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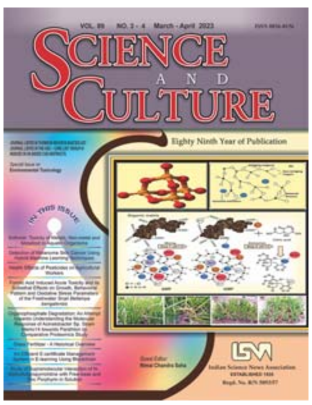
EDITORIAL

TOXICITY OF METALS, NON-METAL AND METALLOID TO AQUATIC ORGANISMS



Pollution is an unavoidable byproduct of all human activities as a result of progressive urbanisation. All human activities ironically, have resulted in increased utilisation of natural resources and the generation of thousands of by-products as waste. Natural and man-made activities cause significant problems by increasing the concentrations of various common chemicals such as arsenic (As), selenium (Se), fluoride (F^-), chromium (Cr), nickel (Ni), zinc (Zn), lead (Pb), and mercury (Hg) which are highly enriched in industrial effluents, sewage, and trade wastes and cause unexpected changes in the aquatic and non-aquatic equilibrium. Due to issues with their disposal in natural water bodies, this has emerged as a major environmental concern. Toxins accumulated in natural water resources may cause adverse changes in aquatic ecosystems as well as hazardous effects on aquatic organisms such as fish and fish food organisms. Various researchers from around the world are working to determine the hazardous effects of As, Se, F^-, Cr, Ni, Zn, Pb, and Hg in aquatic environments, as well as possible remedial measures.

Arsenic: The most prevalent cause of arsenic poisoning is imbibing contaminated water. Typically, arsenic contamination of groundwater occurs naturally. Nevertheless, contamination can also result from mining and agriculture. Other exposure routes include hazardous disposal sites and traditional medicines. Arsenic contamination is a major health concern in many nations today, particularly in South-East Asia, where its elevated concentration in potable water (up to 3,200 µg/l) far exceeds the WHO-declared safe limit of 10 µg/l. Arsenic contamination of potable and cultivable water poses a serious threat to water quality and consequently has a significant effect on crops and public health. To determine the effects of environmental pollution on aquatic ecosystems, fish are typically used as an appropriate model. Through their epidermis, gills, and ingestion of As-contaminated food, fish are perpetually exposed to a noxious environment. A fish's growth, reproduction, ion regulation, immune function, enzyme activities, and histopathology are negatively impacted by the high concentration of arsenic, which exceeds the permissible limit (10 µg/l), in an aquatic ecosystem. Arsenic may induce a cascade of molecular processes that contribute to oxidative stress, iron homeostasis, lipid metabolism disorder, and carcinogenesis.Similar biochemical properties to phosphate, arsenate can replace the phosphate in macromolecular structures (Poly-nucleotides, phospholipid, sugars, and Phosphate binding proteins). As-O bond length longer than the Pi -O bond length, as a result incorporation of Arsenic destabilize macromolecular structures and protein functionality. Such findings demonstrate the need for additional research into the toxicity of As to fish and fish dietary organisms.

Selenium: Selenium, a crystalline metalloid, is found in animals as selenocysteine and in plants as selenomethionine. Selenite (Se^{+4}) and selenate (Se^{+6}), on the other hand, are plentiful in the aqueous environment. Selenite (Se^{+4}) has a higher toxicity than selenate (Se^{+6}). According to the findings, low Se concentrations in drinking water have substantial health consequences. Natural resources include volcanic explosions, marls, gypsum, aerosol particles from the sea or sea spray, biological cycling processes, and weathering of Se-containing rocks and soils. Apart from natural sources, human intervention, such as mining, oil refining, fuel combustion, pesticide usage, photocells, and glass manufacturing, is a significant contributor of Se to the environment. When Se pollution hits 5 ppm, it becomes dangerous and poisonous to different organisms. A generic process involving oxidative stress or damaged organ structures of exposed species that leads to mortality has also described. Selenium can replace sulphur in sulphur containing amino acids (methionine and cystine). Non-specific incorporation of Seleno - amino acids into proteins induces proteotoxic stress (stress caused by misfolded and aggregated proteins), leads to protein structural and functional alterations. Nevertheless, there is insufficient data to correlate the acute and chronic toxicity of Se to fish and other aquatic species with the toxicant concentration in water. It indicates that more research is needed to have a better knowledge of selenium toxicity in natural water bodies.

