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POLLUTION POTENTIAL OF TOXIC METALS IN THE YAMUNA RIVER AT DELHI, INDIA

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The water quality of the Yamuna River at Delhi has been studied with reference to toxic metals during pre- and post-monsoon seasons. The metals analyzed include cadmium, cobalt, chromium, copper, iron, manganese, lead and zinc. The quality of river water has deteriorated due to the continuous discharge of municipal and industrial effluents from various drains. The metal load discharged by various drains is quite high. The results show that the maximum load of metal ions was transported from Najafgarh, Barapullah and Shahdara drains. Most of the metal ions show higher concentrations in the post-monsoon season. The main sources of metal pollution in the Yamuna River include municipal and industrial effluents. The river water is not safe due to the high levels of toxic metals. The presence of toxic metals in groundwater indicates contamination in groundwater, however the impact is not well defined. The water supply for domestic purposes from the Yamuna River should be treated for toxic metal ions, and immediate action should be taken to control the quality of the river water.

INTRODUCTION

The preservation and maintenance of our natural water resources is a very difficult task due to rapid growth of population and increased industrial activities. The quality of water resources is deteriorating day by day due to the continuous addition of undesirable chemicals (L'vovich, 1979). On the other hand, the demand for safe water is increasing continuously due to the increase in population, living standards and industrialization.

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.

Various heavy metals were found in the streams of mountain peaks of central Maryland, USA (Katz, 1985). Houba et al. (1983) has reported the presence of cadmium, zinc, copper and lead in the Vesdre River, Belgium, while Latimer and coworkers (1988) studied the metal pollution of the Pawtuxet River. Mohammed and Hayat (1996) studied metal pollution of the Ravi River in Pakistan. Barak and Kress (1997) have found copper, cadmium and zinc metals in the Kishon River, Israel. Various toxic metals were found in twelve Chilean rivers (Pizarro, et al., 1998). In France, the Seine river water was studied for toxic metals (Alexandrine et al., 1998). Zinc was detected in the Przmsza river in Poland (Pistelok and Galas, 1999).

Sakai et al. (1986) analyzed the distribution of Mn, Zn, Cu, Pb, Cr and Cd in water and sieved sediment samples of the Toyohira River in Japan. Since there was a close relationship between metal changes in water and sediments, the marked distribution trend of Mn, Zn and Cd was almost the same for both. The heavy metal concentrations generally increased with decreasing particle size of sediments. Seasonal changes in concentrations of particles of smaller size, moreover, were greater than changes among the larger particles. Sabri et al. (1993) determined the concentrations of Cd, Cu, Co, Fe, Zn, Mn, Pb and Ni in water, suspended solids and surficial sediments of the Tigris River at the Samarra impoundment, and reported that the metal concentrations in water were within the prescribed standards.

Zhang and Huang (1993) studied eight dissolved trace metals (Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn) in the world's most turbid large river, the Huanghe in China. These metal concentrations occurred at levels lower than frequently reported in China. There were correlations between the metals and major elements in the river indicating the significance of weathering and erosion in controlling water chemistry.

In India, various workers have determined the presence of toxic metals in Indian rivers. Prebha and Selvapathy (1997) have studied the status and trend of river water pollution due to toxic metals. Jain (1996) has reported the presence of iron, zinc and copper in the Kali River in western Uttar Pradesh. Kumar and coworkers (1998) have reported cadmium and zinc in the sediment and water of the Kali and Hindon rivers. Sharma and Pande (1998) studied metal pollution of the Ganga River at Moradabad. Calcium and magnesium were detected in the Puma River at Navsari, India (Mogal and Desai, 1998). Priyadarshani (1998) has reported the presence of zinc, copper, nickel, cadmium, lead, manganese, mercury, cobalt and iron in the Safi River. Recently, we have determined the presence of iron, cobalt, nickel, copper and zinc in the Solani river at Roorkee (Ali and Jain, 1998).

