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LEVELS OF HEAVY METALS IN FISHES *(POLYSTEGANUS COERULEOPUNCTATUS, ARGYROPS SPINIFER AND ARGYROPS FILAMENTOSUS)* FROM THE GULF OF AQABA, JORDAN

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ABSTRACT

Heavy metal concentrations of Zn, Cr, Cd and Cu were investigated using flame Atomic Absorption Spectrophotometer (AAS) in liver, gills and muscles of three mesopelagic fish species from the northern Gulf of Aqaba *(Argyrops filamentosus*, *Argyrops spinifer* and *Polysteganus coeruleopunctatus*) collected during the period from 21/6/2014 to 15/1/2015. The results did not show any significant difference between different fish species, yet liver was found to be the major organ of bioaccumulation of Zn, Cr, Cd and Cu followed by gills, whereas muscles were found to have the lowest level of bioaccumulation. The levels of metal concentration of the present study were generally lower or within the ranges of those found in the fish of the Red Sea. After all, fish of this study were found to be safe for consumption and do not pose a significant threat to the health of human consumers.

KEYWORDS:
Heavy metals, Fishes, Levels, Concentrations, Aqaba, Red Sea

INTRODUCTION

Heavy metals constitute one of the most insidious and dangerous pollutants known to human. They are now considered to be among the most effective environmental contaminants, and their release into the environment has increased since the last decades, threatening all creatures and the environment. Heavy metals are not readily converted into harmless components; they are often accumulated in the tissues of organisms, which can't excrete them [1].

Bioindicators are species that can be used to monitor the health of an environment or ecosystem. They are any biological species or group of species whose function, population, or status can reveal the qualitative status of the environment. Recently, biological organisms such as fish, molluscans, and eechinoderms have been used as indicators for quantitative heavy metal concentrations in their different tissues or organs.

There are many reports about fish contamination by chemicals in the marine environment [2]. Fish may concentrate large amounts of metals from water and they might be toxic for human consumption [3]. According to [4] heavy metals may enter fish bodies by three possible routes, through the body surface, gills and the digestive tract. However, fish are the major part of the human diet, fishes are situated at the top of the aquatic food chain therefore they accumulate heavy metals from food, water and sediment which is one of the most dangerous aspects of pollution [5, 6].

Several studies reveal a susceptibility of the Gulf of Aqaba to metal pollution [7, 8, 9, 10, 11, 12, 13, 14, 15, 16], these studies stated that the Gulf of Aqaba is surrounded mostly by dry desert lands, thus, it has a great chance to get polluted with metals carried by air winds[17], in addition to that, the development of Aqaba city after the declaration from the Jordanian authority that Aqaba city is special economic zone authority in the year 2000, and the large human activity that affected the landscape and marine ecosystem increased the probability to raise the level of heavy metals in the marine biota. This study aims to provide knowledge and establish data base of the levels of heavy metals in three species of the family Sparidae: *Polysteganus coeruleopunctatus*, *Argyrops spinifer* and *Argyrops filamentosus*that live in mesopelagic water and are consumed by local's community.

