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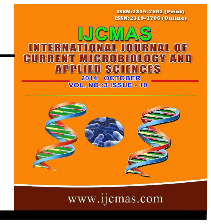

Review Article

Heavy Metal Pollution of the Yamuna River: An Introspection

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Keywords

Heavy metals; Yamuna; Environment; Metal toxicity/ Toxic effects; Anthropogenic activities

ABSTRACT

The Yamuna river, which is the lifeline of Delhi, is one of the most-polluted river in the country. About 85 percent of the pollution is caused by domestic and industrial sources. The quality of the river is severely affected by the discharge of untreated domestic and industrial effluents. The water quality is not fit for bathing, underwater life and domestic supply. A wide range of contaminants are continuously introduced into the river and their toxicity is a problem of increasing significance for ecological, evolutionary, and environmental reasons. Among these contaminants, heavy metals due to their toxicity, accumulation and non-degradable nature, constitute one of the most dangerous groups. Heavy metals viz., Lead (Pb), Copper (Cu), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Nickel (Ni) and Arsenic (As) have adverse effects on human metabolism and health. Bioaccumulation of the heavy metals may cause damage to the central nervous system, lungs, kidneys, liver, endocrine glands, and bones. The prevailing condition of the river is of serious concern, and there is an urgent need to take strict measures to ensure cleansing of the river and prevent further contamination.

Introduction

River water, a natural resource forms the lifeline of all living organisms. Water pollution, which is a major environmental concern of India, is the introduction of contaminating pollutants into the natural water leading to an adverse change. There are numerous data and statistics that claim that the earth's water resources are being depleted, polluted and rendered un-potable at an alarming rate. By the year 2025, two third of the world's population will be facing water shortage. According to UN surveyed reports, India is expected to face critical levels of water stress by 2025 and there will be serious water shortages (UN Climate Report, 2014). Disappearing and drying up of water bodies has resulted in the lack of availability of surface water. Yamuna, the life line of Delhi is the most-polluted river in the country. The current state of the river is of serious concern, and in order to address the pollution crisis effectively, it is important to first understand the causes of pollution.

Approximately, 85% of the river's pollution comes from domestic sources (CWC, 2009). The major sources contributing to the pollution of Yamuna are: untreated sewage, industrial effluents, the dumping of garbage and dead bodies, immersion of idols and pollution due to in-stream uses of water (CPCB, 2006). Further, the dilution capacity of the river is reduced due to significant water abstraction, leading to greater deterioration of the river. The capital of the nation, Delhi is the major contributor of pollution in the Yamuna River, followed by Agra and Mathura (Misra, 2010). Sewage treatment plants (STPs) have been constructed at various urban centers in order to conserve the water quality of the river. The treated, untreated or partially treated sewage from these STPs is discharged directly or through a carrier drain into the river (CSE India, 2007). Due to unavoidable reasons such as power failures, mechanical problems or maintenance issues, these STPs are unable to operate continuously. This poses a major threat to water quality, as the collected sewage is discharged into the river at a few locations without any treatment (CPCB, 2006).

Yamuna river basin

The river Yamuna (Fig. 1) is the largest tributary of the River Ganga. The main stream of the river Yamuna originates from the Yamunotri glacier near Bandar Punch (38^o 59' N 78^o 27' E) in the Mussourie range of the lower Himalayas at an elevation of about 6320 meter above mean sea level in the district Uttarkashi (Uttaranchal). The catchment of the Yamuna river covers parts of the states of Uttaranchal, Uttar Pradesh (U.P.), Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh and the entire state of Delhi. The river Yamuna traverses a distance of about 1370 km in the plain from Saharanpur district of Uttar Pradesh to the confluence with river Ganga at Allahabad. The major tributaries of the river are Tons, Betwa, Chambal, Ken and Sindh and these together contribute 70.9% of the catchment area and balance 29.1% is the direct drainage of main river and smaller tributaries. On the basis of area, the catchment basin of Yamuna amounts to 40.2% of the Ganga Basin and 10.7% of the country (Central Water Commission, 2007).

