SHORT COMMUNICATION

# Comparative Study of Lead and Cadmium Levels in Freshwater Fishes

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## Abstract

Water pollution is one of the major environmental problem in the world. Fishes have a natural tendency to accumulate heavy metals in their bodies. Among the various toxic heavy metals, lead (Pb) and cadmium (Cd) are most widely dispersed metals in the environment and also create global concern due to causing potential hazards to public health. Cadmium (Cd) and lead (Pb) were determined in edible tissues of some economically important freshwater fishes, collected from the various markets of Agra region and analysed for their contamination. Highest concentrations were observed in summer followed by winter and rainy seasons. The frequency of heavy metal contamination was higher in *Labio rohita* than other fish commodities. It was concluded that the levels of metals were different but within the maximum residue levels recommended by National and International standards. Findings of the present study have also been corroborated with some other national and International studies.

**Keywords:** Cadmium, Fish, Health, Heavy metals, Lead, Seasonal variation.

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## Introduction

Water pollution is one of the major environmental and public health problems in India especially in the river Yamuna and Ganga. The Yamuna is the second largest tributary river of the Ganges and the longest tributary in India. Agra is situated on the bank of Yamuna and the heavy metal concentration from various sources contributed towards polluting the river day by day. The main cause of this problem is urbanization and industrialization (UN-HABITAT, 2004). Yamuna River was once described as the lifeline of the Agra city, but now it has become one of the dirtiest rivers in the country. According to the Central Pollution Control Board (CPCB) the water quality of Yamuna River falls under the category "E" which makes it fit only for recreation and industrial cooling, completely ruling out the possibility for under- water life (Hindu, 2002). Numerous actions have been taking by the Government to address the problem of pollution of river Yamuna. The Ministry of Water Resources, River Development and Ganga Rejuvenation are supplementing the efforts of states for checking the rising level of pollution of river Yamuna, by providing financial assistance to states of Haryana, Delhi and Uttar Pradesh in a phased manner since 1993 under the Yamuna Action Plan (YAP).

Fishes are valuable source of high-grade protein, for man and his live stock. Heavy metals from natural and anthropogenic sources like atmospheric precipitation, waste water, industrial discharges are released into aquatic ecosystems, where they pose a serious threat to living beings including fishes because of its toxicity, long persistence, bioaccumulation and biomagnifications in the food chain (Kucykbay and Orun, 2003; Pourang *et al.,* 2005). A lot of studies have been published on the heavy metal levels in the aquatic environment (Rashed, 2001; Canli and Atli, 2003; Farkas *et al.,* 2003; Karadede *et al.,* 2004; Demirak *et al.,* 2006; Velcheva, 2006; Yilmaz, 2006). Toxic heavy metals adversely affect the aquatic bodies and also get accumulated into the tissues of aquatic species including fish intended for human consumption (Kotsanis and Iliopoulou-Georgudaki, 1999; Zyadah and Abdel-Bakey, 2000; Lliopoulou-Georguadaki and Kotsanis, 2001; Samanta *et al.,* 2005; Sharma and Agarwal, 2005; Verma *et al.,* 2005; Jayakumar and Paul, 2006). There are numerous studies about metal toxicity in fish from different locations like Kolleru lake (Adhikari *et al.,* 2009), Cauvery river (Dhanakumar *et al.,* 2015), Gomti river (Gupta *et al.,* 2015), eastern India (Chakraborty et al., 2003) and South East coast (Jayaprakash *et al.,* 2015). Considering the importance of fish in the human diet, consumption of significant amounts of contaminated fish could pose a significant threat to human health. Hence, the present study was proposed to compare the seasonal variation of lead and cadmium in edible fresh water fish species of Agra region with some other relevant studies and to see if there are any variations in their results. Besides this, since attempts of various governments and NGO's to clean environment and decrease pollution of rivers, it would be interesting to know if there is any decrease in level of heavy metal concentration in different seasons in aquatic ecosystem over the years.