In view of the hazardous nature of metal ions, an attempt has been made to study the pollution potential of toxic metals in the Yamuna River at Delhi (India). It warrants immediate attention for the enhancement of the water quality of the river. The improvement of the water quality of this segment cannot be delayed any further, especially because there exists an abstraction point at the Okhla water works which supplies 27,000 kiloliters of drinking water daily to about 3,000,000 people of Delhi. The health and welfare of these people is intimately connected with the quality of drinking water. Furthermore, there are many bathing ghats in this reach of the river where people come and use these ghats for wide varieties of purposes. The motivative forces, which bring people to these ghats, are so wide and strong that any legal threats to prevent them from using these ghats on the ground of bad water quality is bound to fail. The river is highly polluted due to the heavy pollution load of the city itself.

In the present study, the pollution potential of toxic metals has been examined in the pre- and post-monsoon seasons. Water and effluent samples were collected and analyzed for various metals. Some selected groundwater samples were also studied to determine the impact of river water quality on groundwater.

THE YAMUNA RIVER

The Yamuna River originates from the Yamunotri glacier, 6,387 meters above mean sea level (msl), at the Banderpoonch peak in the Uttarkashi district of Utter Pradesh. The river flows 1,367 km from here to its confluence with the Ganga at Allahabad. The annual flow of the river is about 10,000 cumecs. The annual usage is 4,400 cumecs, irrigation accounting for 96 percent of this (Ministry of Environment and Forests, 1994).

On the basis of different geological and ecological characteristics, the Yamuna River has been divided into five segments - Himalayan, Upper, Delhi, Eutrophicated and Diluted - of which Delhi is the most polluted stretch of the river. The 172 km long stretch of the river through the Haryana from the source to the Tajewala barrage is called the Himalayan segment. The stretch from the Tajewala barrage to the Wazirabad barrage, when the river flows 224 km through Haryana, is the upper segment. The Delhi segment comprises the 22 km that the river traverses in Delhi from the Wazirabad barrage to the Okhla barrage. From here to its confluence with the Chambal, 490 km downstream, is the Eutrophicated segment. Beyond this point is the Diluted segment.

An estimated 57 million people are dependent on the waters of the Yamuna River. It is the main source of drinking water for most of the towns along its course. The water quality of the Yamuna River deteriorates almost the moment it reaches the plains. The agricultural belt of Haryana, and the industrial towns all along the river, discharge significant amounts of wastes into the river. However, throughout its course through Haryana and Delhi, the Yamuna becomes a drain, receiving agricultural runoffs containing pesticides and fertilizers as well as industrial and domestic effluents. With several towns and cities discharging their untreated or partially treated wastes into the river, the water quality deteriorates constantly.

The Yamuna River with all its pesticide residues and industrial effluents is the source for more than 70 percent of Delhi's water supply. But the available water treatment facilities are not capable of removing the pesticide traces and heavy metals (Banerji and Martin, 1997). The present study has been carried out to assess the pollution potential of toxic metals on the Yamuna River at Delhi (Figure 1). The river basin area at Delhi is 1084 km^2 having dense population with various industrial establishments. The climate of the region is semiarid due to significant diurnal variations in the temperatures. The average rainfall is about 120 cm, the major part of which is received during the monsoon period. The soil texture of the area is loam to silty loam. Municipal as well as industrial effluents affect the quality and quantity of the river water.

SOURCES OF METAL POLLUTION

The important sources of metal pollution include geological weathering, mining effluents, industrial effluents, domestic effluents and atmospheric sources. The domestic wastewater constitutes the largest single source of elevated metal concentrations in rivers. The metal pollution from domestic and municipal areas is treated in accordance with its sources of origin. There are domestic effluents,

