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Heavy Metal Levels In The Tissues Of Five Commonly Consumed Fish Collected From The Fish Central Market Of Jeddah

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Abstract:
Recently, the global fish consumption increased significantly due to their exceptional health benefits, particularly in reducing cardiovascular diseases and supporting brain development in infants. However, in contaminated areas, fish have a high capacity to absorb heavy metals through their gills and accumulate these metals in their muscles, kidneys, gastrointestinal tracts, and livers at levels greater than those found in the surrounding environment. This study aimed to investigate the concentration of heavy metals in the tissues of five common fish species collected from the Jeddah Fish Central Market. The metals detected included arsenic, mercury, lead, copper, cobalt, cadmium, chromium, nickel, lithium, boron, and barium. The studied fish species were *Epinephelus areolatus* (Hamoor), *Plectropomus pessuliferus* (Najil), *Lethrinus nebulosus* (Shaour), *Scarus frenatus* (Hareed), and *Carangoides orthogrammus* (Bayad), all primarily sourced from the Red Sea of Jeddah. A total of 25 fish specimens from these five genera were analyzed. Variations in heavy metal concentration, measured in mg/kg of dry weight, were noted among different fish species. Overall, the mean levels of heavy metals in all fish tissues were within the accepted limits, and no samples exceeded permissible heavy metal levels. The highest levels of accumulated metals in the muscle tissue were found for nickel (Ni), followed by barium (Ba), boron (B), mercury (Hg), copper (Cu), lead (Pb), lithium (Li), chromium (Cr), arsenic (As), cobalt (Co), and cadmium (Cd). The detected concentrations of these heavy metals were not statistically significant ($p > 0.05$). In conclusion, this study suggests that the fish species collected from the Jeddah fish market are not contaminated with harmful non-essential metals, and the heavy metal concentrations in the tissues of Red Sea fish do not exceed acceptable limits
Key Words: Heavy Metals, Fish, Red Sea, contamination, plasma atomic emission

I. Introduction:

Fish and fish products are crucial sources of protein, as well as minerals, vitamins, long-chain polyunsaturated fatty acids, and omega-3 fatty acids (Mederos et al., 2012; Alewy Almashhadany et al., 2020). With the increasing consumption of wild and aquacultured fish, the importance of edible fish has garnered significant attention (Elnabris et al., 2013; Tilami and Sampels, 2018). However, fish can become contaminated with bacteria, heavy metals, oil, nuclear waste, radiation, and organic materials. Environmental pollution caused by heavy metals has emerged as a serious global issue. The pollution problem worsens due to increasing industrialization and disruptions in natural biogeochemical cycles. Unlike organic substances, heavy metals are non-biodegradable, leading to their accumulation in the environment and aquatic systems, which poses significant risks to both environmental integrity and human health (Khan et al., 2010; Adebayo I, 2017).

Heavy metals can enter the aquatic food chain in two primary ways: through direct consumption via the digestive tract or through non-dietary absorption across the permeable membranes of muscle and gills (Oliveria Ribeiro et al., 2005; Nhiwatiwa et al., 2011; Annabi et al., 2013; Al-Jubouri and Salman, 2019). High levels of heavy metals in marine environments pose significant risks to marine organisms and human health (Bashir et al., 2013). In certain aquatic habitats, contaminated water can infiltrate coastal areas and accumulate in edible fish tissues. The concentration of heavy metals in fish typically reflects the duration of exposure to these metals as well as their levels in surrounding water and sediment (Ribeiro et al., 2005; Annabi and Messaoudi, 2013; Alewy Almashhadany et al., 2020). The increase in heavy metal levels in aquatic environments is largely attributed to human activities, such as domestic effluents, agricultural runoff, offshore oil and gas exploration, and the use of paints, fertilizers, and pesticides (Alhas et al., 2009; Chiarelli and Roccheri, 2014; Ali and Khan, 2018).

