0.001**
	p-value	**<0.001**	**<0.001**		**<0.001**	**<0.001**	

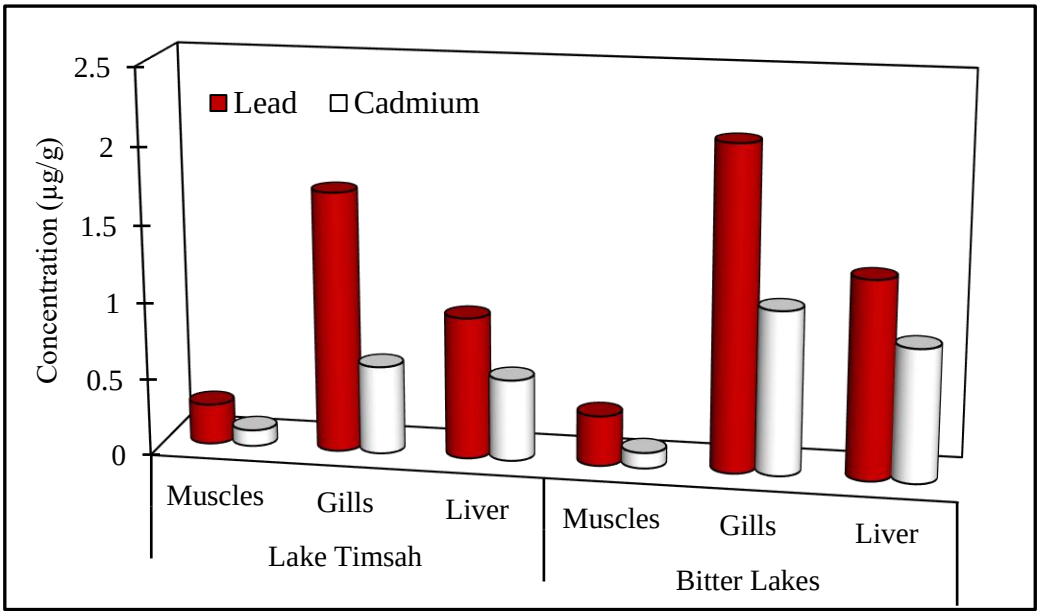

Figure (2): Annual mean of Pb and Cd (µg/g wet wt.) in different organs of fish *S. rivulatus* from Lake Timsah and Bitter Lakes during 2020

Concentrations of Pb and Cd in the muscles of fish *S. rivulatus* collected from the present study areas were compared to concentrations in fish from other Egyptian waters and elsewhere. The obtained data revealed that the present values in fish muscles were similar/or lower than those recorded in the previous studies (El-Moselhy, 1996, 2000; Soliman, 2006; Ali *et al*., 2011; Gorur *et al*., 2012; El- Moselhy et al., 2014; Ahmed *et al*., 2016; Mahmoud, 2017; Sadeghi et al., 2020 and Zaghloul et al, 2022). Conferring to the international organizations, it can be compared levels of Pb and Cd in fish muscles of the present study with the maximum permissible limit (MPL) to evaluate health risk of the consumption fish *S. rivulatus*. The results displayed that the Pn and Cd concentrations in the investigated fish fall lower or within the MPL for human consumption recommended by FAO, WHO, MAFF and Eu (Table 2). Therefore, the fish *S. rivulatus* from the Lake Timsah and Bitter Lakes were found to be safe for consumption and do not pose a significant threat to the health of human consumers.

Table (2) Maximum permissible limit (MPL) of Pb and Cd (µg/g wet wt.) in the muscles of fish *S. rivulatus* according to international standards.

	Pb	**Cd**	**Reference**
FAO (1983)	0.5	0.05	FAO, 1983
FAO/WHO limit	0.5	0.5	FAO/WHO, 1989
England	2	0.2	MAFF, 2000
WHO, 1989	2	1	Mokhtar, 2009
EU	0.3	0.25	Eu, 2014, 2015
Present study	0.22-0.42	0.09-0.11	

Metal Pollution Index (MPI)

Metal pollution index (MPI) used to evaluate the quality of the organisms and compare the total metal content in the different organs of the studied fish. In the current study, MPI varied from 0.165 – 0.182 (muscles), 0.982 – 1.493 (gills) and 0.697 to 1.055 (liver) (Table 3 and Fig. 3). According to MPI in the studied organs, gills showed the highest value followed by liver and muscles, which presented the lowest values. Jovanovi´c *et al.* (2011) indicated that fish could bio-accumulate metals through ingestion of polluted food or direct contact of their respiratory organ with polluted water; while, metal spreading amongst different tissues of marine

organisms depends on the type of exposure. Moreover, MPI was previously studied to assess the metal contamination in the different aquatic compartments, and compare its degree between regions and in different species (Giusti *et al*., 1999; Hamed and Emara, 2006; Ibrahim and Abu El-Regal, 2014, El-Moselhy *et al*., 2016; Girgis *et al.*, 2019 and Zaghloul et al, 2022).