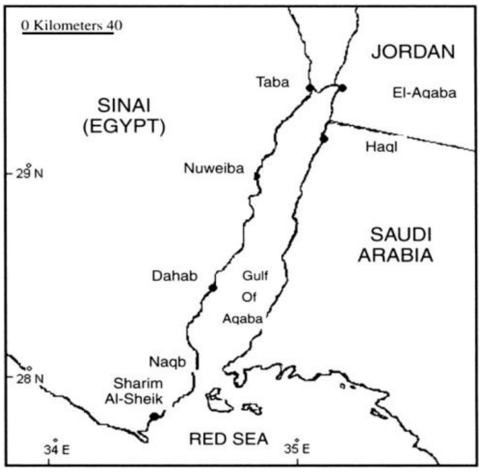

FIGURE 1
Gulf of Aqaba, with its semi-enclosed nature

MATERIALS AND METHOD

Study Area. The Gulf of Aqaba is located at the east fork of the Red Sea (Figure 1). Its coasts are shared by Jordan, Palestine, Egypt and Saudi Arabia. The Gulf contains the only port for Jordan, Aqaba port, which the Gulf is named after. The Gulf biodiversity is unique, and some species are endemic to the area. It gained a high and unique biodiversity due to its semi enclosed nature, which also makes it more susceptible to pollution with these metals. After the year 2000, Aqaba was declared as a special economic zone. The chance for pollution to occur has increased in the Jordanian sector of the Gulf of Aqaba, especially the chance for metal pollution due to the developments that were made along the coastline of the Gulf, represented by the projects carried out in different fields such as industry and tourism [16].

Sample collection. Fifteen fish from each species were collected by professional fishermen using fish traps, long line with about 120 hooks and short long line with about 20 hooks from areas along the Jordanian coast of the Gulf of Aqaba (located at the most northern corner of the Gulf (latitude N29° 30 137` and longitude E 34° 59 200`) (Fig. 1). Fish samples were placed in clean plastic bags and carried to the laboratory of the Marine Science Station., each fish was washed by distilled water, to get rid of any remnants of trace metals on the outer surface of the fish. After that, the samples were dissected using a stainless steel knife. Samples of each of the following organs were taken: liver, muscle, and gills then placed in clean plastic bags and kept under -20°C for further analysis [13].

Sample treatment and digestion. Samples of liver, muscle and gills were dried using oven for 24hrs to obtain a constant weight. Sub sample from each organ (0.1-0.5 mg/ dry. wt.) were burned using muffle furnace at 550ºC, after that samples were cooled to room temperature and then digested in acid cleaned jars with hot concentrated nitric acid to release heavy metals. The organic materials in each sample were completely digested. The digests were allowed to cool, filtered through a 0.45μm Millipore membrane filter, The filtrate was transferred to 25 ml volumetric flasks and made up to mark with 1% nitric acid and diluted with double distilled water to 25 ml. The digests were kept in plastic bottles, heavy elements, Cu, Cr, Cd and Znconcentrations were determined using Atomic Absorption Spectrophotometer (AAS) (modified form [18] available in Marine Science Station. Metal contents were expressed as $\mu g\ g^{-1}$ dry weight [18].

RESULTS

Table (1) show the mean concentration ± Standard Deviation (S.D) of the four elements, Cu, Cr, Cd and Zn in the selected organs,(liver, muscle and gills) of the three mesopelagic fish *A. filamentosus*, *A. spinifer* and *P. coeruleopunctatus*.

Figure 2 shows the mean concentration of Cu, Cr, Cd and Zn in all sampled organs ± Standard Deviation. Liver was found to be the major organ of cupper bioaccumulation ($p < 0.05$), with mean concentration of 15.21 µg/g, followed by the Gills, with mean concentration of 4.35 µg/g, and Muscles with mean concentration of 0.99 µg/g. Liver was found to be the major site of Chromium bioaccumulation, with mean of 30.59 µg/g ($p < 0.05$), followed by the Muscles, with mean concentration of 16.8 µg/g, and Gills with mean concentration of 16.57 µg/g ($p < 0.05$). Liver was found to be the major site of Cadmium accumulation with mean of 6.66 µg/g ($p < 0.03$), followed by the Gills, with mean concentration of 6.22 µg/g, and Muscles with mean concentration of 4.17 µg/g ($p < 0.05$). Liver was also found to be the major site of Zinc bioaccumulation, with mean of 281.2 µg/g, followed by the Gills, with mean concentration of 205.42 µg/g, and Muscles with mean concentration of 94.7 µg/g.

Figures (3-6) summarize the results of the investigated metals (Cu, Cr, Cd and Zn) with the fish species (*A. filamentosus*, *A. spinifer* and *P. coeruleopunctatus*). The results showed that the fish species had no statistical significant effect on all of the metal concentrations.