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## Material and Method

### Site

The study was conducted in Agra, (latitude $27^0$ 10′ N and longitude 78° 5′ E) which is located in the North central part of

India. Information available from different fish dealers indicates that fresh water fishes available in Agra markets are brought from river Yamuna and its tributaries. (Fig.1).

## Sampling

Based on the local consumption, the fish species selected were *Labeo rohita* (Rohu), *Catla catla* (Bhakur), *Channa punctatus* (Girai), *Heteropneustes fossilis* (Singhi) and *Clarias batrachus* (Magur). A total of 150 samples (10 samples of each fish/season) of fishes were purchased from different commercial fishery market of Agra. Fish samples were kept in pre cleaned polythene bags, which were sealed and kept in an ice box until further analysis in the laboratory.

## Analysis of the Heavy Metals

Before analysis, the fish samples were defrosted for about 2 h. After deforestation, the samples were washed with double-distilled water. The muscles of the fish samples were removed out carefully and oven dried to remove moisture and was crushed with a mortar and pestle to fine powdery form. Gloves were worn during dissection of fish tissues to reduce the contamination. Wet digestion method was used for the analysis. All reagents like Sulfuric Acid ($H_2SO_4$), Nitric acid ($HNO_3$) and Hydrogen peroxide used were of analytical grade purchased from E. Merck Ltd, India. Certified reference material (CRM) of lead and mercury was procured from the National Physical Laboratory, New Delhi. To estimate the metal content 5g.±0.1 of samples were digested with conc. $HNO_3$ and conc. $H_2SO_4$ (1:1). The completely digested sample were allowed to cool to room temperature, filtered with a Whatman filter paper (No. 1) and made up to 50 ml with double distilled water (AOAC 1990). The elemental analysis was carried out in a Perkin Elmer AA analyst 100 atomic absorption spectrophotometer as per standard conditions given in Table 1.

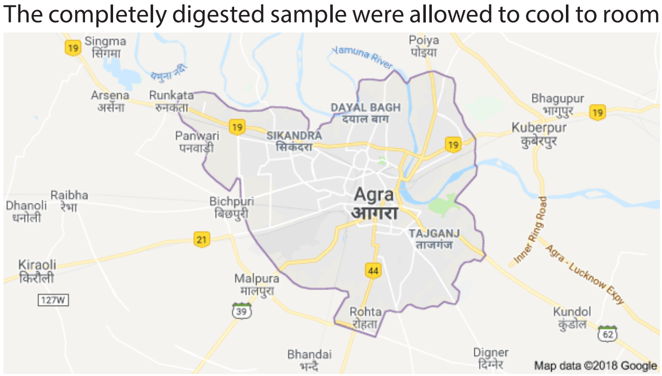


**Fig. 1:** Map of Agra city

## Analyte Recovery and Quality Control

All the reagents used were of analytical grade. Glass wares were soaked in 10% nitric acid for 24 hrs and rinsed with distilled water followed by 0.5% (w/v) $KMnO_4$ solution and finally with distilled water. Homogenized samples (5.0 ± 0.5 g) were spiked with three different concentrations of lead and cadmium at 0.05, 0.1, and 0.2 ppm. The accuracy and precision were verified by analyzing the certified reference material. The recovery experiment was performed at the three concentrations and each concentration was analyzed in triplicates and the mean of each value was taken. A calibration blank and an independent calibration verification standard were also analyzed after every five samples to confirm the calibration status of the AAS. Recoveries were found 98% to 102% for lead and 97% to 101% for cadmium (Table 2).

# Results and Discussion

The mean values and standard deviations of lead and cadmium concentrations detected in the edible portion of the selected species of fish are shown in Table 3. To study the seasonal variation, sampling was carried out during winter, summer and rainy seasons. *Labeo rohita* was found to accumulate higher levels of Pb and Cd as compared to other edible fishes. Lead is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults (Commission of the European Communities 2005). The value of Cadmium is higher in all the fishes in comparison to lead. In the present study, both metals were observed high in both the fish species in summer followed by winter and rainy season (Fig. 2).

