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# Accretion Of Prospective Minerals In Few Commercially Imperative Fishes Collected From Versova Fish Landing Centre In Western Suburbs Of Mumbai, India

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***Abstract:*** *In this study, bioaccumulation of few minerals in edible muscle tissue of eleven commercially importance marine/estuarine water fishes captured from coastal waters off the Mumbai and landed in Versova fish landing centre were determined. The concentration of minerals was in order of B > Fe > Zn > Pb > Cu > Mn > As > Cd > Hg. The accumulation of minerals in different fishes show significant differences (p=0.01). Spearman's Correlation Coefficient was also calculated that showed strong positive correlation between Boron, Copper, Arsenic, Cadmium and Mercury. The present study revealed that, fishes from Versova fish landing centre might not be harmful for consumption as mineral concentrations were observed to be in lesser amount than the permissible limits recommended by FAO/WHO, nevertheless safe disposal of industrial effluents, domestic sewage and navigational activities have to be practiced in coherence with environment and enforcement of laws be enacted to protect our resources and/or, recycled to circumvent these minerals from entering into the marine environment in future. Further it is recommended to inspect contaminants other than the minerals studied for ensuring safety of consumers and also to exploit export potentials of these aquatic resource.*
***Key Words:*** *Bioaccumulation, Minerals, Fin Fishes, Versova Landing Centre, Mumbai.*

## I. Introduction

The progress in industrial development has led to augmented emission of pollutants into environment dilapidating global ecosystems. As a consequence of anthropological activities, aquatic organisms are exposed to elevated intensities of both trace as well as heavy metals. The coastal zones of the maritime states are vastly inhabited and developed areas due to industrial set ups. Fishes are consumed since onset of civilization as an essential food resource to mankind. Fishes are also used as the bioindicators of pollution since they are sensitive to subtle changes in the aquatic environment. Sea food, viz. fin fish as well as shell fish like shrimp, crab, oyster and mussel are delicacies and form an energetic food commodity of the coastal populace. The bioaccumulation potential of minerals in marine/estuarine fishes is of imperative concern to mankind in present time of industrial pollution. The minerals are obligatory microelements and their deficiency might result in impairment of vital biological functions in the living organisms. Nevertheless their excess might cause toxicity to the ambient environment and also to the inhabiting living organisms, albeit biomagnifying into the consumers.

Heavy metals are natural trace components of the marine environment, but their levels have increased due to anthropogenic, industrial, mining and agricultural activities past few decades (Bakan and Buyukgungor, 2000; Altas and Buyukgungor, 2007). Discharge of heavy metals into aquatic environment can change both marine species diversity and ecosystems, due to their toxicity and accumulative behavior (Bat, 2005; Bakan and Ozkoç, 2007). Marine organisms such as fish bioaccumulate these heavy metals to concentrations many times higher than present in water or sediment (Bat et al., 2012; Phillips and Rainbow, 1994). Thus, heavy metals acquired through the food chain as a result of pollution are potential chemical hazards, threatening the health of the consumers.

The bioavailability of trace elements is a key factor in determination of concentration of metals in tissues of aquatic biota. Sea food forms the chief link for the probable relocation of these minerals into the human beings. Information on the level of pollution by these minerals in coastal environment is essential as they are the source for deleterious environmental health hazards. Based on data collected under COMAPS (Coastal Ocean Monitoring & Prediction System) since 1991 coastal waters along Mumbai are reported as some of the areas of concern that needs continuous intensive monitoring (Sakthivel et. al. 2005). Differences in mineral concentrations are related to diet and feeding habits of benthic and pelagic fish species (Bustamente et al., 2003). The studies showed that benthic fishes generally accumulate higher concentrations of these minerals than pelagic fishes. Topping (1973) suggested that mainly plankton feeding fish contains much higher concentration of some heavy metals than bottom feeding fish.