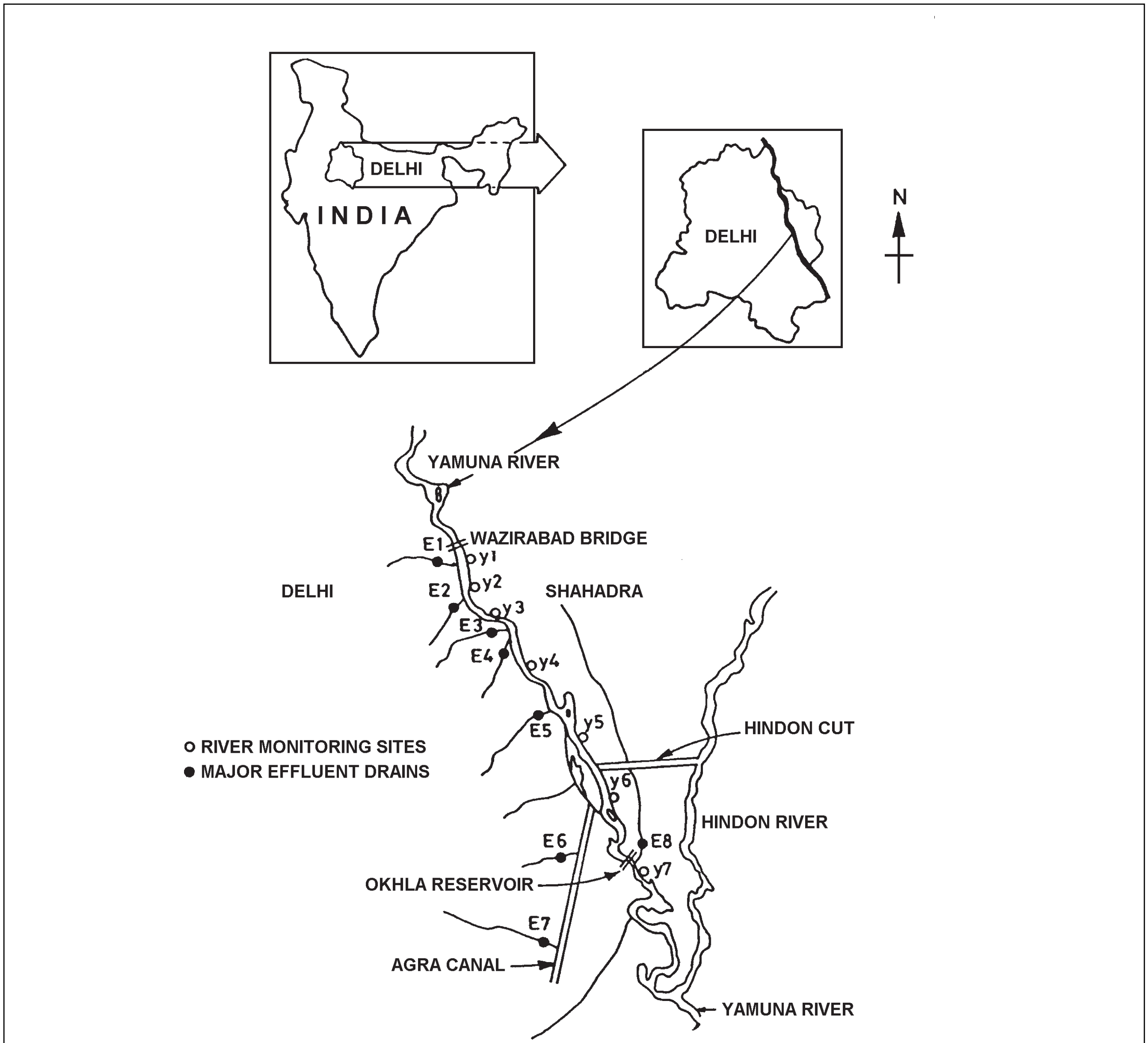

Figure 1. Study area showing location of sampling sites. Effluent drain: E1-Najafgarh drain; E2-Civil Mill drain; E3-Power House drain; E4-Sen Nursing Home drain; E5-Barapullah drain; E6-Kalkaji drain: E7-Tughlakabad drain: E8-Shahdara drain. River monitoring sites: YlWazirabad; Y-Lamba Basti; Y3-Rajghat; y4-Sarai Kalain Khan; Y5-Noida; Y6-Okhla Barrage; Y7-Okhla Reservoir.

which are usually discharged from relatively well-defined point sources, while urban storm water runoff is characterized by a diffuse drainage pattern. The domestic and municipal wastes consist of untreated or solely mechanically treated wastewater, substances which have passed through the filters of biological treatment plants, and waste substances passed over sewage outfalls and discharged to receiving water bodies. Sometimes the corrosion of the urban water supply system also contributes heavy metal pollution to the rivers. The major bulk of the pollution comes from untreated sewage because the city administration lacks sufficient sewage treatment facilities. In an earlier report Jain (1993) has compiled the sources of metal pollution giving various case studies.