Various researchers have determined the presence of toxic metals in Indian rivers. Prabha and Selvapathy (1997) have studied the status and trend of river water pollution. Priyadarshani (1998) has reported the presence of zinc, copper, nickel, cadmium, lead, manganese, mercury, cobalt and iron in

**Table 1:** General Characteristic condition of different metals measured on (AAS, AA analyst 100, Perkin Elmer)

| *Metal* | *Wavelength (nm)* | *Slit (nm)* | *Detection limit (mg/1)* | *Sensitivity (mg/1)* | *Optimum concentration range (mg/1)* | *Linear range* | *Mode* |
|---|---|---|---|---|---|---|---|
| Cd | 228.8 | 0.7 | 0.002 | 0.028 | 0.05-2.0 | 2.0 | Absorption |
| Pb | 283.3 | 0.7 | 0.05 | 0.45 | 1.0-20.0 | 20.0 | Absorption |

Flame: Air - Acetylene

**Table 2:** Recovery (%) of Pb and Cd residues obtained in fresh water fishes

| *S.N.* | *Heavy metals* | *Sample weight (g)* | *Spiked concentration (mg/kg)* | *Recovery concentration (mg/kg)* | *Recovery (%)* |
|---|---|---|---|---|---|
| 1 | Pb | 5.0 ± 0.1 | 0.05 | 0.049 | 98 |
| | | 5.0 ± 0.1 | 0.1 | 0.099 | 99 |
| | | 5.0 ± 0.1 | 0.2 | 0.204 | 102 |
| 2 | Cd | 5.0 ± 0.1 | 0.05 | 0.0485 | 97 |
| | | 5.0 ± 0.1 | 0.1 | 0.101 | 101 |
| | | 5.0 ± 0.1 | 0.2 | 0.196 | 98 |

**Table 3:** Concentration of metal residues (μg kg$^{-1}$) obtained in different fishes during summer, winter and rainy season

| | *Winter* | | *Summer* | | *Rainy* | |
|---|---|---|---|---|---|---|
| *Fish Species* | *Pb* | *Cd* | *Pb* | *Cd* | *Pb* | *Cd* |
| Labeo rohita | (12.0 ± 3.2) | (22.0 ± 1.5) | (25.0 ± 2.3) | (29.0 ± 9.1) | (2.0 ± 3.2) | (19.0 ± 3.5) |
| Catla catla | (3.0 ± 2.1) | (15.0 ± 3.3) | (23.0 ± 7.0) | (31.0 ± 8.2) | (3.0 ± 2.0) | (9.0 ± 3.1) |
| C. punctatus | (5.0 ± 2.7) | (10.0 ± 6.4) | (21.0 ± 9.2) | (15.0 ± 5.1) | (5.0 ± 2.7) | (9.0 ± 2.4) |
| H. fossilis | (3.0 ± 1.2) | (16.0 ± 4.5) | (14.0 ± 6.1) | (17.0 ± 8.2) | (3.0 ± 2.1) | (5.5 ± 3.5) |
| C. batrachus | (5.0 ± 3.2) | (11.0 ± 5.3) | (14.0 ± 6.0) | (21.0 ± 8.2) | (3.0 ± 2.1) | (10.0 ± 1.5) |

Note: Data are presented as the mean (average of ten samples) value± SD, N: Number of samples, FSSAI MRL (as regulation 2011) of Pb, and Cd are 0.3 and 0.3 mg kg$^{-1}$ respectively.