Since muscle tissue is the major portion of fish consumed by the fish eating populace, the present study was under taken to assess the concentrations of minerals like Iron, Zinc, Copper, Boron, Manganese, Lead, Arsenic, Cadmium and Mercury in dorsal muscle tissue of commercially valuable fishes caught from marine/estuarine waters off the Mumbai Coast and landed at the Versova fish landing centre in the western suburbs of Mumbai. Further, their hazardous levels were compared with available certified safety guidelines proposed by World Health Organization (WHO) and Food and Agricultural Organization (FAO) for human consumption.


**Fig. 1 Map of Mumbai showing coastal areas (Courtesy www.googlemaps.com)**

## II. Materials And Methods:

**Sample Collection:** The eleven commercially importance marine/estuarine fin fishes captured from the coastal waters off Mumbai along the West Coast of India were collected from Versova (Andheri) fish landing centre. The following species of fin fishes were selected: Shark (*Scoliodon sorrakowah*), Sting ray (*Dasyatus uarnak*), Mackerel (*Rastrelliger kanagurta*), Oil Sardine (*Sardinella longiceps*), Seer fish (*Cybium guttatum*), Silver pomfret (*Stromateus cinereus*), Indian Salmon (*Elutheronema teradactylum*), Bombay duck (*Harpodon nehereus*), common Sole (*Cynoglossus elongatus*), Ribbon fish (*Lepturacanthus savala*) and Black pomfret (*Parastromateus niger*). Freshly landed fishes frozen in ice and kept in boxes were transported to Zoology Research Laboratory of SVKM's Mithibai College for the further investigations.

**Analysis of Mineral Concentration:** All the reagents of analytical grade were used and ultra-pure water was used for all dilutions. Estimation of the concentration of minerals viz. Iron, Zinc, Copper, Boron, Manganese, Lead, Arsenic, Cadmium and Mercury in edible dorsal muscle tissue of the above mentioned fin fishes was carried out using Flame Atomic Absorption Spectrometry i.e. Direct Air-Acetylene Flame method (Willis, 1962 and Paus, 1971). Muscle tissue was digested using mixture of concentrated hydrochloric acid and nitric acid and heated over sand bath to dryness. Perchloric acid was added and boiled until dense white fumes were released, cooled, filtered using Whatman 42 filter paper and volume raised adequately with double distilled water. All the plastic ware and glass wares were cleaned by soaking in 2M and nitric acid for 48 hrs. and first rinsed with double distilled water and then with deionized water prior to use. Stock standard solutions of the said minerals (1000µg/mL Titrisol, Merck in 2% v/v and nitric acid) were used for preparation of calibration standards.

**Statistical analysis of the data**: Statistical analysis was carried out using statistical package program (IBM SPSS 20$^{th}$ Edition). Inter-heavy metal correlations in the fish muscle were investigated. The Spearman's Correlation Coefficient was used to measure the strength of the association between mineral concentrations in muscle tissue and presented in correlation matrices (Pentecost, 1999). The p-values of less than 0.05 and 0.01 were considered to indicate statistical significance.

**Comparison with standard values:** The observed concentrations of minerals was compared with the guidelines of the Standard Program Codex Committee on Food Additives and Contaminants (FAO/WHO, 1992; 2004) set down for the safe consumption limits of fish and associated risk of metal poisoning to the human health (Table 3).

## III. Results And Discussion

Accumulation of minerals was generally found to be species specific and might be correlated to their feeding habits, the bio-concentration capacity of each species (Fariba et al., 2009) and also to their habitat. Mineral accumulation in soft tissues of marine invertebrates that form the food of some of these fishes fluctuate with the metal of concern. Average concentrations of minerals in edible muscle tissue of fishes from coastal waters off the Mumbai Coast of India are presented in Table 1. The essential minerals, such as iron, zinc, copper, boron and manganese are in higher concentrations, presumably due to their function as co-factors for the activation of a variety of enzymes and regulated to maintain a certain homeostatic mechanism in fish. On the other hand, the non-essential minerals such as lead, arsenic, cadmium and mercury have no biological function or requirement and their concentrations in coastal fishes are generally low that corroborates with the findings of other workers (Yilmaz, 2009; Ahmad and Naim, 2008).