Fluoride: Fluoride, the most powerful oxidising element discovered in nature, may be found in air, water, and soil. It may be found as a free anion, hydrofluoric acid, and various fluoride complexes. Hydrofluoric acid is utilised as a reactant in a variety of sectors, including phosphatic fertiliser manufacture, coal cleaning, semiconductor or metals fabrication, and so on. Fluoride poisoning of groundwater is caused by geological and human reasons. Fluoride pollution of groundwater is a severe concern in many places throughout the globe because of the increased fluoride consumption induced by drinking polluted groundwater. Fluoride levels in industrial effluent may reach 96.8 mg/l and, in severe circumstances, up to 3000-5000 mg/l. Fluoride ions may be taken up directly from the water by aquatic organisms such as fish and invertebrates, or indirectly via the food chain to a much lower amount. Fluoride levels in drinking water that are too high may induce permanent demineralization of bone and tooth tissues, as well as long-term harm to the brain, liver, thyroid, and kidney. Fluoride's potential toxicity in aquatic creatures, particularly crabs and fish, as well as rats, has been thoroughly established at the molecular, cellular, and organism levels. It may able to interact the heme moiety in the macromolecular complexes present in electron transport system (ETS) in mitochondria. Dysfunction of the ETS may cause excessive oxidative stress in the organisms. The data on fluoride toxicity to aquatic creatures is yet inadequate to create worldwide water quality requirements for aquatic organisms. There are few reports on the toxicity of fluoride to fish and other aquatic creatures, indicating that further research is needed to have a better knowledge of fluoride poisoning in natural water bodies.

Chromium: Due to its higher bioavailability, chromium is a potential contaminant. Its presence in aquatic ecosystems as a result of its excessive use in a variety of industrial activities and consequent discharge of untreated effluents directly into aquatic habitats has sparked worldwide concern. The average Cr concentration in groundwater is approximately 0.1 mg/l. The Bureau of Indian Standards (BIS) established a Cr limit of 0.05 mg/l for potable water. However, in many regions of India and other developing nations, the underground water Cr content has been reported to exceed 12 mg/l. This poses a significant danger to aquatic and terrestrial habitat. Fish could rapidly consume, metabolise, and bioaccumulate metal pollutants among aquatic organisms. Therefore, fish can be used effectively and efficiently as a model organism to comprehend and rationalise the molecular mechanism underlying chromium's environmental toxicity. Cr exposure has negative effects on the trachea, kidney, and liver. This results in metabolic and physiological disorders that inhibit growth and alter the behaviour of fish. In addition, hexavalent Cr decreases the glycogen, protein, and lipid contents of the liver. Reports of Cr's toxicity to fish and other aquatic organisms are limited, necessitating additional research for a greater comprehension of Cr poisoning in natural water bodies.

Nickel: Nickel is a component of several enzymes that play crucial functions in carbon, nitrogen, and oxygen cycling in plants and microorganisms. Ni is extensively used in industry and a common pollutant in aquatic environments. In natural waters, the predominant chemical species is Ni^{+2}. In aquatic ecosystems, Ni interacts with numerous inorganic and organic compounds and occurs as soluble ions adsorbing onto substances of various chemical origins. Ni accumulation is likely associated with osmoregulation, active salt resorption, and excess water excretion. The deleterious effects of excess Ni on the health of aquatic animals are well known. Ni's effects on freshwater biota are typically the impairment of gas exchange, inhibition of ion regulation, and promotion of oxidative stress. Probably the primary cause of Ni's toxicity to fish is respiratory problems caused by gill damage. Ni-exposed fish have been found to have oxidative DNA and protein damage as well as a reduction in their antioxidant defences. Reports on the toxicity of Ni to fish and other aquatic organisms are scant, necessitating additional research into Ni poisoning in natural water bodies.