TABLE 1
Mean concentration (μg/g) ± S.D of Cu, Cr, Cd and Zn in, Liver, Muscle and Gills of *A. filamentosus*, *A. spinifer* and *P. coeruleopunctatus*.

Fish species	Element / Organ	*Cu*	*Cr*	*Cd*	*Zn*
A.filamentosus	Liver	26.36 ±32.15	34.01±22.10	7.57±3.26	234.73±118.90
	Muscle	0.39±0.20	17.97±8.19	4.34±0.17	200.74±116.66
	Gills	7.38±3.80	14.98±2.98	6.57±0.28	230.80±49.77
	Mean±S.D	11.38±12.05	22.32±11.09	6.06±1.24	222.09±95.11
A. spinifer	Liver	10.31±7.69	21.92±12.35	6.33±2.85	286.69±171.72
	Muscle	1.32±0.83	13.49±0.81	4.17±0.23	123.62±18.18
	Gills	3.22±1.23	11.99±6.72	6.21±0.32	204.74±48.18
	Mean±S.D	4.95±3.25	15.8±6.63	5.57±1.13	205.02±79.36
P.coeruleopunctas	Liver	8.96±3.90	35.83±30.53	6.07±2.71	322.18±124.94
	Muscle	1.24±0.53	18.93±7.19	3.99±0.21	80.06±20.15
	Gills	2.44±0.65	22.74±16.21	5.87±0.25	180.73±29.65
	Mean±S.D	4.21±1.69	25.83±17.98	5.31±1.06	194.32±58.25
	Permissible Limit	37500*	100**	1250*	125000*

* [19]
**[20]

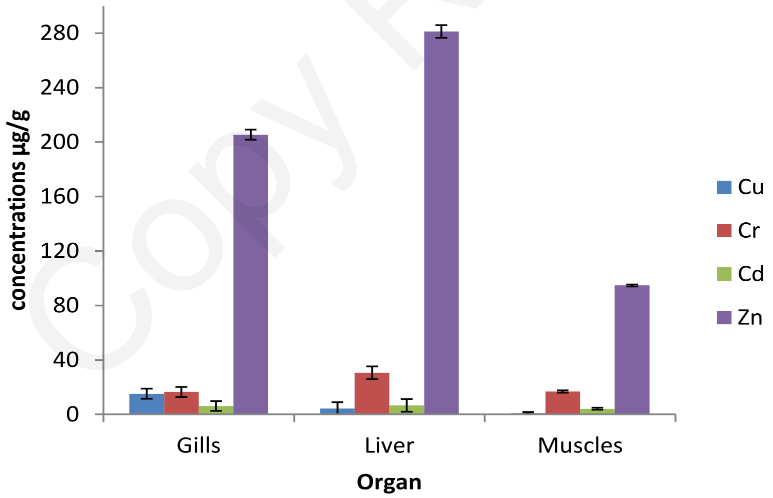

FIGURE 2
Mean concentration (μg/g) ± S.D of Cu, Cr, Cd and Zn in Gills, Livers and Muscles of the three fish species.