**Iron (Fe):** Iron was found moderately abundant in all the species monitored in the study. The concentration varied between 0.993 ppm to 12.7 ppm. Maximum concentration of Fe was observed in *C. elongatus* (12.7 ppm) while the minimum was observed in *S. cenereus* (1.016 ppm) among fin fishes. The reported iron concentration in present study was higher than from marine waters of Turkey (Dural and Bickici, 2010) and Gulf of Aquaba, Red sea (Ahmed and Naim, 2008), but lower than fishes from south west coast of India (Rejomon et. al., 2010) and Caspian sea (Fariba et. al., 2009). The bioaccumulation of high amount of Fe in consumers like human being results in haemochromatosis, characterized by diminished regulatory functions due to tissue damage.

**Zinc (Zn):** The concentration of Zinc was also reasonably high among the metals with moderate variation in among the species. *S. longiceps* showed highest concentration of Zn (2.2038 ppm), followed by *P. niger* (2.1669 ppm). The lowest concentration was observed in *E. tetradactylum* (0.7713 ppm). There was slight variation observed in Zn concentration among elasmobranchs (*S. sorrakowah*, 0.8351 ppm and *D. uarnak*, 1.3134 ppm). However, fishes from West Bengal Coast accumulate high level of zinc than fishes from Turkey (Dural and Bickici, 2010), Red sea (Ahmed and Naim, 2008), South East Coast of India (Raja et. al., 2009) and West Coast of India. Zn is essentially non-toxic trace metal that is vital for enzymatic activity as cofactor and nucleic acid synthesis.

**Copper (Cu):** The lowest concentration of Cu is observed in *H. nehereus* (0.047 ppm) with marginal rise in *S. sorrakowah* (0.056 ppm), *R. kanagurta* (0.089 ppm) and *D. uarnak* (0.1 ppm)**.** While in rest of the fin fishes Cu concentration ranged between 0.659 ppm (*S. longiceps*) to 0.837 ppm (*P. niger*). The higher amount of copper may be due to its relationship with molecular weight proteins forming metallothioneins and for utilization of Iron in formation of haemoglobin. Cu is essential transitional micronutrient for fish and other organisms vital for metabolic and physiologic functions. It is commonly used algaecide and molluscicide (Shaker et. al., 2000). Fariba et. al., (2009) reported the lower concentration of Cu (3.14-3.69 µg/g) and higher concentrations for Zn (37.99-73.81 µg/g) and Fe (73.59-94.78 µg/g) in fishes from Coast of Iran. Bhupander et. al., (2012) observed concentration of copper in muscle tissue was higher in *P. argentius* (9.19 µg/g), medium in *T. trichiurus* (5.66 µg/g) and *Arius sp.* (3.33 µg/g) and relatively low in other species 1.332.83 µg/g.

**Boron (B):** Boron is relatively non-toxic non-metal and showed highest concentration among all the metals under study. Among fin fishes concentration was of the magnitude, *L. savala* (125 ppm)>*C. elongates* (118.7 ppm)>*C. guttatum* (100.8 ppm) while lowest in *S. sorrakowah* (16.9 ppm) and in other fishes it ranged between 55.8 ppm (*H. nehereus*) to 91.5 ppm (*P. niger*). Little is known about the toxic and bioaccumulative dangers to aquatic life posed by borate discharge (Thompson and Davis, 1979). They reported toxicity to under yearling Coho in sea water appeared considerably greater, with salmonids, Boron enters the tissues slowly, necessitating prolonged bioassay tests. Sockeye salmon (*O. nerka*) and juvenile oysters (*Crassostrea gigas*) exposed to sublethal take up Boron roughly in relation to its availability, while oysters showed no bioaccumulative potential or prolonged retention following cessation of dosage. Boron is a naturally occurring element and is used in industrial and domestic products. Its major release into the environment is through weathering processes and wastewater discharge. Boron is an essential micronutrient for plants, but can above certain concentrations be toxic to aquatic and terrestrial organisms. Generally, environmental concentrations of boron found in surface water are below levels identified as toxic to aquatic organisms (Butterwick et al., 1989). Ekert (1998) evaluated growth and teratogenicity in the eye, hatch and 2-wk post hatch developmental stages of trout on exposure to Boron.