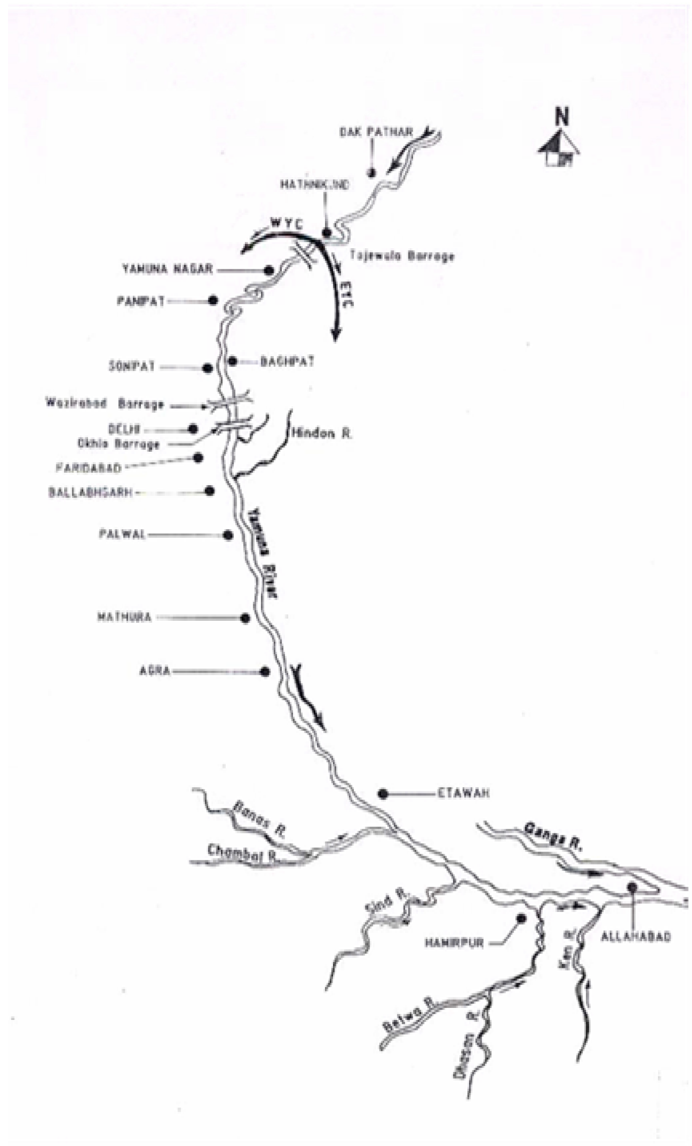

Fig.1 The Yamuna River basin.

Sources of water for National Capital Territory, India

The National Capital Territory is the mega-metropolis situated on the banks of the river Yamuna, which includes Delhi- the capital city of India and its adjoining areas. Spread over an area of 1,483 sq km, it is divided into nine districts having a population of approximately 17.6 million.

The main sources of water in Delhi are river Yamuna (surface water and Western Yamuna Canal WYC), the Ganga (Upper Ganga Canal), Bhakara-Beas storage, groundwater through tube wells and Ranney wells (specially designed high-capacity wells named after founder Leo Ranney). The estimated water availability of NCT of Delhi from surface water sources, viz. the Yamuna, the Ganga and the WYC is about 1150.2 million cubic metres (mcm). The river Yamuna contributes 724 mcm which is a substantial part of the total water requirement. It enters at Palla, traverses through NCT and leaves at Jaitpur in the South. The total area of river zone is about 9700 Ha, out of which approximately 1600 Ha of land is irrigated and 8100 Ha is dry land which contributes as runoff pollution into the river (Jain, 2009).