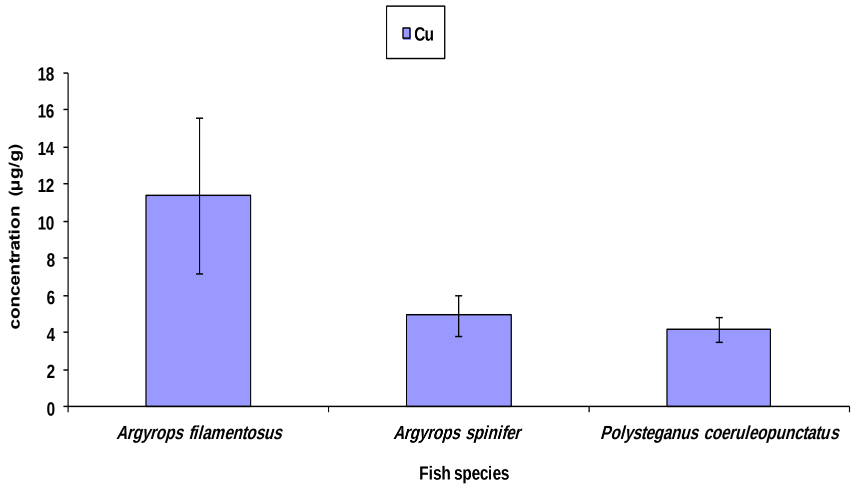

FIGURE 3
Mean concentration (µg/g) ± S.D of Cu in different fish species

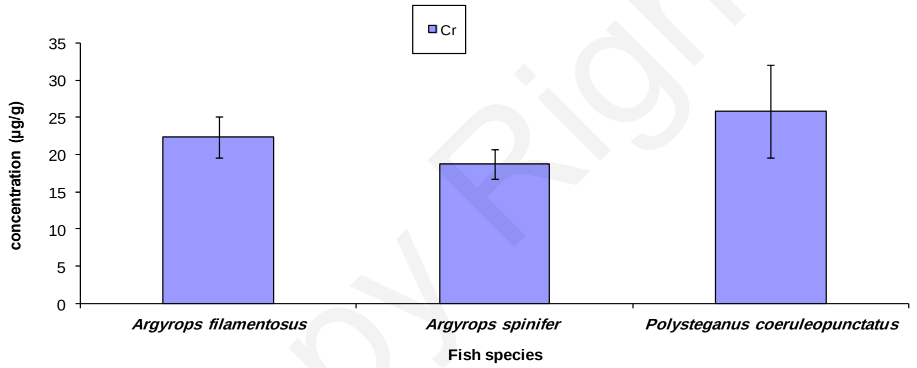

FIGURE 4
Mean concentration (µg/g) ± S.D of Cr indifferent fish species

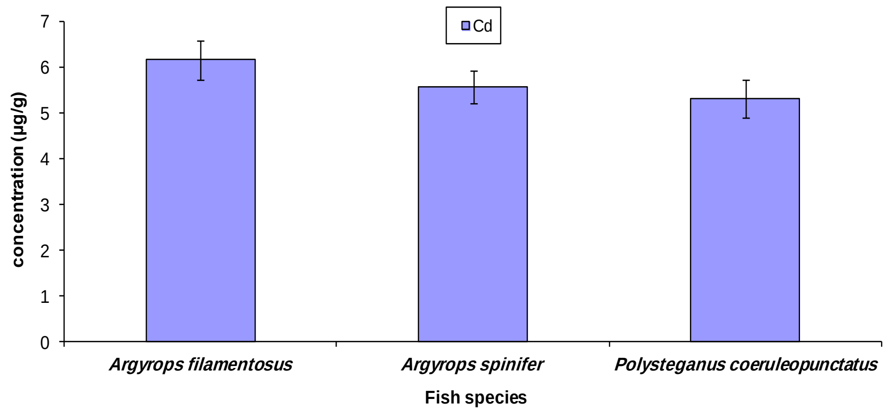

FIGURE 5
Mean concentration (µg/g) ± S.D of Cd indifferent fish species

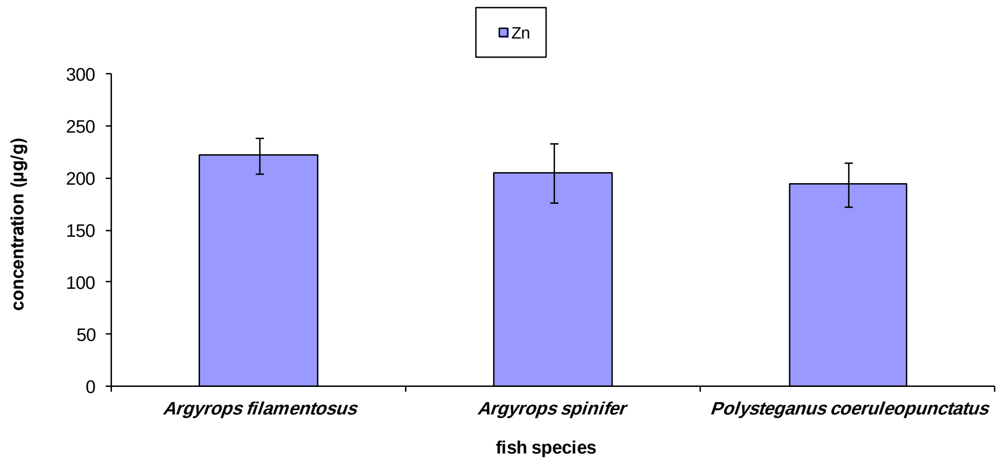

FIGURE 6
Mean concentration (µg/g) ± S.D of Zn in different fish species

DISCUSSION

The assessment and determination of the levels of heavy metals in commercial fish species have reached a considerable level of attention in different countries and organizations around the world because of the toxicity of heavy metals and their accumulation in biota. This interest aimed to insure the safety of the food supply, to minimize the potential hazard effect on human health and to evaluate ecosystem situation.

Our results revealed that, there is no significant difference between heavy metal concentration and different fish species of this study; this could be due to the same feeding habits of the three demersal mesopelagic fish species. Several studies showed that the feeding habits play an important role in the final metal concentrations of different fish species.[8], found significant differences in heavy metal concentrations in six coral reef fish species from the same areaof different feeding habits, from piscivorous species such as the lizardfish (*Synodus variegates*) to those feed on invertebrates, such as the goatfish (*Parupeneus barberinus*), or on algae, such as the Sergeant Major fish (*Abufefduf saxatilis*). In a study on three species, *Oreochromis mossambicus*; an omnivore fish, *Ophiocephalus striatus*; a piscivore fish and *Heteropneus tesfossilis*; a detritivore fish, it was found that the piscivore had the highest bioaccumulation for all metals that were measured because of the bio-magnification factor, except for Fe and Mn, which were the highest in the detritivore species, which might be due to very high levels in the sediments [21].