**Manganese (Mn):** Manganese is a low toxicity metal but has a considerable biological significance and does not seem to bioaccumulated in fish species. In present investigation Manganese concentration was observed to be least when compared with other metals under study. It ranged from 0.004 ppm (*L. savala*) to 0.026 ppm (*E.*

*tetradactylum*). This could be attributed to either low concentration in the environment of efficient utilization or elimination from the living system. Huang, (2003) reported the lower concentration of Mn in muscle tissue of fish as observed in present findings. Bhupander et. al., (2012) reported that lowest concentration of Mn was 0.89 µg/g in *R. kanagurta*, which is in corroboration with present findings and highest (5.3 µg/g) in *H. nehereus* while in other species the concentration ranged from 1.00-5.33 µg/g.

The non-essential minerals entering the fish have a possibility to get bioaccumulated in different parts of the body and the residual amount can build up to a toxic level. Some fishes, being filter feeding, are most recurrently used to monitor the pollution of coastal water by metals. The interdependency of uptake and diminution rates when sufficient levels of the essential elements for metabolism are sequestered in the body, equilibrium is established between the body burden of these minerals and their environmental concentration. The mineral accumulation is more rapid than elimination probably due to the presence of metal binding proteins in tissues often referred to as metallothioneins. Higher concentration of these minerals in the certain tissue suggests that the animal's capability to sequester the elements safely from the body. The study of mineral concentrations in fishes finds relevance to its consumption by human as protein rich food commodity. Several studies in past have shown that mineral concentration in tissue of coastal fishes might vary considerably among different fish species. This was possibly due to differences in metabolism and feeding patterns of the fishes (Sivaperumal et. al., 2007; Raja et. al., 2009; Rejomon et. al., 2010; Bhupander et. al., 2012).

**Lead (Pb):** The concentration of lead in fin fishes ranged between 0.68 ppm in *T. savala* to 1.04 ppm in *R. kanagurta*. It was also observed that the fish with highest water content, *H. nehereus* showed comparatively higher concentration of 0.95 ppm. Among elasmobranchs, the concentration of Pb was 0.75 ppm in *S. sorrakowah* and 0.7 ppm in *D. uarnak*. Lead is toxic to humans, with the most deleterious effects on the blood vascular system, CNS, urino-genital system. Expert Committee on Food Additives establishes a Provisional Tolerable Weekly Intake (PTWI) for lead as 0.3 mg/kg body weight. European Community (No. 1881/2006) and Bulgarian Food Codex (No. 31/2006) set maximum permitted level for Pb in fish of 0.4 mg/kg w.w. Tuzen et. al. (2003) reported for fish species from the middle Black Sea lead levels in the range of 0.22-0.85 mg/kg w.w. Uluozlu et. al. (2007) on investigation of lead contents of fish species from Black and Aegean seas found values in range of 0.33-0.93 mg/kg for edible fish tissue.

**Arsenic (As):** Arsenic was found to show vast variation in concentration in all the fish samples analyzed. Elasmobranchs showed least concentration of 0.009 ppm in *S. sorrakowah* and 0.008 ppm in *D. uarnak*. Among teleost, Arsenic concentration ranged between 0.012 ppm in *H. nehereus* to 0.030 ppm in *T. savala*. Higher concentrations of Arsenic were observed in fishes from Gresik coastal waters of Indonesia by Agoes and Hamami (2007) than present investigation. Arsenic is a widely distributed metalloid, occurring in rock, soil, water and air. It is released in the environment through natural processes such as weathering and may circulate in natural ecosystems for long time. General population exposure to As is mainly via intake of food and drinking water. Chronic exposure to inorganic As may cause serious impact on peripheral and central nervous system. The WHO/FAO (2011) and Bulgarian Food Regulation recommended the maximum levels permitted for As in marine fish as 5.00 mg/kg w.w. Falko et. al. (2006) estimated As concentration in 14 edible marine species from Mediterranean Sea. Alisa et al. (2012) observed As levels in 12 fish species from Malaysia in range from 0.25-6.57 mg/kg w.w. Stencheva et al. (2013) analyzed levels of As in gills and muscles tissues of grey mullet from Varna Lake and Nesebar waters of Black Sea. The samples from both regions showed the higher levels of As in edible tissue than in gills, especially from region of Nesebar (1.1 mg/kg w.w.) are in concurrence with observations in the present investigations.