Zinc: Zinc is a vital nutrient for animals and is crucial in aquatic physiological functions. Yet, too much Zn in aquatic habitats is harmful. Agriculture, urbanisation, and mining all increase the concentrations of Zn in natural water bodies. Zn is enriched in the aquatic environment by processes such as galvanised product corrosion, tyre rubber breakdown, and urban runoff. Zn is absorbed by fish via the gills and the gastrointestinal system. Zn is subsequently delivered to the liver by the metal-binding protein metallothionein, which enables Zn donation to metalloenzymes. Metallothionein also prevents potentially dangerous quantities of Zn from interfering with sensitive cellular entities; nevertheless, at larger levels of exposure, Zn homeostatic control may be overridden, resulting in toxicity. It reduces tissue catalase (CAT) activity while increasing lipid peroxidation. The toxicity of Zn in fish has been widely reported in a variety of fish species. After Zn exposure, fish show physiological and biochemical changes such as changes in chorion shape and permeability, as well as suppression of enzyme activity in organs. Osmoregulation, water permeability, and water parameters such as temperature, dissolved oxygen concentration, hardness, pH, salinity, and so on may all have an impact on Zn toxicity in early life stages of fish. While the toxicity of Zn to certain fish species has been confirmed, the toxicity of this metal to all aquatic organisms remains unknown. Further research is needed to better understand Zn toxicity in natural water bodies.

Lead: Lead is widely acknowledged as one of the most significant and adaptable metal ions in the industry, having several uses in metal polishing, storage batteries, paints, and electroplating. Excessive usage of this heavy metal in conjunction with fast industrialization and urbanisation results in its discharge into the environment, posing a huge Pb pollution issue as well as a substantial environmental health danger due to its non-biodegradability and long-term harm via accumulation. Excess Pb ion consumption may harm the brain, neurological system, reproductive system, kidneys, and possibly cause death. Moreover, such pollution is becoming a severe concern that is gaining worldwide attention because to its harmful effects on fish, humans, and the environment. Lead poisoning in general has severe consequences on fish populations because this heavy metal disrupts several metabolic processes in young fish, causing developmental retardation, morphological and functional abnormalities, and even death in the most vulnerable individuals. It also stimulates energy-intensive detoxifying activities. As a result, the fish exposed to the toxins need less energy for growth. It also has endocrine disrupting properties in fish. Heavy metal ions' pro-oxidative characteristics may cause oxidative stress in fish and oxidative damage to cell membranes.

Mercury: Mercury is pervasive in the environment due to high levels of natural release, such as volcanic eruptions and forest fires, and constant anthropogenic discharge from metal production industries, coalfired power stations, electrical industries, chlorine and caustic soda factories, nuclear reactors, dental offices, gold mining, and pharmaceutical companies producing antifungal drugs, etc. Mercury can remain in the atmosphere for up to a year, enabling for extensive distribution via long-distance atmospheric transport. Several forms of Hg, including elemental, ionic, and organic forms, are present in the aquatic environment, and Hg bioaccumulates in fish primarily through dietary absorption. Fish contaminated with mercury experience severe pathological changes, including inhibition of metabolic processes, blood disorders, and decreased fertility and survivability. In the last three decades or so, studies on fish have demonstrated the effects of sublethal Hg exposure on a variety of reproductive axis endpoints. Principal routes of exposure to Hg compounds are inhalation and ingestion. The gastrointestinal tract absorbs ingested mercury and distributes it to all tissues. The high mobility of Hg in the body is due to the formation of water-soluble Hg complexes that are primarily bound to the sulphur atoms of thiol groups such as glutathione. Mercury can accumulate progressively in the central nervous system and kidney, causing harm to these organs. Fish are becoming increasingly popular models not only for comprehending vertebrate development, but also for human disease and toxicology, as well. There are few reports of mercury's toxicity to fish and other aquatic organisms; more research is required to better understand mercury's toxicity in natural bodies of water.

