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New perspective on heavy metal pollution of water

[*1]Bagul V. R., [2]Shinde D. N., [3]Chavan R. P., [2]Patil C. L. and [1]Pawar R. K.

[1]Department of Chemistry, Arts, Science & Commerce College, Surgana (Nashik), Maharashtra, India
[2]Department of Chemistry, B. N. N. College, Bhivandi(Thane), Maharashtra, India
[3]Department of Chemistry, Dnyanasadhana College(Thane), Maharashtra. India

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ABSTRACT

Due to human and industrial activities the river water is contaminated. This is the serious problem now days.Many heavy metals have their toxic effects on man and environment. The presence of heavy metal results in bioaccumulation and further it can affect the biological and ecological cycles. Both natural and anthropogenic sources were found to be contributing to the pollution load of the rivers in Maharashtra with the anthropogenic activities dominating the influence. Chemical weathering of minerals, mining activities and industrial discharges increased heavy metals concentration in water. Industrial activities were predominantly responsible for the high concentrations of Mn in water. The study revealed the impact of various human activities on the quality of water and indicated a trend to undertake further studies on the affects of polluted river water on the aquatic and human life. The current review summarizes the causes, impacts and preventive measures carried out to know the effect of heavy metals on man, environment, aquatic life, plant and ecology.

Key words: heavy metal, rivers, Maharashtra, causes, impacts, preventive measures.

INTRODUCTION

Water is a source of life. But pollution of water is the biggest threat in today's world. Water is an essential part of our life on which depends life cycle and existence of entire bio-diversity. Human being cannot make or generate either of these basic elements of life in a form in which those are needed. As such the human beings have no right to destroy, waste with any of these resources. Wherever and in whatever form those may be found, it is our basic responsibility to conserve such natural resources. Water quality has become a serious issue due to increasing industrialization, urbanization and man-made problems. The constituents present in the water systems depend on the nature where the water body is situated and the discharge quality from various sources in that water body [1]

Many of the sediments in our rivers, lakes, and oceans have been contaminated by pollutants. Some of these pollutants are directly discharged by industrial plants and municipal sewage treatment plants, others come from polluted runoff in urban and agricultural areas, and some are the result of historical contamination. Contaminated sediments can threaten creatures in the benthic environment, exposing worms, crustaceans and insects to hazardous concentrations of toxic chemicals. Some kinds of toxic sediments kill benthic organisms, reducing the food available to larger animals such as fish. Some contaminants in the sediment are taken up by benthic organisms in a process called bioaccumulation. When larger animals feed on these contaminated organisms, the toxins are taken into their bodies, moving up the food chain in increasing concentrations in a process known as biomagnification. As a result,

fish and shellfish, waterfowl, and freshwater and marine mammals may accumulate hazardous concentrations of toxic chemicals. [2]

Contaminated sediments do not always remain at the bottom of a water body. Anything that stirs up the water, such as dredging, can suspend sediments. Resuspension may mean that all of the animals in the water, and not just the bottom-dwelling organisms, will be directly exposed to toxic contaminants. [3]

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Thallium (Tl) and Lead (Pb).Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. Copper, Selenium and Zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. Heavy metals are dangerous because they tend to bio accumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted.

Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater [4].

The pollution of the aquatic environment with heavy metals has become a worldwide problem during recent years, because they are indestructible and most of them have toxic effects on organisms .Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bio accumulate in aquatic ecosystems [5].

Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota [6], which generally exist in low levels in water and attain considerable concentration in sediments and biota [7]. Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms [8].Heavy metals such as copper, iron, chromium and nickel are essential metals since their play an important role in biological systems, whereas cadmium and lead are non-essential metals, as they are toxic, even in trace amounts.

This study would provide information for impacts of levels of metals in the water, sediment and fish species of the Lake, contributing to the effective monitoring of both environmental quality and the health of the organisms inhabiting the river ecosystem.

Objective of the study:

I. Causes of Heavy Metal Pollutants in Rivers in Maharashtra
II. To study the impacts of heavy metal's concentration (Cd, Cr, Cu, Ni, Pb, Se, Hg, Sb) in rivers in Maharashtra.
III. Preventive measures of Heavy Metal Pollution in Rivers in Maharashtra.