**Cadmium (Cd):** Cadmium is a non-essential, highly toxic and ecotoxic metal observed in lowest concentration among all the fish samples under present study. Its concentration ranged between 0.008 ppm in elasmobranchs, *S. sorrakowah* to 0.078 ppm in teleost, *P. niger*. However in the present study concentration of Cd is lower than South West Coast of India as repoted by Rejomon et. al. (2010). The occupational levels of Cadmium exposure prove to be a risk factor for chronic lung disease and causes testicular degeneration. Cadmium could be readily bioaccumulated in lower portion of food chain and bio-concentrate in multiple organs of fish. Cadmium could originate from water, sediments and food and may accumulate in the human body and may induce kidney dysfunction, skeletal damage and reproductive deficiency (WHO/FAO, 2011). The European Community (No. 1881/2006) and Bulgarian Food Regulation recommended the maximum levels permitted for Cd in sea fish as 0.05 mg/kg w.w. Moreover, the Joint FAO/WHO (2004) has recommended the Provisional Tolerable Weekly Intake (PTWI) as 0.007 mg/kg body weight for this element. Bat et. al. (2012) also determined similar levels for Cd (0.025 $mg/kg^1$) in edible muscle tissue of mullet from Sinop region in Turkey along the Black Sea Coast.

**Mercury (Hg):** Among the non-essential metals estimated, Mercury was observed to be second highest in concentration but below the permissible limit of 0.02-0.2 ppm as prescribed by WHO (1989). In fin fishes its concentration ranged between 0.001 ppm in *S. sorrakowah* to 0.0021 ppm in *P. niger*. The concentrations of Hg in fishes off the Mumbai Coast were comparable with fishes from Malaysia (Hajeb et. al., 2009) and Thailand (Agusa et. al., 2007). Mercury is a heavy metal with neurotoxic and genotoxic properties. In fin fish and shell fish 90% of Hg is in its most toxic form as Methyl mercury (Food Standards, 2004). Menon and Mahajan (2015) confirmed in their study on fishes consumed by villagers from Vittawa village along Thane Creek to consume both fin and shell fishes contaminated with methyl mercury and reported these fishes to have Hg concentration above the permissible limit as proposed by Joint FAO/WHO Expert Committee on Food Additives (2003). Movement of Hg (II) into aquatic ecosystem and its bioaccumulation as methyl mercury in higher trophic levels are strongly influenced by the uptake of bioavailable forms of Hg (II). Fish obtained methylated mercury through dietary uptake, which could be influenced by size, diet, ecological and environmental factors. Mercury is one of the most toxic elements among the studied heavy metals and exposure to high level of this element could permanently damage the brain, kidneys and developing foetus (FAO/WHO, 2004). According to Bulgarian Food Codex and European Community, the maximum mercury level permitted for sea fish is 1.0 mg/kg w.w. Alisa et. al. (2012) determined significantly higher concentration for Hg that ranged from 1.0-6.5 mg/kg w.w. in twelve fish species from Malaysian waters.

