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EFFECTS OF HEAVY METAL TOXICITY ON BIOTA OF FRESHWATER AQUATIC ECOSYSTEMS

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Abstract

The contamination of aquatic habitats caused by human and natural activity has made studying them a major concern nowadays. Due to bioaccumulation and biomagnification, heavy metal contamination of freshwater ecosystems is a global issue brought on by urbanization and industrialization. This pollution poses a hazard to both aquatic and terrestrial ecosystems. Freshwater fishes' dietary patterns and tissue affinity for specific heavy metals are the reasons behind the bioaccumulation of some heavy metals. This review highlights the sources of non-essential heavy metal contamination such as arsenic (As), Cadmium (Cd), Lead (Pb), and Mercury (Hg). The bioaccumulation factor of heavy metals in the food chain is prone to biomagnification in the tissues, which then impacts the biota concerning freshwater aquatic ecosystems.

Keywords: Affinity, Bioaccumulation, Biomagnification, Biota, Heavy metals, Toxicity.

Introduction

Water is an essential natural resource that supports millions of species along with humans. Rivers sustain the primary, secondary, and service sectors of our nation while also giving livelihood to those along the banks of the basin. For a vast number of people around the nation, they offer transportation, electricity, potable water, irrigation, and a means of subsistence. The riverine ecosystems are the source of freshwater and food supplies, so they require special attention due to the rising levels of pollution. There are several diverse river habitats in India. The ecology of the regions they drain is significantly impacted by the 1.56×10^{12} m^3 of runoff that is discharged annually by the 14 major, 44 medium, and 162 minor rivers combined. Industrialization, urbanization, and human activity have put an ecological strain on aquatic habitats in recent decades, raising worries about human health. Intense urbanization in India has led to the release of untreated household wastewater into water bodies, increasing the concentration of bacterial sewage in river water (Khadse et al, 2008; Venugopal et al, 2009).

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To revitalize the inland freshwater ecosystems, the Indian government has implemented national water development and management plans that include water quality requirements. For example, the Ministry of Environment and Forests (1985) initiated the Ganga Action Plan, the Ministry of Environment and Forests (1999) implemented Municipal Waste Rules, the Ministry of Water Resources (MoWR) (2002) introduced the National Water Policy, the Central Pollution Control Board (CPCB), etc. The inland waters national standard is evaluated by measuring the physico-chemical parameters of water.

In cooperation with the U.S. "Environmental Protection Agency" (EPA), the 'Agency for Toxic Substances and Disease Registry' (ATSDR) in Atlanta, Georgia (a part of the U.S. Department of Health and Human Services) reported that in a 'Priority List for 2001' called the 'Top 20 Hazardous Substances', As, Pb and Hg are at the 1st, 2nd and 3rd position, respectively in the list; while Cd is at the 7th place. Therefore, the elements or heavy metals, viz., As, Cd, Pb, and Hg are considered most toxic to humans, animals, and the environment.

There are two categories of trace elements (heavy metals) such as non-essential and essential heavy metals. Certain trace metals, like zinc and manganese, are necessary heavy metals because they participate in enzymatic activities that are necessary for the healthy operation of bodily organs. On the other hand, non-essential trace elements are those that play no part in physiological characteristics or functions. For example, mercury, cadmium, lead, etc., which may severely impact the human community along with other living organisms. Following the release of different pollutants into the aquatic environment, the heavy metal contaminants bioaccumulate along the food chain, which has a biomagnification effect on the human population.

By absorbing trace metals, certain aquatic macroalgae, also known as macrophytes, function as bioremedial organisms. However, heavy metals are not metabolized, they can build up in algae and increase the amount of heavy metals in those aquatic creatures. The result of the food chain is least likely to biomagnification of heavy metals.

The present study is to shed light on the research conducted on the bioaccumulation of heavy metals in aquatic environments and how it affects aquatic life, ultimately leading to biomagnification. With particular attention to fish and aquatic vegetation, it focuses mostly on the non-essential trace elements and their effects on the biota of freshwater aquatic creatures.

Materials and methods

A thorough literature search was conducted using the internet, various journal articles, proceedings of learned societies of hydrobiology and fisheries, various government and non-government organization initiative activities, and textbooks on the effects of heavy metal toxicity on the biota of aquatic ecosystems. This article examined the impact of non-essential heavy

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metals on freshwater aquatic ecosystems and their biota, including arsenic, cadmium, lead, and mercury.