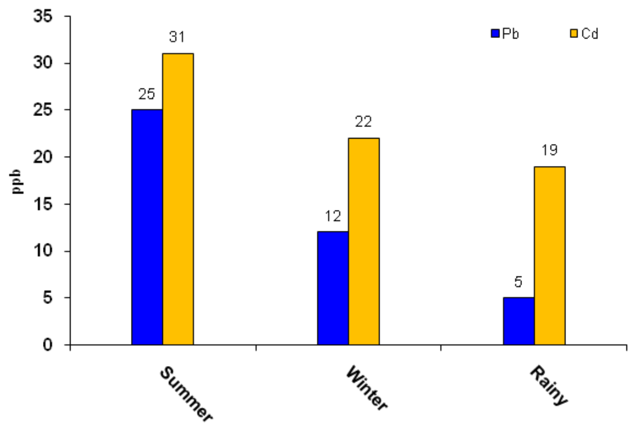


**Fig. 2:** Seasonal variation of Pb and Cd in various fish samples

the Safi River. In present study, lead and cadmium was detected below the tolerance limits recommended by National and International standard, the same result has been reported by Batvari *et al.* (2007). The level of heavy metals in fishes varies with respect to different species depends upon its feeding habit, age, size and length of the fish and their habitats and different aquatic environments. Moreover, the affinity for metal absorption from contaminated water and food may differ in relation to ecological needs, metabolism and the contamination gradients of water, food and sediment, as well as other factors such as salinity, temperature and interacting agents. Kock and Hofer (1998) reported that even low concentrations of heavy metal in the water may result in high concentrations in fish flesh. However, Wong *et al.* (2001) reported that despite high metal levels in the sediments, concentrations of Pb, Cd and Hg in fish flesh did not exceed permissible levels. So, knowledge of heavy metal concentrations in fish is important with respect to environment and human consumption of fish. In the literature, heavy metal concentrations in the tissue of freshwater fish vary considerably among different studies (Papagiannis *et al.,* 2004; Osman, 2012; Jamal *et al.,* 2013) possibly due to differences in metal concentrations and chemical characteristics of water from which fish were sampled, ecological needs, metabolism and feeding patterns of fish and also the season in which studies were carried out. Mansour *et al.* (2012) reported that fish are often at the top of the food chain in a river and have the tendency to accumulate heavy metals from water. Extensive study of heavy metal contamination of heavy metals in water and soil was carried out in the Delhi segment of Yamuna basin (from Wazirabad barrage till the Okhla barrage, 13 sites were chosen). The key findings of the study were: Average heavy metal concentration at different locations in the river water varied in the order of Fe > Cr > Mn > Zn > Pb > Cu > NI > Hg > As > Cd (Sehgal *et al.,* 2012).

In present study, high metal concentration was observed during summer month in comparison to winter and rainy season, similar trend were observed in Mediterranean shrimp and Mediterranean fish (Kargin *et al.,* 2001). Seasonal variation of in metal has been well- documented in different studies from freshwater marine environment (Foster *et al.,* 2000; Kargin *et al.,* 2001; Eastwood and Couture, 2002; Chouba *et al.,* 2007; Ibrahim and Omar, 2013). Similar pattern of metal accumulation has been reported in a number of recent studies also. Thomas *et al.* (2014) shows that the concentrations of most of the heavy metals in fish are higher in summer season than other seasons. In Dhanbad, the metal concentration was found higher in pre monsoon than in post monsoon samples. The seasonal variation can be co-related to the metal content in water (Sophia *et al.,* 2017) that were found higher during pre-monsoon season in water and the order of concentration were Pb>As>Hg. Some international studies also observed the same pattern of heavy metal levels in fishes (Zyadah and Abdel-Bakey, 2000; Bahnasawy *et al.,* 2009; Hashim *et al.,* 2014; Sivakumar *et al.,* 2018). Chouba *et al.* (2007) reported an interesting pattern in fish species *Mugil cephalus* of the lagoon of Ghar El Melh (GEM), Tunisia, He found that concentration of lead were higher in winter where as that of cadmium were higher in summer. In a study conducted in Egypt, the accumulation and bioaccumulation factor of heavy metals Zn, Fe and Cu were found higher in summer season due to increase of temperature (Ibrahim and Omar, 2013). So we can conclude from different studies that heavy metal concentrations in the freshwater fishes were found differ from location to location. The seasonal variation of this current study could be attributed to these factors; differences in metal concentrations of water and sediments from the different collection/sampling sites, metabolism, ecological needs, runoff and feeding patterns of fish.

