ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 09, pp.19956-19963, September, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

ASSESSMENT AND IMPACT OF INDUSTRIAL EFFLUENTS ON RIVER YAMUNA ECOSYSTEM

***,[1]Raj Laxmi, [1]Sandeep Arya, [2]Aisha Sultana and [3]Sanjay Das**

[1]Institute of Environment and Development Studies, Bundelkhand University, Jhansi, UP-284128
[2]Centre for Environmental Management of Degraded Ecosystems, School of Environmental Studies, Delhi University, New Delhi-110007
[3]University School of Environment Management, Guru Gobind Singh Indraprastha University, New Delhi- 110078

ARTICLE INFO

Article History:
Received 05th June, 2015
Received in revised form 21st July, 2015
Accepted 07th August, 2015
Published online 16th September, 2015

Key words:
Yamuna,
Heavy Metals Toxicity,
Water quality,
Biodiversity,
River ecology.

ABSTRACT

The water of river Yamuna caters to diverse needs for the survival of the people. With rapid expansion of industrialization and urbanization the quality of the river is severely affected due to indiscriminate discharge of untreated industrial sludge and some extent to mixing of domestic wastewater with free flowing obnoxious effluents containing multi-level heavy metals, pesticides residue, disinfectants and their byproducts contaminants from the drains into the river which are badly affecting river's overall ecology. Due to the absence of proper disposal facilities for effluents which directly disposed off onto surrounding land, surface water and even groundwater along the bank of river Yamuna through drains without recommended treatment. As a result of this, hazardous chemicals and metal ions will seep into the groundwater and devastate the water quality across huge areas, and finally leads to serious effects on the health, and the harvest, of the river Yamuna. Hence, the broad concept of healthy river Yamuna ecosystem and lack of proper management needs the research work to assess the concentration level of industrial effluents, distribution and enrichment of contaminated heavy metals which shows their bio-toxic impacts on biodiversity and also highlighted the deterioration of water quality of river Yamuna.

***Citation*:** Raj Laxmi, Sandeep Arya, Aisha Sultana and Sanjay Das, 2015. "Assessment and impact of industrial effluents on river Yamuna ecosystem", *International Journal of Current Research*, 7, (9), 19956-19963.

INTRODUCTION

Yamuna, sometimes called Jamuna, is the major tributary of river Ganges (Ganga) in northern India, which originates from Yamunotri glacier (Christopher *et al.,* 2012) near Banderpoonch peaks in Himalayas. It is the sacred river of India which travels a total length of 1,376. The total basin area of the river is 366223 km^2 which covers part of geographical area in the states of crosses several states such as Himachal Pradesh, Uttar Pradesh, Uttarakhand, Rajasthan, Madhya Pradesh, Haryana and NCT-Delhi (CPCB, 2006). On the grounds of different geological and ecological characteristic, the river Yamuna has five segments – Himalayan Segment, Upper Segment, Delhi Segment, Eutriphicated segment, and Diluted segment (Ali and Jain, 2001). The emission of unprocessed domestic and industrial wastes has badly deteriorated the quality of Yamuna in all the segments (Figure 1) except Himalayan segment which maintain river quality standards (Sharma and Chhabra, 2015).

***Corresponding author: Raj Laxmi,**
Institute of Environment and Development Studies, Bundelkhand University, Jhansi, UP-284128

Salient features of river yamuna

Several major tributaries join river Yamuna in the Gangetic plain. The important and major tributaries of the river Yamuna are Hindon, Chambal, Sindh, Betwa and Ken. The total catchment basin of the river Yamuna is 42.5% of the Ganga basin and 10.7% of the total geographical landmass of the country (Central Water Commission, 2007). Out of the total catchment's area of 861404 sq km of the Ganga basin, the Yamuna River and its catchment together contribute to a total of 345848 sq. km area which 40.14% of total Ganga River Basin (Tripathi and Gautam, 2013).

Biodiversity of river Yamuna and their importance

India is rich in biodiversity as evident that the country is included in the list of 12 Mega-diversity nations. Country has a 7% of the world's biodiversity and supports 16 major vegetation types.