Effects of selected heavy metals on aquatic ecosystems

Effect of Arsenic

Humanity has been aware of arsenic since prehistoric times. The compounds were discovered by Arabian chemists in the eighth century, but T. Paracelsus (1493–1541) was the first to employ them medicinally. In small doses, arsenic and its compounds have a tonic effect on the body, enhancing its condition and speeding up metabolism. Arsenic exists in both organic and inorganic compound forms. Arsenic comes from natural sources such as land erosion and mine waste. On the other hand, primary smelters of lead, zinc, and copper as well as producers of glass and chemicals are considered anthropogenic sources of arsenic. Pesticides, herbicides, wood preservatives, chemotherapeutic agents, military applications, urea production facilities, and other products employ arsenical compounds. Compared to pentavalent arsenic compounds, trivalent arsenic compounds are more toxic. The water in river Godavari and its tributaries carry the acceptable limits of Arsenic given by BIS 10500 (2012) standards (Zakir Hussain et al (2017)).

The Toxicity of Arsenic (As) is that Water-soluble inorganic Arsenic is readily absorbed from the digestive system. Inorganic forms of Arsenic are particularly toxic. It irritates the lungs, stomach, and intestine, skin disturbances, and decreases the formation of RBCs and WBCs. Ingested inorganic arsenic has a half-life of roughly 10 hours and is excreted in 50–80% of cases in 3 days through urine. Low-chronic dose consumption builds up in lipid-rich tissues, such as the skin, hair, and nails. Human milk also contains roughly 3 mg/l of arsenic. Arsenic inhaled that was kept in the lungs for a long time. Large doses of Arsenic (70–180 mg) can be fatal if consumed with symptoms of fever, hepatomegaly, melanosis, and cardiac arrhythmia. Prolonged exposure to arsenic causes diarrhea, neurotoxicity, appetite loss, and weight loss. Only in humans arsenic can cause cancers of the skin, liver, blood, nasopharynx, kidney, and bladder. Black foot disease and endemic poisoning were brought on by 0.6–0.8 ppm as concentrations in drinking water in Latin America (USA) (WHO, 1972). Very high concentrations of inorganic Arsenic can cause infertility, skin disturbances, decreased resistance to infections, heart disruptions, brain damage, and death. The acute LD50 (oral) of Arsenic ranges from 10-300 mg/kg (Pandey Govind & Madhuri (2014).

The studies performed in various fishes showed that heavy metals may alter the physiological and biochemical functions of both tissues and in the blood of Carpio. The As and inorganic As compounds have been said to be chemical carcinogens, resulting in the development of cancer in fish. In a snakehead fish (Channa punctatus, Bloch), it was observed that when the high concentration (2 mM) of sodium arsenite (NaAsO) affected these fishes, they died within 2.5 hr. The chromosomal DNA of liver cells was fragmented which indicated that NaAsO might have caused the death of those cells through apoptosis.

Compared to herbivorous fish species, the mean concentration of arsenic in the body organs of carnivorous fish was significantly higher. Fish liver and kidneys have the highest concentrations of arsenic accumulation (Jabeen Ghajala et al 2011). According to Pandey and Shukla (1982), prolonged exposure to arsenic stunts the growth of freshwater fish fingerlings. It has also been shown that natural tropical freshwater fish exhibit impaired protein metabolism, nucleic acid metabolism, and gametogenesis. Fish liver dysfunction has been reported at concentrations between 1 and 20 mg/l (Pandey et al., 2005).

Effect of Cadmium

Cadmium is toxic to both humans and animals when exposed to high concentrations. It is obtained as a byproduct of the refining of lead, zinc, and copper and is associated with other metallic ores, primarily zinc. Cadmium is utilized in a variety of industrial processes, such as electroplating, pigment and paint production, plastic stabilization, welding electrodes, and the production of Cu-Cd alloy for vehicle radiators. Leaching of folders containing metal in water heaters, coolers, and tap fittings is the cause of drinking water pollution with cadmium. Seawater and fertilizers may have higher cadmium concentrations. It can enter the freshwater ecosystem by the disposal of untreated industrial and household waste. Fertilizers often contain some cadmium. The LD50 (oral) of Cd in animals ranges from 63-1125 mg/kg (Pandey Govind & Madhuri S (2014)). Higher zinc concentrations in water, however, may prevent cadmium from bioaccumulating in plants (Kabatapendias and Pendias -1993).