The extraction of heavy metals for various applications has resulted in their release into the environment. During the early life stages of fish, high concentrations of heavy metals primarily affect hatching, larval development, and juvenile growth, as fish are more sensitive during these stages than in their mature phases (Heath, 1995). Accumulation of heavy metals over time in both animals and humans can lead to severe health issues, including neurotoxic effects, carcinogenesis, mutagenesis, and teratogenesis. Symptoms of heavy metal poisoning in humans can include vomiting, gastrointestinal disorders, kidney and liver damage, cardiovascular diseases, pneumonia, and even death (McCluggage, 1991; Castro-Gonzalez and Mendez-Armenta, 2008; Al-Busaidi et al., 2011; Rahman et al., 2012; Kim et al., 2019).

Jeddah is a major city on Saudi Arabia's Red Sea coast. Many international monitoring programs have been established to assess the quality of fish for human consumption and the health of the aquatic ecosystem (Meche et al., 2010). As Jeddah has the largest seaport along the Red Sea coast, this study aimed to detect the presence of heavy metals in fish collected from local fish markets and assess their quality for human use.

II. Material And Methods:

Fish Sampling:

From Jeddah central fish market, five fish samples were collected randomly which located in Jeddah city, western Al-Bagdadiyah, AL corniche Road, Jeddah 22232. The most commonly consumed five species of fish were selected based on a questionnaire done in Jeddah city. The collected Fish species were *Epinephelus areolatus* (Hamoor), *Plectropomus pessuliferus* (Najil), *Lethrinus nebulosus* (Shaour), *Scarus frenatus* (Hareed), and *Carangoides orthogrammus* (Bayad). Fish samples were collected individually in a clean polyethylene bag and kept in icebox and transferred immediately to the laboratory in refrigerated conditions (Nayak *et al*., 2015). Identification was confirmed by specialist, Dr Abdul Hakeem Alsheekh, Saudi Ports Authority. Then, the samples were cleaned with deionized distilled water, stored in cleaned polyethylene bags, and kept frozen at -18°C until further analysis (Djedjibegovic *et al*., 2012).

Digestion of Fish Muscle:

The fish were thawed and the muscular tissues from the dorsal, abdominal, and tail regions of each fish were taken out and homogenized by mortar and pestle. After that, muscle tissue was dried in a pre-cleaned glass container (glass petri dish) in the oven at 103 ± 2°C to a constant weight (Ali *et al*., 2011). After drying the samples were grained into a fine powder using a stainless-steel electric blender and stored in glass bottles until used for acid digestion (Alturiqi and Albedair, 2012; Hindi *et al*., 2014). An advanced microwave system (ETHOS 1, Milestone, Italy) was used to digest fish samples. Half a gram of each dried fish sample was placed in TFM vessel (temperature frequent microwave vessel) and digested by adding a mixture of 7 ml of nitric acid (65%) and 1 ml of hydrogen peroxide (30%). The running microwave system was carried out at 200ºC with power up to 1000 watts for 20 minutes followed by 10 minutes at the same temperature. After cooling to room temperature, vessels were opened in the fume hood and solutions were filtered by using Whatman no. 42 filter paper. Consequently, solutions were diluted to a fixed volume (25 ml) with deionized distilled water (Miloskovic *et al*., 2015).

Determination of Heavy Metal Levels in Fish Muscles:

In this study, 11 metals were chosen to be estimated in fish muscles. They were Arsenic, mercury, lead, copper, cobalt, cadmium, chromium, nickel, lithium, boron, and barium. They were chosen according to their serious dangerous health effect and toxicity on humans which have been not studied enough such as boron, barium, and lithium (Rafiei *et al*., 2010). Metal concentrations were determined by using ICPE-9000 - plasma atomic emission spectrometer, SHIMADZU. The experiment was conducted at King Fahad Centre for Medical Research, KAU, Saudi Arabia.

III. Results:

Heavy metals levels in five fish muscles species were estimated. Fish includes: *Epinephelus areolatus*, *Plectropomus leopardus*, *Lethrinus nebulosus*, *Scarus frenatus*, *Carangoides orthogrammus*. Eleven metals levels were determined in fish muscles: arsenic, mercury, lead, copper, cobalt, cadmium, chromium, nickel, lithium, boron, and barium by using plasma atomic emission spectrometer. According to Tables 1and 2, levels of heavy metals in all fish muscles were within accepted limits according to World Health Organization.