About 1,800 million liters per day (mld) of untreated sewage finds its way through 19 notorious drains into the Yamuna River at various points along its 22 km stretch in Delhi. These drains are: Najafgarh, Magazine road, Sweeper colony, Khyber pass, Metcalfe Bagh, Kudsia Bagh, Moat, Trans Yamuna MCD, Mori Gate, Civil mill, Power House, Sen Nursing Home, Drain no. 14, Barapullah, Maharani Bagh, Kalkaji, Okhla, Tughlakabad and Shahdara.

Though the length and basin area of the Yamuna River at Delhi is only 2 percent, it contributes 71 percent of the wastewater and 55 percent of the BOD load discharged into the river every day. The Najafgarh drain alone contributes 60 percent of the discharge and 40 percent of the BOD load into the river. Industrial wastes from 20 large, 25 medium and about 93,000 small-scale industries located in Delhi also flow into the river through these drains. Though the large and medium industries form only about 0.05 percent of the total industries located in Delhi, they contribute 50 percent of the total 300 MLD of industrial waste generated every day.

EXPERIMENTAL METHODOLOGY

The water and effluent samples were collected from midstream from 15 cm depth using a standard water sampler (Hydro Bios, Germany). Two sets of samples were collected during the pre-monsoon (May 1999) and post-monsoon (October 1999) seasons. In all, 21 water/effluent samples were collected: 7 water samples from the Yamuna River, 8 samples from effluent drain and 6 samples of groundwater. The sample bottles were soaked in 10 percent HNO_3 for 24 h and rinsed several times with double distilled water prior to use. The water samples were filtered through 0.45 um membrane filter and preserved with concentrated nitric acid to bring down the pH to <2.0. The samples thus preserved were stored at 4^0C in sampling kits and brought to the laboratory for metal analysis.

All the chemicals and reagents used were of analytical grade and were procured from Merck, India. The standard solutions of metals were obtained from Merck, Germany. Deionized water was used throughout the study. All glass wares and other containers were thoroughly cleaned and finally rinsed with deionized water several times prior to use.

Trace element analysis was carried out using Perkin Elmer Atomic Absorption Spectrometer (Model 3110). Operational conditions were adjusted to yield optimal determination. Quantification of metals was based upon calibration curves of standard solutions of metals.

RESULTS AND DISCUSSION

The concentrations of metal ions determined in major effluent drains joining the Yamuna River are shown in Figure 2. It is apparent from the results that the concentrations of metal ions vary significantly in different drains depending on the nature and flow of waste effluents. In general the concentration of metal ions were found higher in post-monsoon season. The wastewater/effluent discharge was more than 1,000,000 kiloliters per day in Najafgarh, Barapullah and Shahdara drains.

The industries in Delhi are located primarily within three drainage basins, viz., Najfgarh, Trans-Yamuna MCD and Kalkaji.

The metal loads discharged by major effluent drains into the Yamuna River are graphically shown in Figure 3. It is evident from the results that huge amount of toxic metal ions are released from the drains, which is highly dangerous to the people and the biological system of the Yamuna River. It is further apparent from the figures that the maximum load of metal ions was transported from Najafgarh, Barapullah and Shahdara drains.

The concentration of metal ions at different locations from Wazirabad to Okhla reservoir at Delhi are presented in Figure 4. The different metal ions show different trends depending upon the discharge of different effluent drains. The contents of metal ions were higher during post-monsoon season. This may be due to flushing out of the effluent discharge from various industrial units through surface runoff. The concentration of metal ions in Yamuna river water was found much higher than the permissible limits except for cobalt, copper and zinc. Therefore, the use of the Yamuna water for domestic supply is not safe without the proper treatment of water.

The 22 km stretch of the Yamuna River at Delhi, which is the most affected reach of the river, warrants immediate attention for the enhancement of the water quality of the river. The improvement of the water quality of this reach cannot be delayed any further, especially because there exists an abstraction point at Okhla water works which supplies 27,000 kiloliters of drinking water daily to at least 3,000,000 people. The health and welfare of these people are intimately connected with the quality control of the Okhla water works.