Cadmium is absorbed at 15–30% through the respiratory system. Cigarettes are a non-occupational source of respirable cadmium.The edible portion of fish, or fish muscle, typically contains very little cadmium, although organs like the kidneys and liver can accumulate large amounts of the metal. Slow, therefore the organs may be highly polluted; it is best not to eat them. (Yalsuyi AM, Vajargah MF - 2017&Vajargah MF, Hedayati A – 2017). It can damage the kidneys, the central nervous system, and the immune system. It can also cause bone fractures and reproductive problems. It can cause stomachaches, diarrhea, and vomiting.

The tissues of Cyprinus carpio (common carp) have higher levels of cadmium bioaccumulation. In marine organisms, cadmium builds up and quickly alters genetic makeup (Nimmo et al. - 1978 Nevo et al. - 1986). Seddek (1996) found 0.62 ppm of cadmium in Oreochromis fish. High cadmium accumulation in the liver may be caused by cadmium's strong binding to metallothionein's cysteine residues. It results from agricultural and industrial activities. The tissues of Tilapia mossambica found in the Kollidam River, Tamilnadu, had the lowest

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concentrations of cadmium, while the liver tissues showed the highest concentrations. The tissue's affinities towards cadmium may be the reason for it (G. Ambedkar & M. Muniyan; 2011).

The reproductive rate of aquatic organisms may also be affected due to exposure to heavy metals which can lead to a gradual extinction of their generations in polluted waters (Sridhara et al; 2008). For example, Cd and mercury (Hg) damage the kidney and produce signs of chronic toxicity, including impaired reproductive capacity and kidney function, tumors, hypertension, and hepatic dysfunction (Mansour and Silky; 2002).Effects of cadmium on freshwater Fish - Gasterosteus aculeatus was the formation of vacuoles, and sloughing of the epithelial layer from the secondary lamellae and the enlarged sub-epithelial spaces reduces the amount of oxygen diffusing into fish by increasing the water to blood distance; severe constriction of the blood spaces and the enlarged red blood spaces and the enlarged red blood cells reduce blood flow and make oxygen transport less efficient. Many of the chloride cells degenerate Eller (1971), Oronsaye (1997), Oronsaye and Bradfield (1984); in Fundulusheteroclutus fish the effects are increased in the number of chloride cells (Gardner and Yevich (1970), Oronsaye (1997)); in Oreochromis mossambicus fish the cadmium effects are reduction of proteins due to the impact on the protein synthetic pathway (Muthukumaravel et al. (2007)) and in Cyprinus carpio the cadmium effects to enhance susceptibility to disease due to decrease in innate immune response (Ghiasi et al. (2010)).

The water in River Godavari and its tributaries carry the acceptable limits of Cadmium given by BIS 10500 (2012) standards (Zakir Hussain et al; 2017). In the studies of Srinivas Naik Banavathu&Jagadishnaik Mude (2017) from Krishna River Vijayawada, Cadmium concentration in fishes L. rohita and C. straitus was found high but, it is within permissible limits of NCBP 2.1 micrograms per gram. However, Cadmium is classified as a carcinogen by the International Agency for Research on Cancer. So, it is need to control the contamination of Cadmium in river water and subsequently its accumulation in fish.

Lead

The oldest known industrial toxicant to humans is lead. Lead makes up 0.00002% of the weight of Earth. Lead can be found in nature in the forms of galena sulfide, lead carbonate (cerussite), and lead sulfate (anglesite). Ores that have been mined typically contain 3–8% Pb. There are both organic and inorganic forms of lead. Lead is widely used in printing, paints, water pipes, battery production, ceramics, soldering, pesticides, and other industries. Additionally, it is utilized as an antiknock agent in petrol that is 20% consumed by humans; this accounts for 96 to 98% of lead-related pollution issues. Due to lead's low solubility, breathing inhalation absorbs a larger percentage of lead into the body than eating it. For a worker with heavy occupational exposure, the total lifetime accumulation of lead could be as much as 200 mg to more than 500 mg. Urine excretes lead, which is then retained in bones. There have also been reports of Indian women who apply sindoor or red lead, to their foreheads and scalps running the risk of developing lead poisoning. Anaemia results from the effects of lead on heme synthesis. Prolonged exposure causes damage to the nervous system, liver, kidneys, and weight loss. Additionally, Lead is carcinogenic (IARC, 1987). Lead also causes embryotoxicity, which can result in malformations, abortions, and physiological problems in the affected child.