## Conclusion

A number of studies including the present one showed that heavy metals find their way in fish tissues. The level of accumulation varies seasonally, possibly due to change in concentration in river water. Though heavy metals are found in edible tissues of the fishes, in none of the samples the metal concentration exceeded the FSSAI recommended Maximum Permissible Level.

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## References

Adhikari, S., Ghosh, L., Rai, S.P. and Ayyappan, S. 2009. Metal concentrations in water, sediment, and fish from sewage-fed aquaculture ponds of Kolkata, India. *Environmental Monitoring Assessment* **159**: 2.

AOAC 1990. Official methods of analysis. Washington, DC: Association of Official Analytical Chemists, 15$^{th}$ Ed., pp. 858.

Bahnasawy, M., Khidr, A. and Dheina, N. 2009. Seasonal variations of heavy metals concentrations in Mullet, *Mugil cephalus* and *Liza ramada* (Mugilidae) from Lake Manzala, Egypt. *Journal Applied Science Research* **5**(7): 845-852.

Batvari, B.P.D., Kamala-Kannan, S., Shanthi, K., Krishnamoorthy, R., Lee, K.J. and Jayaprakash, M. 2007. Heavy metals in two fish species (*Carangoidel malabaricus* and *Belone stronglurus*) from Pulicat Lake, North of Chennai, Southeast Coast of India. *Environmental Monitoring Assessment* **145**: 167-175.

Canli, M. and Atli, G. 2003. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. *Environmental Pollution* **121**: 129-136.

Chakraborty, R., Dey, S., Dkhar, P.S., Ghosh, D., Singh, S., Sharma, D.K. and Myrboh, B. 2003. Accumulation of heavy metals in some fresh water fishes from eastern India and its possible impact on human health. *Enviromedia* **22**(3): 353-358.

Chouba, L., Kraiem, M.W.N., Tissaoui, C., Thompson, J.R. and Flower, R.J. 2007. Seasonal variation of heavy metals (Cd, Pb and Hg) in sediments and in mullet, *Mugil cephalus* (Mugilidae), from the Ghar El Melh Lagoon (Tunisia). *Transit Waters Bulletin* **4**: 45-52.

Commission of the European Communities 2005. Commission Regulation as regards heavy metals, Directive 2001/22/EC, No: 466/2001.

Demirak, A., Yılmaz, F., Tuna, A.L. and Özdemir, N. 2006. Heavy metals in water, sediment and tissues of *Leuciscus cephalus* from a stream in southwestern Turkey. *Chemosphere* **63**: 1451-1458.

Dhanakumar, S., Solaraj, G. and Mohanraj, R. 2015. Heavy metal partitioning in sediments and bioaccumulation in commercial fish species of three major reservoirs of river Cauvery delta region, India. *Ecotoxicology and Environmental Safety* **113**: 145-151.

Eastwood, S. and Couture, P. 2002. Seasonal variations in condition and liver metal concentrations of yellow perch (*Perca flavescens*) from a metal-contaminated environment. *Aquatic Toxicology* **58**: 43-56.

Farkas, A., Salánki, J. and Specziár, A. 2003. Age-and size specific of heavy metals in the organs of freshwater fish *Abramis brama* L. populating a low-contaminated site. *Water Research* **37**: 959-964.

Foster, E.P., Drake, D.L. and Di Domenico, G. 2000. Seasonal changes and tissue distribution of mercury in largemouth bass (*Micropterus salmoides*) from Drena Reservoir, Oregon, Arch. *Environmental Contamination and Toxicology* **38**: 78-82.

FSSAI (2011) Contaminants, toxins and Residues Regulations, P1-65

Gupta, S.K., Chabukdhara, M., Singh, J. and Bux, F. 2015. Evaluation and potential health hazard of selected metals in water, sediments, and fish from the Gomti River. *Human and Ecological Risk Assessment* **21**(1): 227-240.