Various pathways of mineral accumulation in fish include ingestion of food, suspended particulate matter, ionic exchange through gills and integument. From these pathways, minerals probably get absorbed into the blood and transported to various organs for either storage or excretion. Levels of these minerals in different organs of fish is often used as an index of pollution in an ecosystem, which is considered as an important tool to highlight the role of elevated level of elements in aquatic organisms. Concentration of minerals in different tissues/organs of fishes is directly influenced by contamination in aquatic environment, uptake, regulation and elimination inside the fish body. Mineral bioaccumulation in tissues considerably depends upon the accretion capacity of the tissue. Many authors have reported that metal accumulation by liver and gills occur in higher magnitude than muscle of fish. Gill is the main place for gaseous exchange in fish. In this organ, because of the short distance between blood and surrounding seawater, metal ions might directly take up from the passing water (Farkas et. al., 2003). Furthermore, literature states that the occurrence of non-essential metals including mercury and others were also related to length, weight and age of fish (Agusa et. al., 2005). The influence of aquatic environments as well as anthropogenic activities at specific point of time may contribute to accumulation of heavy metals in fishery products (Zhang and Wong, 2007). Accumulation of these minerals in the aquatic environment have been concomitant with urban runoff, sewage treatment plants, industrial effluents and wastes, mining processes, navigation, agricultural pesticide runoff and domestic sewage.

Marine organisms like fishes are characterized by a greater spatial ability to accumulate some metals when compared with bottom sediments. The concentration of few metals measured in the muscle of the species studied in present investigation was higher than the levels issued by WHO/FAO (WHO, 1989; FAO, 1983) (Table 3). Moreover, comparisons with the Canadian food standards (Cu: 100 µg/g; Zn: 100 µg/g), Hungarian standards (Cu: 60 µg/g; Zn: 80 µg/g) and Australian acceptable limits (Cu: 10 µg/g; Zn: 150 µg/g) demonstrate that the content of these metals in the muscle tissue of the examined fishes is not higher than the guidelines mentioned earlier though not for Manganese, which is lower than certified level or marginally for few other metals like Cadmium and higher for the other metals under study raising a matter of concern in fish bioaccumulation and biomagnification through food chains to human consumers. Excessive pollution of surface waters can lead to hazards in human health, through consumption of contaminated seafood. Nevertheless exposure to heavy metals can also affect reproductive efficiency of aquatic organisms leading to a steady annihilation of their generations in polluted environment.

## IV. Statistical Evaluation

Obtained data was statistically evaluated with the help of IBM SPSS Statistics program ($20^{th}$ Edition). With the help of Shapiro-Wilk Test, we have found that the obtained data was not normally distributed. As data was not normally distributed we have to go for non-parametric tests. The data was further analyzed with the help of Friedman's Repetitive ANOVA and it was found that the mineral concentration in fishes were significantly different. Spearman's Correlation Coefficient Analysis (Table 2) reveals that, in fishes there is strong positive correlation between Arsenic and Boron. Cadmium and Mercury showed positive correlation with Boron. Arsenic also showed positive correlation with Copper.

## V. Conclusion

In view of the prominence of fishes that form an integral part of protein rich diet of human, it is necessary that biological monitoring of the fish meant for consumption should be carried out recurrently to warrant safety of the seafood. Fishes are also major component of the marine ecosystem with tremendous export potential, thus assessment of the minerals is particularly important. This study will contribute to the accrual of new data on their levels in species of marine organisms with commercial significance, thus to make a more valid conclusion further experimentation would be mandatory so as to tap the source of these pollutants and bioaccumulation at various trophic structures of the aquatic ecosystem. From this analysis, status of coastal waters off the Mumbai Coast will be apparently predicted for their pollution by minerals. Safe disposal of industrial effluents, domestic sewage and navigational activities should be practiced in harmony with nature and enforcement of laws be enacted to protect our marine environment and/or, recycled to circumvent these minerals and other contaminants from entering into the marine environment. Further study warrants assessment of contaminants other than minerals studied before proclaiming them safe for human consumption and export.