Most of the lead is found in fish bones; soft parts like the heart, gonads, and digestive organs do not contain significant amounts of lead. In certain regions of the world, it is possible to measure and analyze the level of lead in fish bones rather than muscles to evaluate the extent of environmental lead pollution. (Vajargah– 2021). Nzeve, J.K. et al. (2014) work at Masinga Reservoir, Kenya revealing that African catfish and Tiapia have different feeding habits, so the former had higher Pb levels than the latter. According to Pradeep Kumar et al.; 2019, Labeorohita in the Ganga River, has been found to have the highest concentrations of lead accumulation due to its higher biomass. The water in River Godavari and its tributaries carry the acceptable limits of Lead given by the standards of BIS 10500 (2012)(Zakir Hussain et al (2017)). Studies of Godavari River water at the KovvurGodavari River bridge area show high levels of Lead 5.05 micrograms per liter, but it is within the permissible limits of 10 micrograms per liter (WHO;2012) (Namrata Jain and Srinivasa Reddy; 2022). The WHO recommended a 2.0 mg/kg limit of lead in fish and fish products. (Nzeve, J.K. et al. - 2014).

Lead inhibits liver enzymes, tremors the muscles, and lowers the production of hemoglobin in fish. Lead can affect the physiological functions of fish species' embryonic and larval development, and its concentration in tilapia tissues exceeded the allowable limit set by the EQSQC (1993) (Kaovd&El-Dahshan - 2010). Effects of lead on freshwater Fish Tilapia galillilaeus& Clarias lazera was delay in embryonic development, suppress reproduction, and inhibit growth, increase mucus formation, neurological problem, enzyme inhalation and kidney dysfunction (Al-kahtani (2009)); impact on Clarias gariepinus was as lamella shrinkage, degeneracy of epithelium, branchial arterial rupture and ischemia, reduction in growth rate and loss in body weight, degenerates liver cells synctial arrangement(Olojo et al. (2005));in Salmo gardnerii& Salvelinus namaycushit inhibits egg hatching, excessive mucus secretion, hypertrophy and deformation of gill(Weber e al. (1997)); in Poecilialatipinna,filaments and hyperplasila of epithelial cells hence lamellae fuses and gill lamellae curls at the tips, increases secretion of mucus from gills and skin, dilation of bile canaliculi and liver sinusoids, extravasation of blood and necrosis/pyknosis cell nuclei in liver(Mobarak et al ; 2010) and in Auratus auratus, genotoxic and cytotoxic damage in both gill and fin epithelia cells(Cavas ; 2007).

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Effect of Mercury

Mercury is a well-known toxic metal that gained attention following the 1953–1960 Minimata disease case in Japan. In the environment, mercury can be found in elemental, inorganic, and organic forms. In the earth's crust, mercury can be found as metallic mercury, mercuric sulfide, and mercuric chloride. Mining, melting, battery lamps, switches, caustic soda, medications, and instruments are examples of anthropogenic sources of mercury. Chlor-alkali plants preserve 25% of the world's mercury production; the remaining 75% is used in paints, electrical equipment, dentistry, sphygmomanometers, and other measurement and control applications. In seed drilling, methyl and ethyl mercury have been used extensively. During human activities like burning fossil fuels, disposing of waste, and industrial processes, mercury is released into the environment. Fifty percent of the world's annual production (9,000 tons) is lost to the environment. The maximum allowable limits of mercury in drinking water, as per WHO (1971) standards, should not be greater than 0.001 ppm.