Hashim, R., Song, T.H., Muslim, N.Z. and Yen, T.P. 2014. Determination of heavy metal levels in fishes from the lower reach of the Kelantan River, Kelantan, Malaysia. *Tropical Life Science Research* **25**(2): 21-39.

Hindu 2002. "Delhi reduces Yamuna to a sewage drain," New Delhi, http://www.hinduonnet.com/thehindu/2002 /06/25/ stories/2002062506380400.htm

Ibrahim, A.T.A. and Omar, H.M. 2013. Seasonal variation of heavy metals accumulation in muscles of the African Catfish *Clarias gariepinus* and in River Nile water and sediments at Assiut Governorate, Egypt. *Journal of Biology and Earth Sciences* **3**(2): 236-248.

Jamal, Q., Durani, P., Khan, K., Munir, S., Hussain, S., Munir, K. and Anees, M. 2013. Heavy metals accumulation and their toxic effects: Review. *Journal of Bio-Molecular Sciences* **1**(1-2): 27-36.

Jayakumar, P. and Paul, V.I. 2006. Patterns of cadmium accumulation in selected tissues of the catfish *Clarias batrachus* (Linn.) exposed to sublethal concentration of cadmium chloride. *Veterinarski Arhiv* **76**: 167-177.

Jayaprakash, M., Kumar, R.S., Giridharan, L., Sujitha, S.B., Sarkar, S.K. and Jonathan, M.P. 2015. Bioaccumulation of metals in fish species from water and sediments in macrotidal Ennore creek, Chennai, SE Coast of India: A metropolitan city effect. *Ecotoxicology and Environmental Safety* **120**: 243-255.

Karadede, H., Oymak, S.A. and Ünlü, E. 2004. Heavy metals in mullet, *Liza abu*, and catfish, *Silurus triostegus*, from the Atatürk Dam Lake, Euphrates, Turkey. *Environment International* **30**: 183-188.

Kargin, F., Donmez, A. and Cogun, H.Y. 2001. Distribution of heavy metals in different tissues of the shrimp *Panaeus semiculatus* and *Metapenaeus monocerus* from the Iskenderun gulf, Turkey: Seasonal variations. *Bulletin of Environ Contamination and Toxicology* **66**: 102-109.

Kock, G. and Hofer, R. 1998. Origin of cadmium and lead in clear soft water lakes of high-altitude and high latitude, and their bioavailability and toxicity to fish. *Fish Ecotoxicology* **86**: 225-257.

Kotsanis, N. and Iliopoulou-Georgudaki, J. 1999. Arsenic induced liver hyperplasia and kidney fibrosis in rainbow trout (*Oncorhynchus mykiss*) by microinjection technique: A sensitive animal bioassay for environmental metal-toxicity. *Bulletin of Environmental Contamination and Toxicology* **62**: 169-178.

Kucykbay, F.Z. and Orun, I. 2003. Copper and zinc accumulation in tissues of the freshwater fish Cyprinus carpio L 1758 collected from the Karakaya Dam Lake, Malatya, Turkey. *Fresenius Environmental Bulletin* **12**: 62-66.

Lliopoulou-Georguadaki, J. and Kotsanis, N. 2001. Toxic effects of cadmium and mercury in rainbow trout (*Oncorhynchus mykiss*): A short term bioassay. *Bulletin of Environ Contamination and Toxicology* **66**: 77-85.

Mansour, S. and Sidky, M. 2002. Ecotoxicological Studies. 3. Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. *Food Chemistry* **78**(1): 15-22.

Osman, A. 2012. Biomarkers in Nile Tilapia *Oreochromis niloticus* (Linnaeus, 1758) to assess the impacts of River Nile pollution: Bioaccumulation, biochemicaland tissues biomarkers. *Journal of Environmental Protection* **3**: 966-977.