I. Causes of Heavy Metal Pollutants:

Heavy metals are introduced into the environment either by natural means or by human activities.

Natural sources: In nature excessive levels of trace metals may occur by geographical phenomena like volcanic eruptions, weathering of rocks, leaching into rivers, lakes and oceans due to action of water.

Anthropogenic Sources: Small amounts of heavy metals are released while mining and uncontrolled smelting of large quantities of metal, ores in open fires. With the industrial revolution, metals were extracted from natural resources and processed in the industries from where heavy metals passed on into the atmosphere. Similarly traces of heavy metals get into the environment through discharge of waste - both domestic, agricultural and from auto exhausts. Following list shows the various human activities through which heavy metals get into the environment. (i) Smelting or processing of ores of metals. (ii) Mining. (iii) Burning of fossil fuels such as coal, petrol, kerosene

oil.(iv)Discharging agricultural waste. (v) Discharging industrial waste.(vi)Discharging domestic waste. (vii) Discharge from auto exhausts. (viii) Using pesticides containing compounds (salts) of heavy metals [9].

Some heavy metals are lead, cadmium, mercury, arsenic selenium, as also iron, copper, manganese, selenium, zinc, etc. All these metals have atomic number greater than 20. Low concentrations of metal like iron, copper, zinc and some others are essential for organisms. They are called 'trace metals'. On the other hand metals like lead, mercury, cadmium and some others are toxic to organisms above a certain concentration. A trace metal is defined as one which occurs in 1000 ppm (parts per million or mg/lit) or less in the earth's crust.

Mining activity poses significant risks for heavy metal pollution; this sector is not the only culprit in the industrial sector. Many industrial processes can generate heavy metal pollution, and in a large number of ways. Clearly, some industries will be more likely to pollute than others.

Mining Activities: Heavy metals occur in the earth's geological structures, and can therefore enter water resources through natural processes. For example, heavy rains or flowing water can leach heavy metals out of geological formations. Such processes are exacerbated when this geology is disturbed by economic activities such as mining. These processes expose the mined-out area to water and air, and can lead to consequences such as acid mine drainage (AMD). The low pH conditions associated with AMD mobilize heavy metals, including radionuclides where these are present.

Mineral extraction: Mineral processing operations can also generate significant heavy metal pollution, both from direct extraction processes (which typically entail size reduction - greatly increasing the surface area for mass transfer - and generate effluents) as well as through leaching from ore and tailings stockpiles.

Electroplating industry: It produces large volumes of metal-rich effluents, will naturally be a more likely polluter than the food processing industry, for example, this is not to say that players in this industry will necessarily pollute, and it is in fact in the electroplating industry's best economic interests to minimize metal discharges, since these are inversely proportional to resource efficiency. Reducing losses by minimizing drag-out from plating baths leads to reduced metal discharges, for example. The lead-acid battery manufacturing industry is another example of an industry which can generate metal-rich effluents as well as airborne lead pollution which can subsequently be deposited in surface water resources (and of course on land). So clearly, where an industry uses heavy metals as key input materials, pollution risks increase [10].

Power generation plants: A large non-point source of heavy metal pollution is coal-fired power generation, which can contaminate water resources through aerial deposition of mercury emitted from boiler flues. The industry also generates large amounts of ash which itself contains heavy metals, including uranium [11].

Fertilizers petroleum Industry: Cadmium is produced as an inevitable by-product of zinc (or occasionally lead) refining, since these metals occur naturally within the raw ore. However, once collected the cadmium is relatively easy to recycle.

The most significant use of cadmium is in nickel/cadmium batteries, as rechargeable or secondary power sources exhibiting high output, long life, low maintenance and high tolerance to physical and electrical stress. Cadmium coatings provide good corrosion resistance, particularly in high stress environments such as marine and aerospace applications where high safety or reliability is required; the coating is preferentially corroded if damaged. Other uses of cadmium are as pigments, stabilizers for PVC, in alloys and electronic compounds. Cadmium is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum products [12].