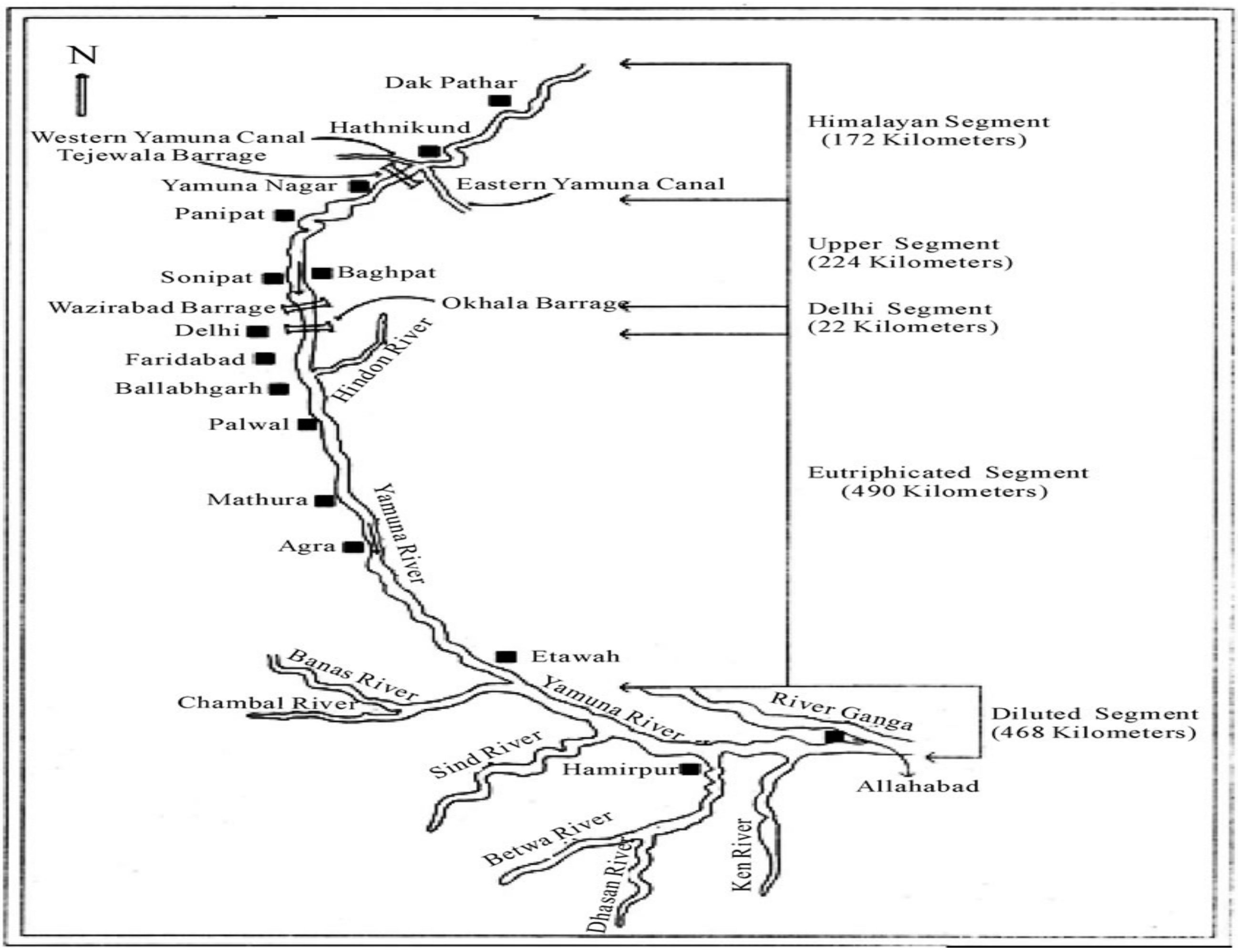

Figure 1. River Yamuna Basin (Source: Mishra, 2010)

Table 1. State wise land use pattern of river Yamuna catchment area

State	Area (sq km)	Area (% of total Catchment)	Land Use Pattern			Land actually cultivated (%)	Land under habitational use (%)
			Non-Arable Land (%)	Forest Land (%)	Cultivable Land (%)		
Himachal Pradesh	5799	1.6	25.0	59.4	15.6	14.2	1.5
Haryana	21265	6.1	18.1	2.4	79.5	59.9	3.6
NCT-Delhi	1485	0.4	51.0	1.0	48.0	46.5	43.7
Uttarakhand	3771	1.1	5.0	22.0	23.0	14.3	1.6
Uttar Pradesh	70437	20.4	14.5	3.9	81.1	68.0	5.1
Rajasthan	102883	29.8	40.8	8.8	50.4	43.9	2.2
Madhya Pradesh	14028	40.6	26.0	18.0	56	50.7	1.8

(Source: Mishra, 2010, CPCB, 2006)