Due to their high sensitivity to qualitative and quantitative changes in aquatic habitats, freshwater fish are one of the most threatened taxonomic groups to metal, nonmetal, and metalloid toxicity. Therefore, they are frequently used as bioindicators for the evaluation of water quality. The advances in fisheries science and aquatic toxicology had provided a number of biomarkers, which can be used to estimate the effects of different chemicals to fish and other aquatic organisms during their exposure to those contaminants. The Hepatosomatic index (HSI), Gonadosomatic index (GSI) and Fecundity are the important bio-indicators of contaminant exposure, as they are the effective means to estimate the impact of toxicants in the aquatic ecosystem. The Hepatosomatic index (HSI) (ratio of liver weight and body weight) is used as the indicator of energy reserves in the liver. On the other hand, the Gonadosomatic index (GSI) (ratio of gonad weight and body weight) and Fecundity indicate structural information on general health of fish, reproduction of fish, maturation status of gonads and breeding period of fish. The GSI reflects food availability in the environment and the physiological status of fish health. The vitelogenesis can increase both the HSI and GSI which are changeable to stress in aquatic ecosystem. The number of eggs produced by an organism during study period i.e. fecundity of fish is greatly influenced by the changes in environment. Different chemicals and metals are the major contributor to this change in aquatic ecosystem. The metal, nonmetal and metalloid pollution in a water body can be detected properly by using a fish as a bio-indicator by determining its HSI, GSI and fecundity etc.

These pollutants may also cause neurotoxicity, haematological disruption, histopathological disruption in gills and liver and may deplete antioxidant capacity and increase vulnerability to oxidative stress in freshwater fish. The earlier study also indicates that the environmental concentrations of metals, non-metals, and metalloids which are not yet directly harmful to fish, it may raise the concerns for other sensitive ecological relevant species and keystone species whose survival is critical for ecosystem stability and survival of other aquatic organisms. The utilisation of living organisms, including fish, crustaceans, and molluscs can be implemented as bio indicators for detecting pollution and assessing the overall quality of the environment. International regulations are required to maintain the standard quality of physicochemical properties of surface water, groundwater, and composition of biota in order to maintain water quality. The advancement of science and technology, coupled with the increasing depth of ecotoxicological insights, will play the key role to find out novel tolerance mechanisms in aquatic organisms against metal, non-metal and metalloid toxicity. The primary research goal of future ecotoxicological study should also involve the identification and characterization of genes in aquatic organisms that regulate the absorption and transportation of the toxicants. This will facilitate the development of proper remediation techniques that can effectively reduce metals, non-metals and metalloids toxicity in aquatic organisms. ❐

Nimai Chandra Saha

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Professor Dr. Nimai Chandra Saha is working as the Vice-Chancellor of the University of Burdwan since November 2016. Securing First class first position in M.Sc. (Zoology) from the University of Kalyani he received Ph.D. degree in 1992 from the same University. Later on he received D.Sc. degree in Zoology from the Raiganj University in 2021. He acquired more than 35 years of teaching as well as 37 years in the field of research and above 20 years of administrative experiences. He has also to his credit more that 160 research papers and 10 book chapters published in national and international journals. Professor Saha supervised and guided 15 research students for their Ph.D. Degree in Zoology. He has also visited the University of Dhaka, Bangladesh in 2017 and 2018. He visited the Seoul National University, South Korea as a Resource Person in 2018 to deliver invited lectures.

Professor Saha also contributed immensely in research focusing the areas of (a) aquaculture and fish breeding technology, (b) ecotoxicology and its bioremediation, and (c) probiotics technology. The research holds tremendous potential towards sustainable and cost-effective measures for aquaculture as well as against various pollutants by using microorganisms and herbal plant products. Professor Saha is a true academic administrator serving the positions like Vice-Chancellor/ Director of Public Instruction, WB/ Professor/Principal/Head of the University/Colleges/ Departments of Higher Education Service as well as serving various academic committees of Government bodies by holding positions like Chairman of the NAAC PEER TEAM/Member/Coordinator, etc.

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