Furthermore, there are many bathing ghats in this reach of the river which people come and use for a wide variety of purposes. The motivative forces, which bring people to these ghats, are so wide and strong that legal threats to prevent them for using these ghats on the grounds of bad water quality are bound to fail. In these circumstances, instead of attempting to change the use pattern of the citizens, it is the social obligation of the Municipal Corporation of Delhi (MCD) to improve the water quality of this reach of the river so that bathing may be continued without risking the people's health.

In order to study the possible impact of Yamuna river water on groundwater quality, a few selected groundwater samples were collected from the vicinity of the Yamuna River. The concentrations of most of the metals analyzed were found to be within the permissible limits. However, the presence of various metals in the groundwater indicates the possibility of groundwater contamination due to seepage from the Yamuna River. The surface water bodies play a significant role in the groundwater flow system. The hydraulic gradient imparts significant role in lateral and vertical migration of contaminants in groundwater aquifers. However, further detailed studies are needed to confirm this observation.

CONCLUSION

Delhi is the largest contributor of pollution to the Yamuna River, which receives almost 80 percent of its pollution load through various drains. Delhi generates about 2,270 MLD of sewage against installed capacity of 1,270 MLD of sewage treatment. The balance of untreated sewage, along with a significant quantity of partially treated sewage, is discharged into the Yamuna River every day. The river receives sewage and industrial wastes through nineteen drains, which join the Yamuna River between Wazirabad and Okhla. It is clear from the results that the Yamuna River is highly polluted