Our results indicated that, metal concentration vary among different fish organs. It was found that the livers of a three commercially important fish species studied had higher levels of Cu, Cr, Zn and Cd compared to muscle tissues and gills. The lowest concentrations were measured in muscles. The high accumulation of heavy metals in the livers of the three species of this study has likewise been reported in numerous studies [14, 15, 22, 23]; these studies suggested that the liver plays an important role in the metabolic processes of heavy metals in fishes. According to [24], muscles are primary part of metal intake, the liver is an organ that specializes in metal storage and detoxification, and the gills are directly exposed to the surrounding environment. Our results are in accordance with the study of [13], where the researchers reported that muscles have the lowest concentration of metals in most of the nine species that were studied, while stomach and liver had the highest. Also, our results are in accordance with the study by [14], they indicated significant differences for most of the heavy metal elements among different organs of the same species, particularly the presence of low concentrations of Cu, Pb, Zn, Cd and Fe in the muscles of *D. macarelleus* and low concentrations of Ni, Pb, Zn and Fe in the musclesof *D. macrosoma*. Similarly, in *D. russelli* the lowest concentration of Cu, Pb, Zn, Cd and Fe were found in muscles. In contrast, [15], found that, Cu, Pb, Cd and Fe were mainly concentrated in the liver and kidney, he found that there are no significant differences in the concentrations of metals between the two fish species *Caesio varilineata* and *Caesio lunaris*, but it was found that different organs have concentrated different metals. [23], studied trace element concentrations in the livers and muscles of *E. affinis* collected from Malaysia, and found that almost all elements have higher concentrations in the liver than those in the muscles, especially Zn, were they found that *E. affinis* had extremely high level of

TABLE 2
Heavy metals in muscles (mg/g) of fish from the Red Sea and other regions.