As shown in Figures 1, 2, 3, 4, and 5, Ni, Cu, Ba, and B concentrations among the other metals showed higher concentrations, whereas Co, Cd and As are the least concentrations obtained from fish muscles. Ni exhibited in highest concentration in *Epinephelus areolatus* which is 1.2 mg/l followed by *Plectropomus leopardus* which is 0.05 mg/l. Cu exhibited in highest concentration in *Lethrinus nebulosus* which is 0.07 mg/l while Ba displayed maximum level in *Scarus frenatus* which is 0.9 mg/l. The highest accumulated metal in all fish muscle is for Ni followed by Ba, B, Hg, Cu, Pb, Li, Cr, As, Co, and Cd which are 5.443, 3.066, 1.7113, 0.9684, 0.8543, 0.2897, 0.2583, 0.1353, 0.0257, 0.0219, 0.0199 mg/l, respectively (Figure 6).

Metal	*Epinephelus areolatus* (mean ± SD)	*Plectropomus leopardus* (mean± SD)	Accepted level (FAO/WHO, 1987)
Hg	0.0295±0.005	0.0278±0.008	0.5
Pb	0.0218±0.009	0.0105±0.003	0.5
Ni	1.1859±1.969	0.0526±0.058	30
Cu	0.0624±0.010	0.0455±0.011	30
Cr	0.0095±0.003	0.0097±0.006	0.15
Co	0.0016±0.002	0.0005±0.0003	0.5
Cd	0.0006±0.0004	0.0008±0.0009	0.5
As	0.0018±0.003	BDL*	0.01
Ba	0.0277±0.003	0.0242±0.002	10
B	0.0558±0.018	0.0474±0.026	10
Li	0.0209±0.001	0.0114±0.004	10

Table 1: Heavy metals levels (mg/kg) in *Epinephelus areolatus* and *Plectropomus leopardus* muscles.
*BDL means below detected limits.

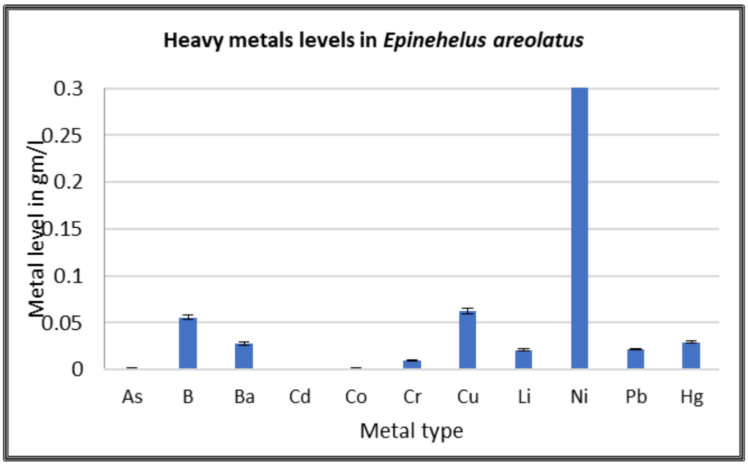

Figure 1: Some heavy metal levels (mg/kg) in *Epinephelus areolatus* muscle

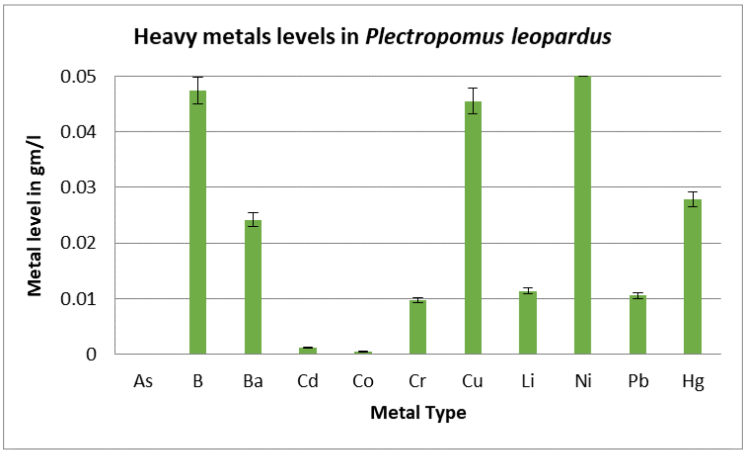

Figure 2: Some heavy metal levels (mg/kg) in *Plectropomus leopardus* muscle

Table 2: Heavy metal levels (mg/kg) in *Lethrinus nebulosus, Scarus frenatus* and *Carangoides orthogrammus* muscles.