Papagiannis, I., Kagalou, I., Leonardos, J., Petridis, D. and Kalfakakou, V. 2004. Copper and Zinc in four freshwater fish species from Lake Pamvotis (Greece). *Environment International* **30**(3): 357-362.

Pourang, N., Tanabe, S., Rezvani, S. and Dennis, J.H. 2005. Trace element accumulation in edible tissues of five sturgeon species from the Caspian Sea. *Environmental Monitoring Assessment* **100**: 89-108.

Prabha, S. and Selvapathy, P. 1997. Heavy metal pollution in Indian Rivers. *Indian Journal of Environmental Protection* **17**(6): 641-649.

Priyadarshani, N. 1998. Trace elements in the sediments of the Safi river in Bachra area of north Karanpura coal fields of Hazaribagh District. *Indian Journal of Environmental Protection* **18**: 511-515.

Rashed, M.N. 2001. Monitoring of environmental heavy metals in fish from Nasser Lake. *Environmental International* **27**: 27-33.

Samanta, S., Mitra, K., Chandra, K., Saha, K., Bandopadhyaya, S. and Ghosh, A. 2005. Heavy metals in water of the rivers Hooghley and Haldi and their impact on fish. *Journal of Environmental Biology* **26**(3): 517-523.

Sehgal, M., Garg, A., Suresh, R. and Dagar, P. 2012. Heavy metal contamination in the Delhi segment of Yamuna basin. *Environmental Monitoring and Assessment* **184**: 1181-1196.

Sharma, R.K. and Agrawal, M. 2005. Biological effects of heavy metals: An overview. *Journal of Environmental Biology* **26**(2): 301-313.

Sivakumar, S., Vimal, S., Abdul Majeed, S., Santhosh Kumar, S., Taju, G., Madan, N., Rajkumar, T., Thamizhvanan, S., Shamsudheen, K.V., Scaria, V., Sivasubbu, S. and Sahul Hameed, A.S. 2018. A new strain of white spot syndrome virus affecting *Litopenaeus vannamei* in Indian shrimp farms. *Journal of Fish Diseases* **41**(7): 1129-1146.

Sophia, S., John Milton, M.C. and Prakash, M. 2017. Analysis and seasonal variation of heavy metals in water and sediment from Adyar Estuary. *Environmental Risk Assessment and Remediation* **1**(2): 23-28.

Thomas, Jr. R.C., Willette, D.A., Carpenter, K.E. and Santos, M.D. 2014. Hidden diversity in sardines: genetic and morphological evidence for cryptic species in the Goldstripe Sardinella, *Sardinella gibbosa*. *PLoS One* **9**(1): e84719.

UN-HABITAT 2004. The State of the World's Cities: Globalization and Urban Culture. UN-HABITAT, Human Settlements Programme, Nairobi.

Velcheva, I.G. 2006. Zinc content in the organs and tissues of freshwater fish from the Kardjali and Studen Kladenets Dam Lakes in Bulgaria. *Turkish Journal of Zoology* **30**: 1-7.

Verma, R.S., Khan, M.A., Tripathi, R., Shukla, S. and Sharma, U.D. 2005. Heavy metal toxicity to fresh water prawn, *Macrobrachium dayanum* (Crustacea-Decapoda). *Aquaculture* **6**(1): 57-62.

Wong, C.K., Wong, P.P. and Chu, L.M. 2001. Heavy metals concentrations in marine fishes collected from fish culture sites in Hong Kong. *Archives of Environmental Contamination and Toxicology* **40**(1): 60-69.

Yılmaz, F. 2006. Bioaccumulation of heavy metals in water, sediment, aquatic plants and tissues of *Cyprinus carpio* from Kızılırmak, Turkey. *Fresenius Environmental Bulletin* **15**(5): 360-369.

Zyadah, M.A. and Abdel-Bakey, T.C. 2000. Toxicity and bioaccumulation of copper, zinc and cadmium in some aquatic organisms. *Bulletin of Environmental and Contamination Toxicology* **64**: 740-747.