Natural Biological Processes: The degassing of the Earth's crust, emissions from volcanoes and evaporation from natural bodies of water is the major natural source of mercury. World-wide mining of the metal leads to indirect discharges into the atmosphere. The usage of mercury is widespread in industrial processes and in various products (e.g. batteries, lamps and thermometers). It is also widely used in dentistry as an amalgam for fillings and by the pharmaceutical industry [13].

II. Impacts of Heavy Metals:

Heavy Metal Toxicity: Extraction and trading of metals have been in practice since early days. Heavy metals like iron, copper and lead have been useful in so many ways. With growth of human population, industrialization, enormous increase in vehicular traffic and use of chemical fertilizers and pesticides, our environment has been contaminated with heavy metals. Heavy metals may also be present in water bodies, underground water in some areas which are close to the minerals which occur in nature.

The importance of minimizing heavy metal pollution for industrial organizations extends beyond simple compliance. The impacts of heavy metal pollution on living organisms are very serious. Heavy metals are bio-accumulative, toxic at high concentrations, have neurological impacts, and some are carcinogenic. They can also interfere with chemical processes by poisoning chemical catalysts and can impact on biochemical processes by interfering with enzyme action. There are hence serious environmental, economic and social impacts associated with heavy metal pollution.

Effects of Antimony on the environment

Antimony is a metal used in the compound antimony trioxide, a flame retardant. It can also be found in batteries, pigments, and ceramics and glass. Exposure to high levels of antimony for short periods of time causes nausea, vomiting, and diarrhea. There is little information on the effects of long-term antimony exposure, but it is a suspected human carcinogen. Most antimony compounds do not bioaccumulate in aquatic life [14].

Effects of Cadmium on the environment

Cadmium derives its toxicological properties from its chemical similarity to zinc an essential micronutrient for plants, animals and humans. Cadmium is biopersistent and, once absorbed by an organism, remains resident for many years (over decades for humans) although it is eventually excreted.

In humans, long-term exposure is associated with renal dysfunction. High exposure can lead to obstructive lung disease and has been linked to lung cancer, although data concerning the latter are difficult to interpret due to compounding factors. Cadmium may also produce bone defects (osteomalacia, osteoporosis) in humans and animals. In addition, the metal can be linked to increased blood pressure and effects on the myocardium in animals, although most human data do not support these findings.

The average daily intake for humans is estimated as 0.15µg from air and 1µg from water. Smoking a packet of 20 cigarettes can lead to the inhalation of around 2-4µg of cadmium, but levels may vary widely[15].

Effects of Chromium on the environment

Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Low-level exposure can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and damage too circulatory and nerve tissue. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium[16].

Effects of Copper on the environment

Copper is an essential substance to human life, but in high doses it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from overexposure to copper. Copper normally occurs in drinking water from copper pipes, as well as from additives designed to control algal growth [17].

Effects of Lead on the environment

In humans exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing foetus and infant being more sensitive than the adult. High levels of exposure may result in toxic biochemical effects in humans which in turn cause problems in the synthesis of hemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system.

Lead poisoning, which is so severe as to cause evident illness, is now very rare indeed. At intermediate concentrations, however, there is persuasive evidence that lead can have small, subtle, subclinical effects,

particularly on neuropsychological developments in children. Some studies suggest that there may be a loss of up to 2 IQ points for a rise in blood lead levels from 10 to 20µg/dl in young children.

Effects of Mercury on the environment
Mercury is a toxic substance which has no known function in human biochemistry or physiology and does not occur naturally in living organisms. Inorganic mercury poisoning is associated with tremors, gingivitis and/or minor psychological changes, together with spontaneous abortion and congenital malformation.

Monomethylmercury causes damage to the brain and the central nervous system, while foetal and postnatal exposure have given rise to abortion, congenital malformation and development changes in young children.