Fish Species	Site	Cu	Zn	Cr	Cd	Reference
Acanthopagurus bifaclatus	Red Sea	0.51	4.34	0.72	0.26	[32]
Ctenochaetus striatus	Gulf of Aqaba Red Sea	0.87	21.38	1.36	0.83	[12]
Lethrinus sp.	Red Sea	0.40	8.00	0.34	0.45	[29]
Scomberomrus commerson	Yemen Gulf Aden	1.3	8.00	0.9	0.39	[33]
Boops boops	Black Sea	3.08	6.81	0.22	0.10	[34]
Thunnus thynnus	Mediterranean Sea	1.01	16.54	0.74	0.05	[35]
Nemipterus japonicas	Hurghada Red Sea	0.28	2.13	0.82	0.02	[36]
Caranxsex faciatus	Jeddah coast Red Sea	0.91	5.33	0	0.9	[31]

Zn in liver compared to the muscles. Liver had the highest level of Mg, this could be related to the role of Mg in the detoxification reactions in the liver, as a cofactor for enzymes that catalyze phase II detoxification reactions.

According to [25], muscles are not an active site for metal biotransformation and accumulation, but in polluted aquatic habitats the concentration of metals in fish muscles may exceed the permissible limits for human consumption and imply severe health threats. To assess public health risk of fish consumption in the Gulf of Aqaba, we compared metal levels in muscles of the current study with the maximum permissible limits for human consumption reported by [26]. The metal concentrations in the examined fish species from the Gulf of Aqaba were below the permissible limits for human consumption. The results from previous literatures (Table 2) were somewhat closer to or lower than our obtained concentrations for other fish species. For instance, [27], recorded the concentrations of Cd, Pb, Cu and Zn in the muscles of *Sardinella aurita, Sardinella. rivulatus* and *Synodus saurus* from two main harbors in Alexandria, Egypt, who reported metal levels much higher than those recorded in the same species of the current work. In addition, metal levels in the present study were generally lower or within the ranges of those found in the fish of the Red Sea recorded by [28, 29, 30, 31]. After all, fishes of this study were found to be safe for consumption and do not pose a significant threat to the health of human consumers.

CONCLUSIONS

Heavy metals concentrations in the three studied fish species were within the same range or lower than other species from previous studies in the Jordanian water or elsewhere.

The results showed that metal accumulation varied between organs, the highest concentrations was for livers and the lowest concentrations for muscels, which agrees with the previous studies for the other fishes of the Gulf of Aqaba in which liver is the sink of these heavy metals, andthe detoxification site.The results showed that the studied heavy metals accumulation did not vary between species. The heavy metals concentrations in the examined fish species from the Gulf of Aqaba were below the permissible limits for human consumption reported by WHO, (1989).

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REFERENCES

[1] Phillips, D.J.H. (1977) The use of biological indicator organism to monitor trace metal pollution n marine and 154 estuaries environment - A review. Knvirnn. Pollution International. 13: 281-317.

[2] Hajeb, P., Jinap, S., Ismail, A., Fatimah, A.B., Jamilah J., and Rahim, M.A. (2009) Assessment

of mercury level in commonly consumed marine fishes in Malaysia. Food Control 20(1): 79-84.

[3] Rasheed, R.O. (2012) Assessment of some Heavy Metals in Muscle Tissue of *Silurus triostegus* from Derbendikhan Reservoir, Kurdistan Region –Iraq, Raf. J. Sci. 23(1): 11-18.

[4] Javed, M. (2005) Heavy metal contamination of freshwater fish and bed sediments in the river Ravi stretch and related tributaries. Pakistan Journal of Biological Sciences. 8: 1337-1341.