Table (3) Annual mean (µg/g wet wt.) and metal pollution index (MPI) of Pb and Cd in organs of fish *S.*

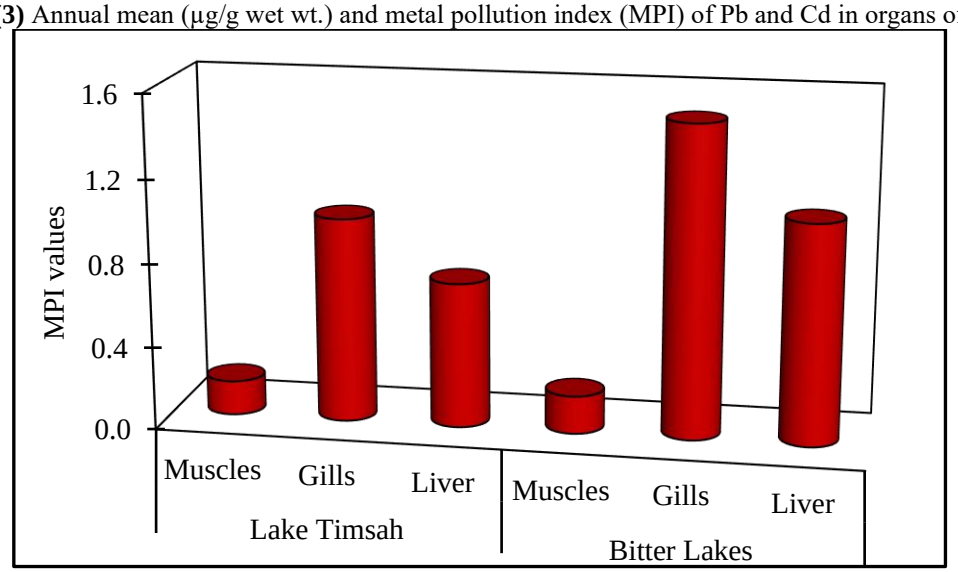

Figure (3): Metal pollution index (MPI) of Pb and Cd in different organs of fish *S. rivulatus* from Lake Timsah and Bitter Lakes during 2020

Estimated daily intake of fish (EDI):

Metals, particularly Pb and Cd, are harmless elements that have no essential role and can have hazardous impacts, and may lead to reduced cognitive development and mental health in kids and enhance cardiovascular illnesses in adults, in addition to reproductive and kidney dysfunction (Ahmed *et al*., 2015). Estimated Daily Intake (EDI) is a process used to detect the amount of contaminants consumed every day. In the current studied fish, EDI was estimated and presented in Table (4). It can be noticed that the EDI of Pb and Cd from consumption of the present fish muscles was lower than those of recognized TDIs guidelines (WHO, 1989), and considered safe for child and adult consumers in both cases of normal consumers (64g fish/day) or high consumers (200g fish/day). The tolerable intake is commonly applied to clarify the levels of safe intake and can be expressed on either a tolerable daily intake basis (TDI) or a tolerable weekly intake basis (TWI)

Table (4): Estimated Daily Intake (EDI µg/kg bw/day) of Pb and Cd in the muscles of fish *S. rivulatus* consumed by Egyptian adult and child compared with Tolerable Daily Intake (TDI µg/day)

Location	Consumer		Pb	Cd
Lake Timsah	Normal consumer (64 g fish/day)	Adult	0.24	0.10
		Child	1.11	0.45
Bitter Lakes		Adult	0.30	0.09
		Child	1.39	0.44
Lake Timsah	High consumer (200 g fish/day)	Adult	0.75	0.30
		Child	3.48	1.40
Bitter Lakes		Adult	0.93	0.29
		Child	4.35	1.36
TDI (µg/day) *			58.3	105

* Toxicological limit (µg/day) [61]

Conclusion

Fish *Siganus rivulatus* is an important fish in the Egyptian marine fishing, which is distributed in all Egyptian marine water from the Red Sea to the Mediterranean bathing through Suez Canal and its lakes. So, studying the different pollutants in its tissues is a main role to follow up the bioaccumulation rate of these pollutants and how much influenced the human health. In the present study, Pb and Cd, which are toxic elements, were analyzed in the muscles, gills and liver of fish *S. rivulatus* collected from Suez Canal Lakes (Lake Timsah and Bitter Lakes). The accumulation pattern in the different organs showed the order: gills > liver > muscles for the two studied metals. Levels of Pb were higher than Cd in all fish tissues. Fish from Bitter Lakes accumulated Pb and Cd more than those of Lake Timsah. Winter showed values of Pb and Cd in the fish tissues higher than summer season. According to the analyzed data of the present study, it can be concluded that the muscles of fish *S. rivulatus* collected from Lake Timsah and Bitter Lakes is safe for human consumption.

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