Biological Contamination of River Yamuna

Although the Yamuna is polluted almost throughout its entire length in the plains, but the maximum of the pollution occurs during its journey through the NCT. The Central Pollution Control Board (CPCB), Central Water Commission (CWC), Delhi Pollution Control Committee (DPCC), State Pollution Control Board (SPCB) regularly monitors the river Yamuna at 19 locations. In addition, twenty eight major drain outfalls into Yamuna are also being monitored by the (CWC, 2007). The organic pollution level increase significantly at Delhi and the Biochemical Oxygen Demand (BOD) level do not confirm to the stipulated standard form. The same stretch of the river shows fluctuations in Dissolved Oxygen (DO) level from Nil to well above the saturation level. This reflects the presence of organic pollution load and prevalence of eutrophic conditions. Bacteriological contamination is significantly high in the entire Yamuna River stretch (Malik *et al* 2014). The main sources of pollution in this region are:

- Rising density of human population on the river banks and poor sanitation practices by residents
- Untreated domestic wastewater and untreated industrial effluents
- Diffuse pollution (agricultural runoffs; dead body dumping and cattle washing)
- Undetected and untreated pesticide residues leave a toxic mark all across the river
- Religious activity and immersion of idols

Monitoring data shows that pollution measured in terms of BOD load has increased 2.5 times from 1980-2005. The BOD load, which was 117 tonnes per day (TPD) in 1980 increased to 276 TPD in 2005. The river has no fresh water flow for virtually nine months. Delhi impounds water at the barrage constructed at Wazirabad. Water that flows subsequently is only sewage and waste. The anaerobic condition in the river is frequently observed and as evident from the presence of masses of rising sludge from the bottom, gas bubbles and floating solids on the surface (CPCB, 2006). As on March 2007, the sewage treatment capacity of STPs in Delhi is 512.4 million gal/day- MGD (2321 million litres/day-MLD) with only 50% of treatment. Rest of the untreated sewage which falls into the river Yamuna is the major cause of river pollution (Delhi Economic Survey, 2008). The NCT region has 17 sewage treatment plants with a treatment capacity of around 2,330 MLD. However, due to silting and settlement of sewage, treatment capacity of only 1,570 MLD is in use at present (Jain, 2009).

Approximately 40% of India's sewage treatment capacity belongs to Delhi, yet a massive gap remains between sewage generation and treatment (Anon, 2006). Scientific data shows that the level of industrial pollution in the Yamuna River is nearly 13 times the permissible limit. Data collected over a 10-year period by the Central Water Commission, through its 371 monitoring stations across the country, shows that Yamuna has the highest level of Biochemical Oxygen Demand (BOD) concentration when it passes through Delhi. Chemical Oxygen Demand (COD) tests are carried out to measure the level of industrial pollution in rivers (Sharma, 2011). Delhi has been identified with 26 industrial areas contributing their load to the river Yamuna. The river has been getting a large amount of partially treated and untreated wastewater during its course through National Capital Territory (NCT) of Delhi, especially between Wazirabad and Okhla (Paliwal and Sharma et al. 2007).

5. **Heavy metal Pollution sources of River Yamuna**

As a result of ecological stress created by humans on the aquatic environment, the pollution levels have significantly increased. Numerous studies have been conducted for testing the presence of heavy metals in the river Yamuna. In a study for determination of heavy metals in fish species (Sen *et al*., 2011), characterization of heavy metals in fish elucidated that the concentrations of Ca, K, Mg, Na and P were too high as compared with other metal and were not in the maximum permissible level set by World Health Organization (WHO). Industrial discharge, release of organic material into water, domestic waste etc. have caused a reduction in oxygen level and are a major reason for eutrophication. Another research conducted by TERI (Yamuna, the poisoned river, 2012), showed moderate levels of toxic metals in the water at several locations. The samples were taken across various locations around Yamuna in Delhi and Haryana. The study also emphasized on the effect of heavy metals on the vegetables growing on the river banks as well as on the population dependent on river 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) (Sehgal *et al.,* 2012). 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