Metal	*Lethrinus nebulosus* (mean± SD)	*Scarus frenatus* (mean± SD)	*Carangoides orthogrammus* (mean± SD)	Accepted level (FAO/WHO, 1987)
Hg	0.0336±0.002	0.1945±0.288	0.0373±0.026	0.5
Pb	0.024±0.006	0.0192±0.002	0.0210±0.023	0.5
Ni	0.0606±0.062	0.4162±0.609	0.099±0.071	30
Cu	0.0669±0.009	0.0575±0.013	0.0524±0.028	30
Cr	0.0109±0.004	0.0083±0.002	0.0066±0.002	0.15

Co	0.0018±0.002	0.0015±0.001	0.0018±0.002	0.5
Cd	0.0013±0.0002	0.0004±0.001	0.0053±0.006	0.5
As	0.0016±0.003	0.0016±0.003	0.0034±0.006	0.01
Ba	0.0456±0.030	0.8984±0.748	0.0261±0.009	10
B	0.0657±0.029	0.3423±0.312	0.0591±0.055	10
Li	0.0198±0.005	0.017±0.008	0.0169±0.028	10

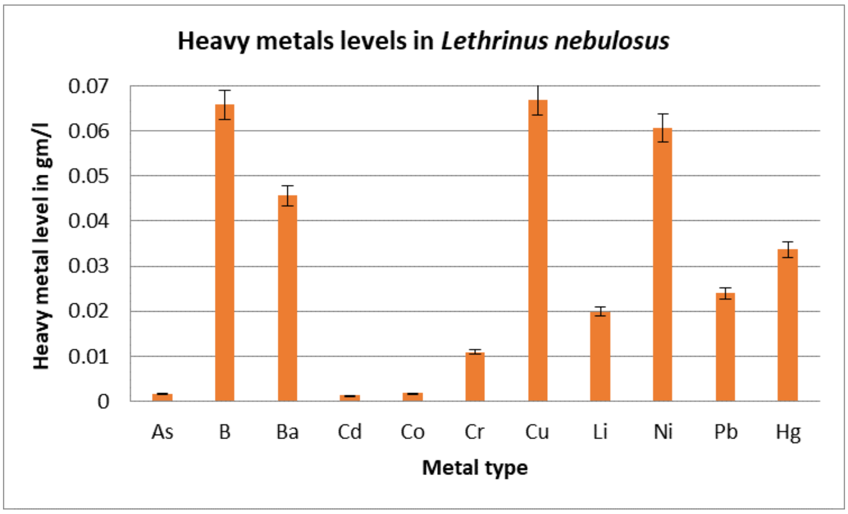

Figure 3: Some heavy metal levels (mg/kg) in *Plectropomus leopardus* muscle

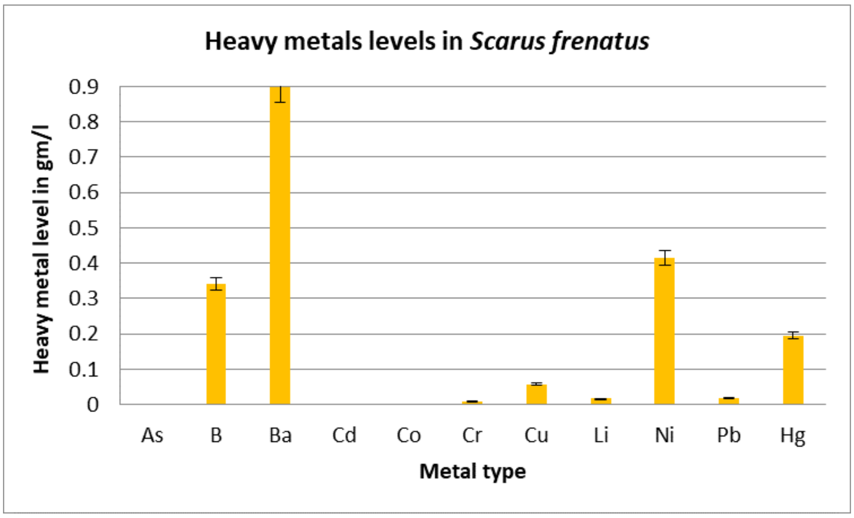

Figure 4: Some heavy metal levels (mg/kg) in *Scarus frenatus* muscle

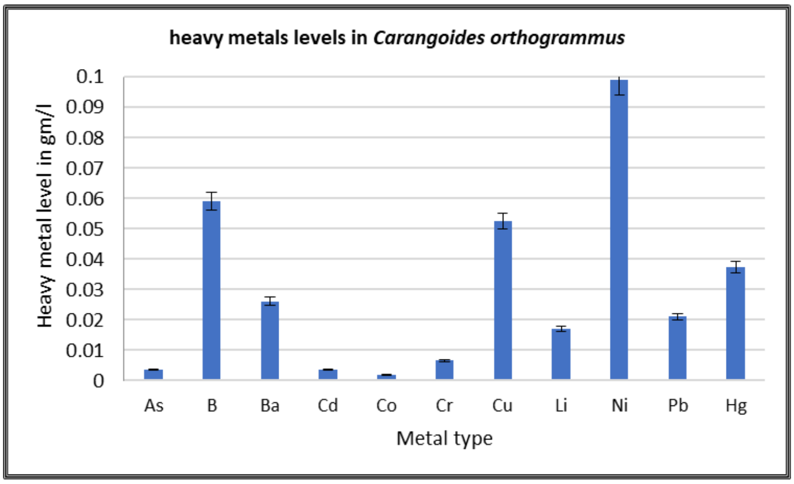

Figure 5: Some heavy metal levels (mg/kg) in the muscle of *Carangoides orthogrammus*

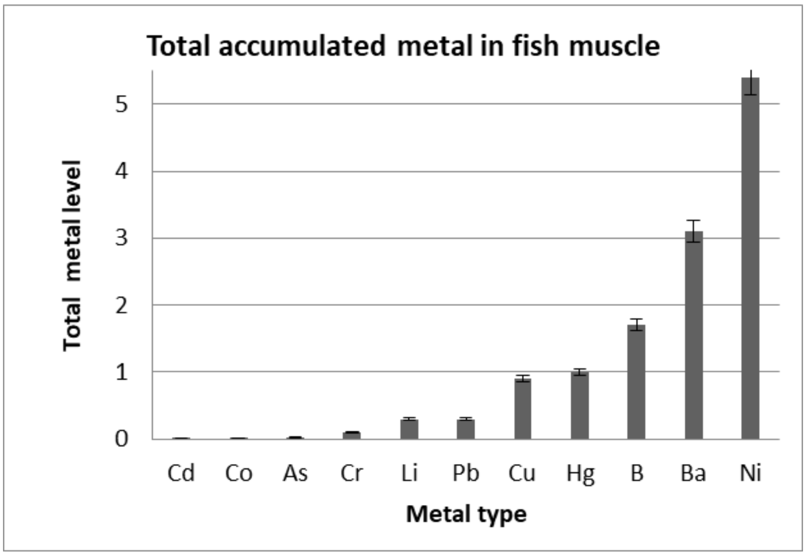

Figure 6: Total accumulated heavy metals (mg/kg) in the muscle of five collected fish

IV. Discussion:

In this study, the heavy metals concentration in muscles of five common fish collected from the Jeddah central fish market was investigated for Hg, Pb, Ni, Cu, Cr, Co, Cd, As, Ba, B, and Li concentration by using plasma atomic emission spectrometer after microwave digestion. Variations of metal concentration by mg/l were observed between different fish species. It was noticed that all metal concentrations were within accepted limits by universal administrations.

Similarly, El-Bahr and Abdelghany study (2015) on Spangled emporer (*Lethriuns nebulosus*), Red striped seabream (*Pagrus major*), and Black seabream (*Spondyliosoma cantharus*) indicated that fish muscles contain relatively less burden of heavy metals Cd, Pb, Cu, Zn, Fe and Mn. The values of heavy metals, Cu and Pb accumulated in the muscle of *Lethrinus nebulosus* examined in the current study were higher than that observed in the same fish by El-Bahr and Abdelghany study. Otherwise, the values of Cd were approximately the same in both studies. Furthermore, there were variations among metal contents in the muscles of all fish species in both studies. *S. cantharus* accumulated the highest levels of Cu while in the present study, *L. nebulosus* exposed the higher level of Cu.