A wide variety of flora and fauna exists in the Yamuna basin, and their spatial variability largely depends on the geo-physical environment (Rai *et al.,* 2012). The drainage basin of the river, particularly till it meets the plateaus, is filled with semi alpine, alpine, sub-tropical and temperate foliage, and huge stretches are covered by jungles aids in survival of a variety of wildlife. All planktonic and benthic communities determine processes, functions and attributes related to the aquatic ecosystem (Tare, 2012). The water quality characteristics strongly influence distribution and extent of biodiversity in river and subtle morphological and physiological changes (Malhotra *et al.,* 2014). Many researchers have put their sincere efforts for biodiversity studies along rivers. Malhotra (2012) has studied the diversity of Zooplanktons of river Yamuna and recorded the *Cladocera* as the dominant group followed by *Rotifera, Copepoda, Protozoa and Ostracoda*. The low population density of the Zooplanktons in river water depicted that river Yamuna is in a very poor tropic status. Kaushik and Gupta (2014) studied the Dyanamics of Avifauna of Yamuna and recorded Birds like Garganey (*Anas querquedula*), Gadwall (*Anas strepera*) were not at all seen in river stream. Common Teal (*Anas crecca*), Northern Pintail (*Anas crecca*), Northern Shoveller (*Anas clypeata*), Eurasian Wigeon (*Anas Penelope*), common Red Shank (*Tringa totanus*) etc. markedly very low numbers in Yamuna stream although these birds were seen in as large numbers, as 300-400 specially Northern Shoveller, Northern Pintail, Common Teal were in few numbers (5-10) in stream. Few birds like Black headed Gull (*Larus ridibundus)*, Pallas Gull (*Larus ichthyaetus)* and River Lapwing (*Vanellus duvaucelii)* were specific to Yamuna. Sen *et al*. (2011) determined fish samples Rahu (*Labeo rohita*), Tilapia (*Tilapia zilli*) and Catfish (*Chrysichthys nigrodigatatus*) with heavy metal concentration in river Yamuna. Similarly, Bhatnagar *et al.* (2013) also recorded 13 taxa of Zooplankton and 8 taxa of Macrozoobenthos. Also recorded 35 taxa contributed to the Phytoplankton community. Yamuna River has rich ecological, social and economical significance with religious beliefs in addition to the huge varied biodiversity, but due to global industrialization Yamuna's original glory decreasing continuously.

Water quality status of river Yamuna

There had been rapid urbanization, industrialization and agricultural development in Yamuna basin after 70's, which is still ongoing (CPCB, 1999-2005). Several large cities have been built on banks of river Yamuna because of advantageous position for harbors and the easily presence of fresh water. There are huge number of industrial clusters at various places including Indore, Gwalior, Kota, Khetri, Panipat, Yamuna Nagar, Nagda, Delhi, Baghpat, Sonepat, Ghaziabad, NOIDA, Faridabad, Mathura, Agra and other places. There are many industries like Distilleries, Pulp, Paper mill, Cement, metal industries, Sugar mill, Weaving, Electroplating, Oil Refineries, Ply board, Chemical, Drugs, Automobiles, Thermal Power Plants, foodstuff industries etc. discharging wastewater into river Yamuna (Sharma and Chaudhary, 2013 and Sharma and Chhabra, 2015).

The criteria for a healthy river are

1. Dissolved Oxygen: Atleast 5 mg/l (vital for survival of aquatic life).
2. Biochemical Oxygen Demand: About 3 mg/l
3. Faecal Coliforms counts should not exceed 500 per 100 mL of water (Sharma and Chhabra, 2015 and Dhillon *et al.,* 2013).

According to the Central Pollution Control Board (CPCB) the water quality of Yamuna River falls under the category "E" which makes it fit only for recreation and industrial cooling, completely ruling out the possibility for under- water life (The Hindu, 2002). The agriculture run-offs from agricultural belt of Haryana and heavy load of domestic and industrial wastes along its ~1200 km journey through the states of Haryana, Delhi and Uttar Pradesh due to industrial towns along the bank of the river Yamuna, the Yamuna becomes a pale and stinking drain and its quality degrades constantly (Sharma *et al.,* 2014; Kazmi and Hansen, 1997; Mishra and Moza, 1997; Moza and Mishra, 2003 and CPCB, 2005). Only Delhi contributes around 3,296 MLD (million litres per day) of sewage by virtue of drains falling into the river Yamuna (Anonymous, 2009) which is highest by any Indian city (Figure 2).