• The average heavy metal concentration at different locations in soil varied in the order of Fe>Mn>Zn>Cr> Pb> Ni>Hg>Cu>As>Cd

Free Ammonia levels of 1.4-6.6 mg/l was present at Okhla Barrage were found to be unfit for propagation of wildlife and fisheries. Flamingos have been observed in thousand in the lake formed at Okhla Barrage where they come to feed on fish, insect, seeds and roots of marsh plants. They make their nests in a mound of mud, which look like a depression. There is an urgent requirement to restore the water quality for conservation of habitat of rare and endangered Flamingos at Okhla Barrage (Mamta et al., 2013).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 bioaccumulate in aquatic ecosystems (Goldstein, 1990; Gledhill et al, 1997).

Heavy metals are considered the most important form of pollution of the aquatic environment because of their toxicity and accumulation by marine organisms (Malik, 2014; Gurnham, 1975). The concentration of heavy metals in the fish from the River water has shown that the metal concentration found in the fish samples were higher than the range of maximum acceptable limits as per WHO. The various industrial outlets which drain into the river is a probable source of the heavy metals in the Yamuna, leading to severe deleterious effecst in humans, fish and plants (Sen *et al*, 2011). Various national and international agencies (CPCB, WHO) have determined the recommended range of heavy metals permissible to human health (Singh et al, 2014) (Fig 2.)

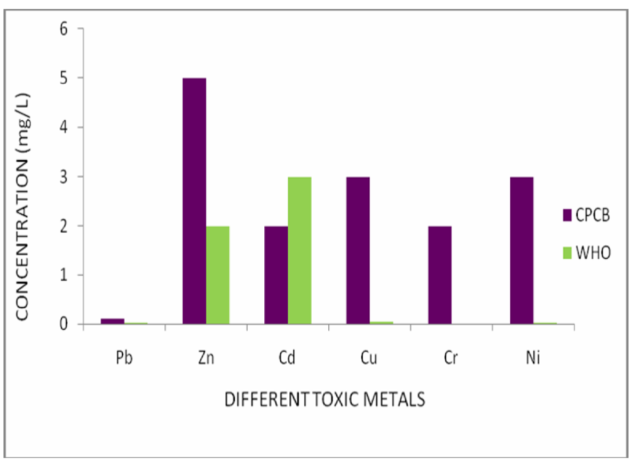

Figure.2 Prescribed limits of heavy metals The acceptable range of heavy metals viz. Lead, Zinc, Cadmium, Copper, Chromium, Nickel reported by CPCB (Central Pollution Control Board) and the WHO (World Health Organization) in a waterbody.

Immersion of idols in the river during the festival season has become a cause for concern because of increased use of cheap lead and chrome-based paints in most of them. Increased use of plaster of Paris is not only affecting the humans and animals dependent on them but is also deteriorating the ecological condition of the river. During the immersion ceremony, puja articles such as polythene bags, foam cut-outs, flowers, food offerings, decorations, metal polish, plastic sheets, cosmetic items, all of which are highly polluting, are also thrown into the water (Kaur *et al*, 2013).

Among various organic and inorganic water pollutants, metal ions are toxic, dangerous and harmful because of their tissue degradation in nature. Toxic metals are also bioaccumulative and relatively stable, as well as carcinogenic, and, therefore, require close monitoring (Zuane, 1990). The poisoning of arsenic, cadmium, chromium and lead is quite well known (Forstner and Wittmann, 1983). The acute toxicity of metal ions has attracted scientists towards their detection in natural water resources. Among various natural water resources, rivers are highly polluted by toxic metals due to the direct discharge of municipal and industrial effluents into the rivers. River water is being used for domestic water supply in different parts of the world and, therefore, the analysis of toxic pollutants in river water has received great attention. Amongst the heavy metals, Cadmium, Nickel and Lead are scantly present in the river, whereas, zinc and iron are present in significant range. Among pesticides, BHC is reported to be present in significant amount, whereas Aldrin, Dieldrin, Endosulfan, and DDT are rarely present (Kaushik *et al*, 2008). The micro-pollutants are generally observed during dry seasons and over the years they have declining trends.