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**Table 1. The mean±SD* (ppm) and range of minerals in edible muscle tissue of fin fishes collected from Versova fish landing centre, Mumbai (n=6)**

| **Fin Fish** | **Concentration of Minerals (ppm)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Fe** | **Zn** | **Cu** | **B** | **Mn** | **Pb** | **As** | **Cd** | **Hg** |
| ***Scoliodon sorrakowah*** | **2.204<br>±0.044** | **0.8351<br>±0.016** | **0.056<br>±0.0001** | **16.9<br>±0.338** | **0.028<br>±0.0005** | **0.75<br>±0.015** | **0.009<br>±0.00018** | **0.008<br>±0.00016** | **0.001<br>±0.00002** |
| ***Dasyatus uarnak*** | **6.961<br>±0.139** | **1.3134<br>±0.026** | **0.100<br>±0.002** | **57.5<br>±1.15** | **0.108<br>±0.002** | **0.7<br>±0.014** | **0.008<br>±0.00017** | **0.017<br>±0.00034** | **0.0015<br>±0.00003** |
| ***Harpodon nehereus*** | **1.659<br>±0.033** | **0.7807<br>±0.015** | **0.047<br>±0.0009** | **55.8<br>±1.11** | **0.030<br>±0.0006** | **0.95<br>±0.019** | **0.012<br>±0.00025** | **0.013<br>±0.00026** | **0.001<br>±0.00002** |
| ***Rastrelliger kanagurta*** | **1.508<br>±0.030** | **0.9215<br>±0.018** | **0.089<br>±0.0017** | **74.5<br>±1.49** | **0.031<br>±0.0006** | **1.04<br>±0.020** | **0.016<br>±0.0003** | **0.044<br>±0.00088** | **0.0014<br>±0.000028** |
| ***Sardinella longiceps*** | **2.197<br>±0.043** | **2.2038<br>±0.044** | **0.659<br>±0.0130** | **67.2<br>±1.344** | **0.072<br>±0.0014** | **0.89<br>±0.018** | **0.018<br>±0.0003** | **0.014<br>±0.00028** | **0.0013<br>±0.000026** |
| ***Stromateus cinereus*** | **1.016<br>±0.020** | **0.7477<br>±0.014** | **0.781<br>±0.015** | **86.9<br>±1.738** | **0.033<br>±0.0006** | **0.85<br>±0.017** | **0.021<br>±0.0004** | **0.016<br>±0.00032** | **0.0014<br>±0.000027** |
| ***Elutheronema tetradactylum*** | **1.463<br>±0.029** | **0.7713<br>±0.015** | **0.806<br>±0.016** | **83.2<br>±1.664** | **0.026<br>±0.0005** | **0.78<br>±0.016** | **0.023<br>±0.0004** | **0.017<br>±0.00033** | **0.0013<br>±0.000027** |
| ***Cybium guttatum*** | **4.601<br>±0.092** | **0.9048<br>±0.018** | **0.735<br>±0.0147** | **100.8<br>±.016** | **0.091<br>±0.0018** | **0.74<br>±0.015** | **0.026<br>±0.0005** | **0.015<br>±0.00031** | **0.0016<br>±0.000032** |
| ***Cyanoglossus elongatus*** | **12.70<br>±0.254** | **0.8713<br>±0.017** | **0.656<br>±0.013** | **118.7<br>±.374** | **0.045<br>±0.0009** | **0.72<br>±0.014** | **0.027<br>±0.0006** | **0.018<br>±0.00036** | **0.0013<br>±0.000026** |
| ***Lepturacanthus savala*** | **1.895<br>±0.037** | **1.0698<br>±0.021** | **0.631<br>±0.012** | **125.0<br>±2.5** | **0.004<br>±0.00008** | **0.68<br>±0.013** | **0.030<br>±0.0006** | **0.028<br>±0.0005** | **0.0017<br>±0.000034** |
| ***Parastromateus niger*** | **2.087<br>±0.019** | **2.1669<br>±0.029** | **0.837<br>±0.013** | **91.5<br>±2.9** | **0.074<br>±0.00012** | **0.86<br>±0.017** | **0.027<br>±0.0005** | **0.078<br>±0.0036** | **0.0021<br>±0.000043** |