[5] Rayment, G.E. and Barry, G.A. (2000) Indicator tissues for heavy metal monitoring-additional attributes. Marine Pollu. Bull. 7: 353-358.

[6] Turkmen, A., Turkmen M., Tepe, Y. and Akyurt, I,(2005) Heavy metals in three commercially valuable fish species from Iskenderun bay, Northern East Mediterranean Sea, Turkey. Food Chem. 91: 167-172.

[7] Wahbeh, M.I., (1985) Levels of zinc, iron, magnesium and cadmium in the tissue of fish from Aqaba, Jordan. Dirasat. 12: 35-42.

[8] Wahbeh, M.I., and Mahasneh, D.M., (1987) Concentrations of metals in the tissues of six species of fish from Aqaba, Jordan. Dirasat. 14: 119-129.

[9] Al-Sayed, M. (2008) Levels of trace metals in some Carnivorous fish of Gulf of Aqaba, Red Sea. Master’s Thesis, Hashemite University, Zarka.

[10] Al-Zgool, A. (2008) Levels of trace metals in food chain of some carnivores fishes (Family: Carangidae) collected from the Gulf of Aqaba, Red Sea. Master’s Thesis, Hashemite University, Zarka.

[11] Batayneh, M. (2010) Levels of trace metals in some Herbivorous fish of Gulf of Aqaba, Red Sea. Master’s Thesis, Hashemite University, Zarka.

[12] Ismail, N.S. and Abu-Hilal, A.H. (2008) Heavy metals in three commonly available coral reef fish species from the Jordan Gulf of Aqaba, Red Sea. JordanJournal of Biological Sciences. 2: 61-66.

[13] Abu-Hilal, A.H. and Ismael, N.S. (2008) Heavy metals in eleven common species of fish from the Gulf of Aqaba, Red Sea. Jordan Journal of Biological Sciences. 1:13-18.

[14] Khalaf, M. A., Al-Najjar, T., Alawi, M., Disi, A. M. (2012) Levels of Trace Metals in Three Fish Species *Decapterus macrellus*, *Decapterus macrosoms* and *Decapterus russelli* of the Family Carangidae from the Gulf of Aqaba, Red Sea, Jordan. Natural Science. 4: 362-367.

[15] Al-Najjar T., Khalaf, N., Allawi, M., Disi, A. (2012) Levels of Trace Metals in Two Fish Species *Caesio varilineata* and *Caesio lunaris* of the Family Caesionidae from the Gulf of Aqaba, Red Sea. Fresen. Environ. Bull.. 21(5): 1152-1157.

[16] Al-Najjar, T., Abu Khadra, K., Rawashdeh, O.Y., Khalaf, M., Wahsha, M. (2015) Levels of Trace Metals in (*Euthynnus affinis*) Fish from the Gulf of Aqaba, Jordan. Fresen. Environ. Bull.. 24(9a): 2995-3000.

[17] Chen, Y., Paytan, A. , Chase Z., Measures C., Aaron, J., Sergio, B., San, A., Wilhelmy, U., and Anton F. P. (2008) Sources and fluxes of atmospheric trace elements to the Gulf of Aqaba, Red Sea. Journal of Geophysical Research. 1-13.

[18] Bernhard, M. (1976) Manual of Methods in the Aquatic Environment Research, FAO Fisheries Technical Paper, Food and Agriculture Organisation, no.158

[19] Mokhtar, M. (2009) Assessment level of heavy metals in *Penaeusmonodon* and *Oreochromis spp*. in selected aquaculture ponds of high densities development area. Eur J Sci Res. 30: 348-60.

[20] Katz, S.A., Salem, H. (1992) The toxicology of chromium with respect to its chemical speciation: A review. Journal of Applied Toxicology. 13 (3): 217–224.