Effect of heavy metals on human health

Heavy metals have been shown to mainly enter the human body through food and water and are known to have serious health implications (Schwartz, 1994). Table 1 is a summary of the various heavy metals detected in the environment and their effect on human health. Lead (Pb) is ubiquitously present heavy metal which is used in paints, storage batteries, and the oxide is used in producing fine crystal glass. Higher levels of Pb lead to cognitive impairment in children to peripheral neuropathy in adults (Kaur, 2012). The heavy metal Copper (Cu), is used in electroplating industries situated on the banks of the rivers (Boxall *et al*., 2000). When present at low concentrations, Cu causes headache, nausea, vomiting and diarrhea, and at higher levels of deposition, it leads to liver and kidney malfunctioning (USEPA, 1999). Zinc (Zn) is discharged in the rivers in the form of effluents from electroplating industries, sewage discharge and the immersion of painted idols. Zinc toxicity causes vomiting, diarrhea, icterus, liver and kidney damage (Boxall *et al*., 2000; Dean *et al*., 1972). Nickel (Ni) is discharged into the rivers by industries like Stainless steel manufacturing units, electroplating factory discharge. Ni is neurotoxic, genotoxic, and carcinogenic agent which may cause health problems like nickel dermatitis etc (Das *et al*, 2008). Cadmium (Cd) is produced by several industrial processes such as protective coatings (electroplating) for metals like iron, preparation of Cd-Ni batteries, control rods and shields within nuclear reactors and television phosphors. Cd when partaken over a long period of time leads to its bio-accumulation in the kidney and liver and causes severe damage. Chromium (Cr) present in the Yamuna river is attributed to electroplating industries situated near the banks of the river. Ingestion of large amounts of Cr also has severe detrimental health effects like gastrointestinal, hepatic and renal damage (Bagchi *et al*, 2002).

Table.1 Heavy metals and their effects on human health

S. No	Pollutants	Major Sources	Effect on Human Health
1.	Lead	Paint, Pesticide, Batteries, Crystal Glass Preparation.	Cognitive Impairment In Children, Peripheral Neuropathy In Adults, Developmental Delay
2.	Copper	Electroplating, Pesticide Production, Mining.	Headache, Nausea, Vomiting Diarrhea And Kidney Malfunctioning
3.	Zinc	Effluents From Electroplating Industries, Sewage Discharge, The Immersion Of Painted Idols	Vomiting, Diarrhea, Icterus, Liver And Kidney Damage
4.	Nickel	Stainless Steel Manufacturing Units, Electroplating Factory Discharge	Neurotoxic, Genotoxic, And Carcinogenic Agent, Nickel Dermatitis
5.	Cadmium	Electroplating, Preparation Of Cd-Ni Batteries, Control Rods, Shields within Nuclear Reactors, Television Phosphors.	Kidney And Liver Damage. Renal Dysfunction, Gastrointestinal Damage.
6.	Chromium	Mines, Electroplating	Gastrointestinal, Hepatic, Renal, Neuronal Damage

This review article summarizes the current situation of pollution in the waters of Yamuna. A study of the biological contamination of the Yamuna shows that the BOD and COD levels of the river are far above the recommended concentrations. The heavy metal levels detected in the river are also higher than those that are acceptable.

The metals enter the environment through aquatic life systems and plants and animals surrounding the river. The danger of bioaccumulation and biomagnification of the heavy metals make them a big threat to human health and welfare. Hence, it is mandatory that steps be taken to reduce the biological and metallurgical effluent load deposited into the river.

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