Certain anaerobic bacteria transform inorganic mercury (Hg) in the environment into more toxic methylmercury compounds, which are then absorbed by fish and enter the food chain. Methylmercury is a thousand times more soluble in lipids than in water. Muscle, brain, and central nervous system (CNS) tissues contain most of this methylmercury. The brain's posterior cortex exhibits a higher affinity for organic mercury (methylmercury). Inhaling elemental mercury has an affinity for the central nervous system and red blood cells. Every type of mercury can affect the fetus by passing through the placenta. Mercury is more affinitous towards the kidneys. The toxicity of mercury includes; kidney damage, disruption of the nervous system, damage to the brain, DNA and chromosomal damage, allergic reactions, sperm damage, birth defects, and miscarriages. The LD50 of mercury is as low as 1 mg/kg in small animals. Mercury decreases the synthesis of DNA in mammals(Pandey Govind & Madhuri; 2014).

Fish concentrations of mercury might exceed 10,000–100,000 times the initial levels in the nearby waters. While mercury depurates slowly, it deposits quickly. Polluted oysters depurate more quickly than less polluted prawns, which depurate mercury more slowly. Additionally, fish have a substantially slower rate of mercury depuration. In fish, methylmercury has a half-life of roughly two years. However, such mercury contamination has no appreciable negative impact on public health. The FAO/WHO (1992) (0.5 ppm), the Egyptian Organisation for Standardisation and Quality Control (EOSQC) (1993) (0.5 mg/kg), and the Boletinofficial Del Estado (1991) in Spain (1.0 mg/gram) were all more than the permissible limits for mercury in tilapia tissues. The highest concentration of bioaccumulated and biomagnified mercury was found in the muscles of O. niloticus. (HA Kaovd& AR El-Dahshan - 2010). Mercury inhibits enzymes and protein synthesis in fish (Pandey Govind & Madhuri; 2014). For saltwater fish, the average mercury levels ranged from 0.35 to 70.02. As a result of mercury accumulation, marine creatures experience rapid genetic changes (Nimmo et al., 1978; Nevo et al., 1986).

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According to the research, carnivorous fish showed tissue-specific bioaccumulation of heavy metals based on what was likely to be their food. Fish bioaccumulate non-essential heavy metals from water because the transfer factor of heavy metals in fish from water was higher than that of fish from sediments. The concentration of arsenic was higher in carnivorous fishes than in herbivorous fishes. Lead concentrations were highest in floating plants, whereas cadmium and mercury concentrations were highest in plants with floating leaves (Samecka-Cymerman& Kempers; 1995).

Conclusion

Heavy metals are conservative and diffusible pollutants, they can negatively impact both terrestrial and aquatic ecosystems by bioaccumulating and biomagnifying through the food chain. The bioaccumulation of heavy metals and their effects on terrestrial and aquatic ecosystem biota have been extensively studied, both nationally and internationally. Because of industrialization and urbanization, there is an ever-increasing of heavy metal pollution in our environment. These heavy metals can enter the aquatic ecosystem and eventually target the human population through the food chain. So, it is at most essential to control the pollutants in our environment and protect the human community from disorders caused by the biomagnification of non-essential heavy metals along with the conservation of aquatic biodiversity.

References:

1. Abdel-Baki, A.S; Dkhil MA; Saleh Al-Quraishy(2011). Bioaccumulation of some heavy metals in Tilapia fish relevant to their concentration in water and sediment of Wadi Hanifah, Saudi Arabia.*African Journal of Biotechnology* Vol.10(13), pp. 2541-2547, 28 March 2011.

2. Ambedkar G and Muniyan M (2011).Bioaccumulation of some Heavy Metals in the selected five freshwater fish from Kollidam River, Tamil Nadu, India. *Pelagia Research Library.Advances in Applied Science Research,* 2011, 2 (5):221-225.

3. Egyptian Organization for Standardization and Quality Control -EOSQC (1993). Maximum residue limits for heavy metals in food. Ministry of Industry. No. 2360/1993. PP. 5

4. FAO/WHO (1992) Food Monitoring and Assessment Programme, WHO, Geneva 5, UNEP, Nairobi. 52. Report of the Third Meeting of the GEMS/Food.

5. Ghazala Jabeen et al (2011). Assessment of Heavy Metals in the Fish Collected from the River Ravi, Pakistan. *Pakistan Veterinary Journal.* ISSN: 0253-8318 (PRINT), 2074-7764 (ONLINE).

6. Ibemenugaand Keziah Nwamaka (2013). Bioaccumulation and Toxic Effects of Some Heavy Metals in Freshwater Fishes. *Animal Research International* 10(3): 1792 – 1798.