[21] Wijesinghe, M.R., Wijeratne, Y.N.A., and Hewamanna, R. (1999) Bio-accumulation of heavy metals in *Oreochromis mossambicus* (extended abstract).

[22] Honda, K., Sahrul, M., Hidaka, H. and Tatsukawa, R. (1983), Organ and tissue distribution of heavy metals and their growth-related changes in Antarctic fish, *Pagothenia borchgrevinki*. Agricultural and Biological Chemistry. 47: 2521–2532.

[23] Agusa, T., Kunito, T., Kubota, R., Tanabe, R. and Iwata, H. (2012) Exposure, metabolism, and effects of arsenic in residents from arsenic-contaminated Groundwater Areas of Southeast Asia. Interdisciplinary Studies on Environmental Chemistry Environmental Pollution and Ecotoxicology. 125-132.

[24] Kotze, P.H., Preez, H.H. and VanVuren J.H.J. (1999) Bioaccumulation of copper and zinc in *Oreochromis mossambicus* and *Clarias garicpinus*, from the Olifants River, Mpumalanga, South Africa. Water SA. 25: 99-110.

[25] Elnabris, K.J., Muzyed S.K., El-Ashgar, N.M. (2013) Heavy metal concentrations in some commercially important fishes and their contribution to heavy metals exposure in Palestinian people of Gaza Strip (Palestine).Journal of Association of Arab Universities for Basic and Applied Sciences. 13: 44-51.

[26] WHO. (1996) Guidelines for Drinking Water Quality Volume 2, Health Criteria and Other

Supporting Information, World Health Organization, Geneva, Switzerland.
[27] Abdallah, M.A.M. (2008) Trace element levels in some commercially valuable fish species from coastal waters of Mediterranean Sea. Egyption. Journal of Marine System. 73: 114-22.
[28] Hanna, R.G.M. (1989) Levels of heavy metals in some Red Sea fish before Hot Brine pools' mining.Marine Pollution Bulletin, 20, 631–635.
[29] Abdelmoneim, M.A., El-Deek, M.S. (1992) Lethrinus family: a model of edible Red Sea fish with low heavy metals accumulation. National Institute of Oceanography and Fisheries. 19: 589-596.
[30] Emara, H.I., El-Deek, M.S., Ahmed, N.S. (1993) A comparative study on the levels of trace metals in some Mediterranean and Red Sea fishes. Chemistry and Ecology. 8: 119-127.
[31] Ali, A.A., Elazein, E.M., Alian, M.A. (2011) Investigation of heavy metals pollution in water, sediment and fish at Red Sea- Jeddah Coast-KSA at two different locations. Journal of Applied Environmental Biological Sciences, 1(12): 630-637.
[32] Abdelmoneim, M. Khaled, A. and Iskander, M. (1994) A study on the levels of some heavy metals in EL-mex, west of Alexandria, Egypt .The 4th conf. of the Environ. Prot. 10-12 May, 155-174.
[33] Al-Adrise, M.A.M. (2002) Concentration of some heavy metals in Khor-Kutheb Area (Al-Hodiedah) as a result of the sewage effluent impacts. M.Sc Thesis. Faculty of Science, Sana'a University, Yemen.
[34] Gorur, F.K., Keser, R., Akcay, N., Dizman, S. (2012) Radioactivity and heavy metal concentrations of some commercial fish species consumed in the Black Sea Region of Turkey. Chemosphere. 87, 356-361.
[35] Hussein, A., and Khalid, A. (2014) Determination of metals in tuna species and bivalves from Alexandria, Egypt.Egyptian Journal of Aquatic Research. 40(1): 9-17.
[36] El-Moselhy, K.H.M., Othman, .A.I., Abd El-Azem,B. H. and El-Metwally M.E.A. (2014) Bioaccumulation of heavy metals in some tissues of fish in the Red Sea, Egypt. Egyptian Journal of Basic and Applied Sciences. 1: 97 - 105.

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