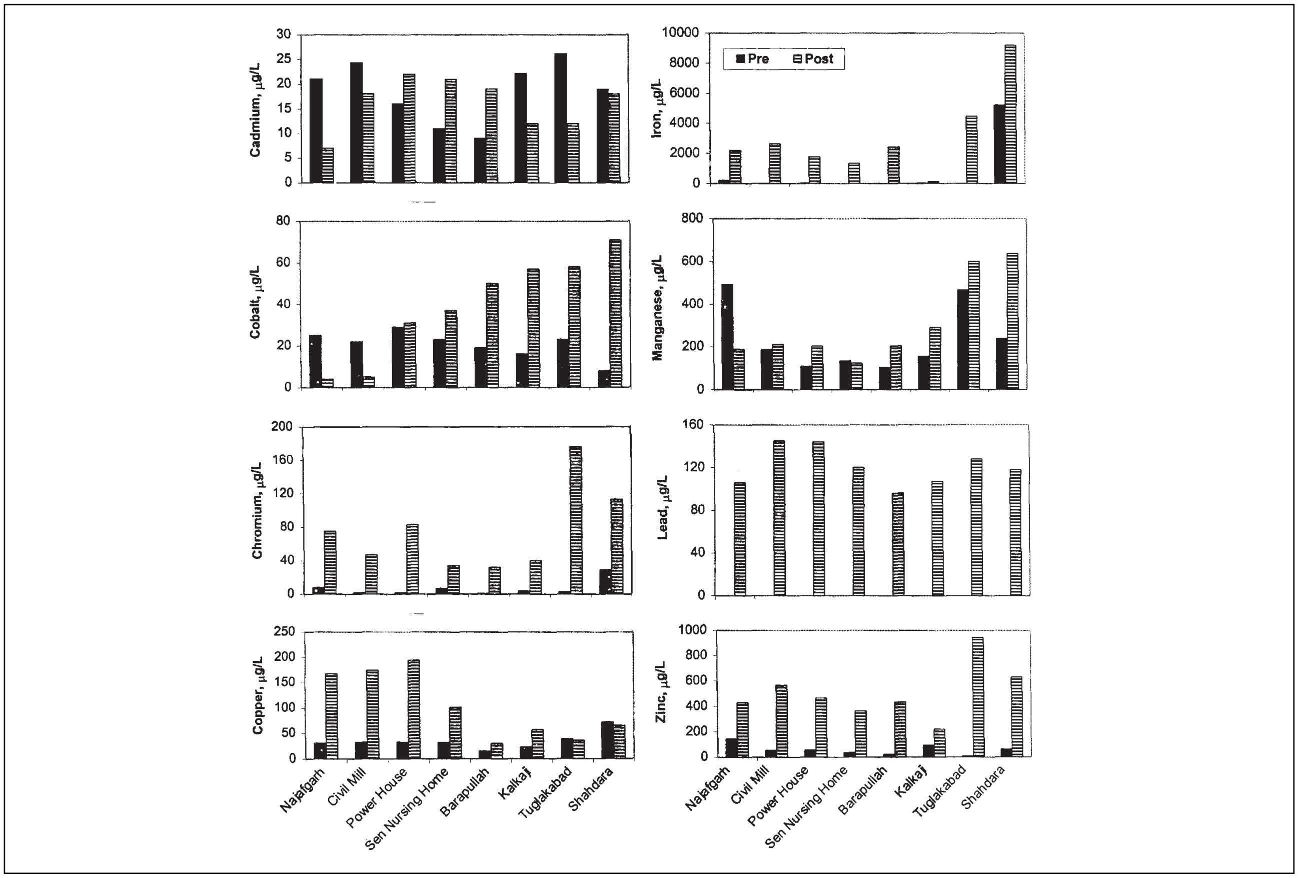

Figure 2. Concentration of metal ions in major effluent drains.