Additionally, the concentration of Cu and Hg were higher in muscle of *Lethrinus nebulosus* in the present study than Ali *et al*., (2011) who collected fish from Red Sea at Jeddah Islamic Port Coast. Also, the current study recorded lower levels for Pb and Cd.

Al-Atoom *et al*., (2016) concluded that the levels of Cd, pb, Fe, Zn, Cu and Hg in muscles and skin of tested fish species: spotted grouper (*Epinephelus tauvina*); barred mackerel (*Scomberomorous commerson*); parrot fish (*Scarus frenatus*) and Snubnose emperor (*Lethrinus borbonicus*) collected from the local market of Taif city were within acceptable limits by FAO standards that match the present study result. It was noticed that Cd, Pb, and Cu were exhibited higher levels in *Scarus frenatus* in Al-Atoom *et al*., study than the present study. Otherwise, Hg exposed higher levels in the present study. Al-Atoom *et al*. (2016) work reveals significant differences of metal concentration among different fish species, particularly the presence of lesser concentrations of metals in muscles than those in skin. Similar conclusions were reported by the present study.

Conversely, In Jizan study, heavy metals were quantified in muscle tissues of 12 fish species. The following wide ranges of heavy metal concentrations (µg/g, wet weight) in studied fish species were recorded, Cr (0.013–0.477), As (0.002–0.935) and Pb (0.150–0.386). Comparing with international permissible limits, lower levels were recorded in Jizan study. Compared to the current study, Cr and As were exposed lower levels in the present study. Also, Pb exposed lower levels in current study except for Greasy grouper fish (Said *et al*., 2014).

In different circumstances, the concentrations of heavy metals Cr, Cd, Pb, Ni, Cu, and As in the muscle tissue of four fish species *Oreochromis niloticus*, *Clarias gariepinus*, *Poecilia latipinna* and *Aphanius dispar* collected from Wadi Hanifah, Saudi Arabia were detected. Nevertheless, the concentrations of the studied heavy metals, except for Cd, Pb, Ni and Cu in *A. dispar* and *P. latipinna*, were found to be below the safe limits recommended by various authorities and thus provide an indication of the extent of pollution of these metals. Also, the study demonstrated that Cr were the least accumulated metals in the studied fish muscle tissues (Mahboob *et al*., 2014). But in the present study, Ni and Cd were recorded the highest and least, respectively, accumulated metal in the studied fish which agreed with (Supriya *et al*., 2020) who recorded high Ni concentrations in fish samples collected from the Chennai coast, India.

In contrast, Nisbet *et al*., (2010) determined the average value of metal concentrations in 10 species of fish samples collected from the Middle Black Sea Coast, Turkey. The averages were determined as follows, 2.38 μg/g for Cu, 3.40 μg/g for Ni, 0.77 μg/g for Pb and 0.022 μg/g for Cd, but Hg was not detected. These values were lower than the maximum permissible levels of FAO/WHO standards, but the lead level was found to be higher. All averages are higher than the results of this study except for Hg and Ni.

The average value of Li in the present study was 0.2583 mg/kg which disagreed with the results of Thibon *et al*. (2021) who measured Li concentration in fish muscle collected from three distinct biogeographic areas (the Bay of Biscay, New Caledonia, and the Kerguelen Islands) that are 0.06 ± 0.08 μg/g. Fish gills and kidneys showed relatively high Li concentrations, 0.26 and 0.15 μg/g, respectively while the fish brains showed a large range of Li contents (up to 0.34 μg/g), whereas fish liver contained 0.07 ± 0.03μg/g. Comparing to Supriya *et al*. (2020) results, the Li level was higher than that obtained by the present study.

V. Conclusion:

All the heavy metal levels measured in the examined fish muscle samples were below the acceptance limits set by FAO/WHO (1987). This is a positive indication that the fish available in the Jeddah fish market are safe to eat and do not contain harmful heavy metals.

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