**Table 2. Spearman's Correlation Coefficient between the minerals in edible muscle tissue of fin fishes collected from Versova fish landing centre, Mumbai**

| Minerals | Fe | Zn | Cu | B | Mn | Pb | As | Cd | Hg |
|---|---|---|---|---|---|---|---|---|---|
| **Fe** | 1.000 | 0.455 | -0.182 | 0.055 | 0.555 | -0.536 | -0.023 | -0.1 | 0.046 |
| **Zn** | 0.455 | 1.000 | 0.055 | 0.100 | 0.482 | -0.055 | 0.105 | 0.360 | 0.502 |
| **Cu** | -0.182 | 0.055 | 1.000 | 0.555 | 0.264 | -0.055 | 0.606 | 0.374 | 0.493 |
| **B** | 0.055 | 0.100 | 0.555 | 1.000 | 0.018 | -0.436 | 0.938 | 0.615 | 0.641 |
| **Mn** | 0.555 | 0.482 | 0.264 | 0.018 | 1.000 | -0.036 | -0.128 | 0.068 | 0.378 |
| **Pb** | -0.536 | -0.055 | -0.055 | -0.436 | -0.036 | 1.000 | -0.305 | -0.091 | -0.318 |
| **As** | -0.023 | 0.105 | 0.606 | 0.938 | -0.0128 | -0.305 | 1.000 | 0.553 | 0.527 |
| **Cd** | -0.100 | 0.360 | 0.374 | 0.615 | 0.068 | -0.091 | 0.553 | 1.000 | 0.693 |
| **Hg** | 0.046 | 0.502 | 0.493 | 0.641 | 0.378 | -0.318 | 0.527 | 0.693 | 1.000 |

= > Correlation is significant at the 0.05 level (2-tailed)
= > Correlation is significant at the 0.01 level (2-tailed)

**Table 3. The levels of metals (µg/g dry wt.) in muscles of fishes from Coastal waters of selected regions**

| Regions of study | Minerals | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|
| | Cu | Zn | Mn | Fe | Cd | Hg | As | |
| **WHO** | **30** | **100** | **1.00** | **1.00** | **1.00** | **0.5** | **-** | **WHO, 1989** |
| **FAO** | **30.0** | **40.0** | **-** | **-** | **0.5** | **-** | **86** | **FAO, 1983** |
| **South East Coast (India)** | **0.1-0.3** | **14.1-35.5** | **0.31-1.20** | **24.1-50.3** | **0.18-0.54** | **-** | **-** | **Raja et. al., 2009** |
| **Gulf of Cambay (India)** | **2.4±0.5** | **38.2±1.6** | **12.1±0.7** | **94.4±2.6** | **0.2±0.03** | **1.0±0.3** | **1.7±.0.9** | **Mallampati et. al., 2007** |
| **Cochin (India)** | **15-24** | **0.6-165** | **0.08-9.2** | **-** | **0.07-1.0** | **0.05-2.31** | **0.1-4.14** | **Sivaperumal et. al., 2007** |
| **South West Coast (India)** | **3.09-3.62** | **79.3-84.3** | **-** | **541-649** | **4.35-6.38** | **-** | **-** | **Rejomon et. al., 2010** |
| **North East Coast (India)** | **3.9 ±0.7** | **19.9 ±2.4** | **3.0 ±0.3** | **49.2±4.3** | **0.33 ±0.03** | **0.48 ±0.03** | **0.64 ±0.05** | **Bhupander et. al., 2012** |
| **Mediterranean sea** | **0.3-16.7** | **3.3-42.6** | **0.1-2.6** | **18.5-57.6** | **0.02-0.21** | **-** | **-** | **Turkmen et. al., 2008** |
| **Gresik Coast (Indonesia)** | **3.5-28.9** | **15.5-68.4** | **-** | **-** | **NT-0.05** | **-** | **NT-2.33** | **Agoes and Hamami, 2007** |
| **Aquaculture ponds (Malaysia)** | **0.3-2.6** | **1.9-13.0** | **0.11-0.20** | **2.88-7.21** | **0.01-0.25** | **-** | **-** | **Mazlin et. al., 2009** |