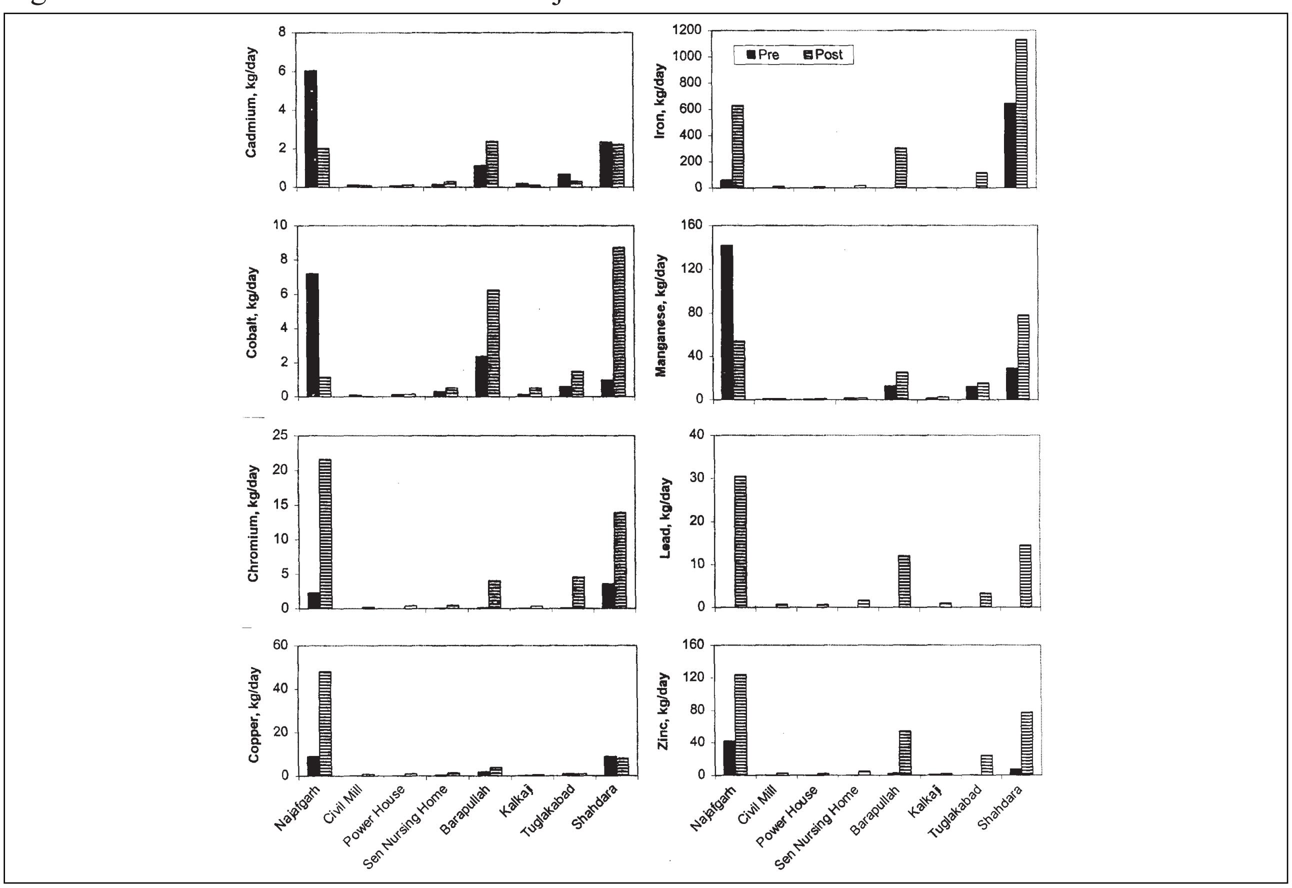

Figure 3. Metal loads contributed by major effluent drains.

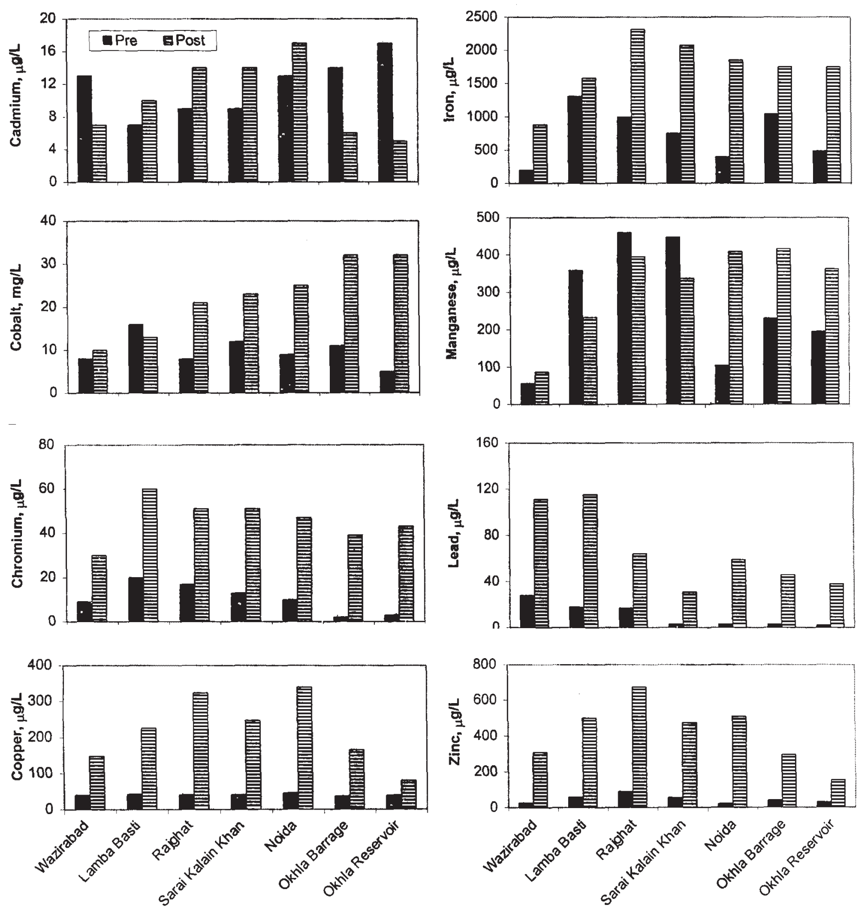

Figure 4. Concentration of metal ions in the Yamuna River at Delhi.

due to toxic metals. The quality of the Yamuna River water is not safe for domestic use. In order to preserve the quality of river water, effluent discharge from various industries should be treated to an adequate extent. The presence of toxic metals in groundwater in the vicinity of the Yamuna River also indicates the possibility of groundwater contamination due to seepage from the river. However, detailed studies need to be carried out to confirm this observation.

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