Natural biological processes can cause methylated forms of mercury to form which bioaccumulate over a million-fold and concentrate in living organisms, especially fish. These forms of mercury: monomethylmercury and dimethylmercury are highly toxic, causing neurotoxicological disorders. The main pathway for mercury to humans is through the food chain and not by inhalation [18].

Effects of Nickel on the environment
Small amounts of Nickel are needed by the human body to produce red blood cells, however, in excessive amounts, can become mildly toxic. Short-term overexposure to nickel is not known to cause any health problems, but long-term exposure can cause decreased body weight, heart and liver damage, and skin irritation. Nickel can accumulate in aquatic life, but its presence is not magnified along food chains [19]

Effects of Selenium on the environment
Selenium is needed by humans and other animals in small amounts, but in larger amounts can cause damage to the nervous system, fatigue, and irritability. Selenium accumulates in living tissue, causing high selenium content in fish and other organisms, and causing greater health problems in human over a lifetime of overexposure. These health problems include hair and fingernail loss, damage to kidney and liver tissue, damage to circulatory tissue, and more severe damage to the nervous system [20].

Effects of Thallium on Environment
Thallium (Tl) is a rare but widely dispersed element. All forms of thallium are soluble enough to be toxic to living organisms. Thallium is more toxic to humans than mercury, cadmium, lead, copper or zinc and has been responsible for many accidental, occupational, deliberate, and therapeutic poisonings since its discovery in 1861. Its chemical behavior resembles the heavy metals (lead, gold and silver) on the one hand and the alkali metals (K, Rb, Cs) on the other. It occurs almost exclusively in natural waters as monovalent thallouscation. The solubility of thallous compounds is relatively high so that monovalent thallium is readily transported through aqueous routes into the environment. Tl can be transferred from soils to crops readily and accrues in food crops [21].

Molecular Basis of Heavy Metals Toxicity:
Toxicity in organism is caused by three general mechanisms although the toxic effects on physiology of different organisms. Some of the common mechanisms are: (i) Metals have strong affinity for Sulphur. Sulfhydryl (S-H) group is present in some enzymes in the organisms. The metal attaches to S–H group and blocks the active site of the enzyme. The normal functioning of the enzyme gets impaired. (ii) A heavy metal may displace an essential ion during synthesis of biomolecule. The biomolecule loses its activity e.g. Pb replaces Ca of the bone, making it fragile. (iii) Metal ions may cause conformational changes in enzymes rendering them inactive. Toxicity is also caused when the metal blocks the defense proteins of the body which fight infections of organism. Also certain forms of heavy metals can pass through cell membrane protecting vital organs like the brain or foetal membranes in a pregnant mother and cause harm.

III. Preventive measures of Heavy Metal Pollution in Rivers

Heavy metals cannot be removed rapidly from the environment. These are not detoxified (made harmless) by organisms through metabolic activity (biochemical reactions within the body). Heavy metals are also not broken down into simpler products by microorganisms. In other words, they are non-biodegradable. Thus heavy metals accumulate in the environment and have harmful effects on organisms causing heavy metal pollution.

It is very difficult to remove metal pollutants as metals are present in a very low concentration, There are however, two ways of designing systems for removal of metal pollution:
(i) Design process for removal of one metal or
(ii) Design one process which removes several metals.
For rivers and sediments contaminated by heavy metals; the following have been suggested.
(i) Place layers of uncontaminated clean soil over contaminated sediment so that the metal containing sediment may not get washed away by rivers.
(ii) Treating with CaCO3 which increases pH of the sediment and immobilizes heavy metals.
(iii) Limestone, gypsum, iron sulphate and activated charcoal can be used as detoxifying.
(iv) Using water Plants such as pistia and hydriella which pick up mercury from water bodies and help in reducing mercury-pollution.

CONCLUSION

Although in India the Central Pollution Control Board (*CPCB*) is responsible for restoration and maintaining the wholesomeness of aquatic resources under Water Prevention and Control of Pollution Act 1974, it is expected that to maintain or restore the water quality at desired level it is important to have monitoring on regular basis. It is expected that the regular water quality monitoring study will help in understanding the water quality trends over a period of time and prioritizing pollution control efforts.

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