7. Jakir Hussain et al (2017). Studies on heavy metal contamination in Godavari River basin.*Appl Water Sci* (2017) 7:4539–4548.

8. Kamaleshwar Pandey, Dr Shukla J.P and Dr Trivedi S.P. (2005). Fundamentals of Toxicology, *New Central Book Agency (P) Ltd*, India.

9. Kaoud HA and El-Dahshan AR (2010). Bioaccumulation and histopathological alterations of the heavy metals in Oreochromis niloticus fish. *Nature and Science*[Internet]. 2010 ;8(4).

10. Khadse, G.K et al(2008). Qualitative evaluation of Kanhan River and its tributaries flowing over the central Indian plateau. *Environ. Monitor. Assess*. 147, 83–92.

11. Mansour SA andSidky MM, (2002). Ecotoxicological Studies, Heavy metals contaminating water and fish from Fayoum Governorate. *Egypt J Food Chem.* 78(1), 15-22.

12. Namrata Jainand P. Srinivasa Reddy (2022).Studies on Heavy Metal Contamination and Physico-chemical Properties of Godavari River Water at Rajahmundry, Andhra Pradesh, *Oriental Journal of Chemistry* Volume 38, No 3

13. Nzeve, J.K et al; (2014). Bioaccumulation of heavy metals in Clarias gariepinus and Oreochromis spirulusniger from Masinga Reservoir, Kenya; *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)* e-ISSN: 2319-2402, p-ISSN: 2319-2399. Volume 8, Issue 10 Ver.1 (Oct. 2014), PP 58-63.

14. Pandey Govind & Madhuri S (2014). Heavy Metals Causing Toxicity in Animals and Fishes. *Research Journal of Animal, Veterinary and Fishery Sciences* - ISSN 2320 – 6535 Vol. 2(2), 17-23, February (2014).

15. Pradip Kumar Mauryaa et al (2019). Bioaccumulation and potential sources of heavy metal contamination in fish species in River Ganga basin: Possible human health risks evaluation; *Toxicology reports* 6 472-481.

16. Samecka-Cymerman, A and Kempers A.J. (1996). Bioaccumulation of Heavy Metals by Aquatic Macrophytes around Wroclaw, Poland. *Ecotoxicology and Environmental Safety* 35, 242–247 Article No. 0106

17. Seddek AS, et al(1996). Cadmium, lead, nickel, copper, manganese and fluorine levels in River Nile fish. *Assiut Veterinary Medical Journal,* Egypt 35: 95-102.

18. Sridhara CN, et al (2008). Assessing the risk of heavy metals from consuming food grown on sewage-irrigated soils and food chain transfer. *Ecotoxicol. Environ Saf*. 69:513-524.

19. Srinivasa Naik Banavathu& Jagadish Naik Mude (2017), Assessment of Heavy Metals Concentration in Water and Fish from Krishna River, Vijayawada, India; *International Journal of Zoology and Applied Biosciences* - ISSN: 2455-9571; Volume 2, Issue 6, pp: 315-319.

20. U.S. Environmental Protection Agency (USEPA; 1995). National Water Quality Inventory: 1994 Report to Congress. EPA 841-R-95-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

21. Vajargah MF (2021). A Review on the effects of Heavy Metals on Aquatic Animals. *Journal of Biomedical Research and Environmental Sciences.* DOI: 10.37871/jbres1324.

22. Vajargah MF and Hedayati A (2017). Toxicity effects of cadmium in grass carp (Ctenopharyngodonidella) and Big Head Carp (Hypophthalmichthys nobilis). *Transylvanian Review of Systematical and Ecological Research*;19(1):43-48. Doi: 10.1515/trser-2017-0004.

23. Venugopal, T et al(2009). A comprehensive geochemical evaluation of the water quality of River Adyar India. *Bull. Environ. Contam. Toxicol.* 82, 211–217.

24. Vinodhini, R. and Narayanan, M. (2008). Bioaccumulation of heavy metals in organs of freshwater fish Cyprinocarpio (common carp). *International Journal of Environmental Science and Technology*, 5(2): 179 – 182.

25. Yalsuyi AM andVajargah MF(2017). Acute toxicity of silver nanoparticles in Roach (Rutilus rutilus) and Goldfish (Carassius auratus). *Journal of Environmental Treatment Techniques*;5(1): 1-4. https://bit.ly/3AY9i5Z.