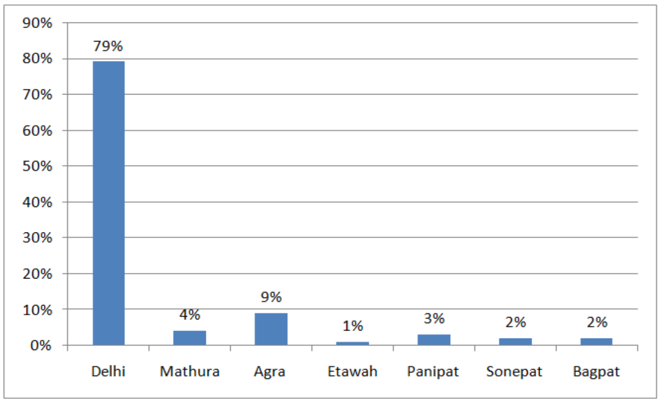

Figure 2. City-wise Contribution of Pollution Load in Yamuna River (Source: CPCB, 2006)

According to CPCB (2006) report, different water quality parameters of river Yamuna are: Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO). Till date, numerous studies have been done on physico-chemical parameters for testing the status of water quality of river Yamuna by many biologists in India. Dhillon *et al.* (2013) extensively studied river Yamuna with regard to physical and chemical characteristics and BOD level found exceeding the permissible limit of 2 mg/l, except river at Palla

Table 2. Used based Water Quality Criteria of Surface Water in India

Designated Best-use	Class of Water	Criteria
Drinking Water Source without conventional treatment but after disinfection.	A	1. Total Coliforms Organism MPN/100ml shall be 50 or less. 2. pH between 6.5 and 8.5. 3. Dissolved Oxygen 6mg/l or more. 4. Biochemical Oxygen Demand 5 days 20° C 2mg/l or less.
Outdoor bathing (Organised)	B	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20° C 3mg/l or less
Drinking water source after conventional treatment and disinfection.	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20° C 3mg/l or less
Propagation of Wild life and Fisheries.	D	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal.	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 25° C micro mhos/cm Max.2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l

(Source: CPCB, 2012)

BOD level starts increasing due to falling out of drains in river Yamuna. COD levels at Palla and Surghat found to be below 50 mg/l. Pantoon Pool show highest COD (460 mg/l). Delhi for most of the year at all the studies location sees DO level around Zero except Palla and Surghat. This indicates a complete failure of Pollution control measures. Singh *et al,* (2013) assessed Physico-chemical analysis of Yamuna River water at Mathura, U.P. and recorded DO ranged between 2.5 to 8.6 mg/l during summer, 3.0 to 5.0 during rainy and 3.0 to 10.4 in winters. COD value found higher during summer (54.8 mg/l) and in winter (11.4 mg/l). BOD is varied from 3.2 mg/l (minimum) to 16.4 mg/l (maximum) in winter, from 14.0 mg/l (minimum) to 52.7 mg/l (maximum). These observations indicated polluted nature of river Yamuna. Vasudevan *et al,* (2011) studied waste loading scenario of river Yamuna and analyzed that DO varied from 4mg/L in the first 3 km to almost zero along the downstream.

The DO is significantly reduced due to the mixing of sewage from the drains at the bank. The carbonaceous BOD is predicted upto 20mg/L as slow carbonaceous oxygen demands (CBODs) and 35 mg/L as fast carbonaceous oxygen demands (CBODf) which is showing good match with the observed values even though predicted CBODf is lower. The simulated total coliform increases from 5000 to 40000 Colony Forming Units (cfu)/100ml, but the observed counts can be higher than this. Finally revealed that found that proper waste load allocation has to be carried out for the protection of the river Yamuna with the focus on the quantity and quality of the incoming flow. Sehgal *et al.* (2012) analyzed average heavy metal concentration at different locations in the river Yamuna at Delhi, from Wazirabad barrage till the Okhla barrage, water varied in the order of Fe>Cr>Mn>Zn>Pb> Cu >Ni>Hg>As>Cd. The river basin soil shows higher level of contamination with lesser variation than the water samples among sampling locations with free ammonia levels of 1.4-6.6 mg/l were recorded which are unfit for propagation of wildlife and fishes. The degree of pollution on river Yamuna can also be assed from an incident that, on 13th June 2002, thousands of dead and dying fishes were found strewn over the Sikendra Taj Mahal area along the water body (Mishra, 2010).

Causes of Yamuna river pollution

The major causes contributing to the pollution of Yamuna are: untreated sewage, industrial effluents, the dumping of garbage, open sewage drains, lack of sufficient sewage treatment plants, soil erosion, open and dead bodies, immersion of idols, Aesthetic activities and pollution due to in-stream uses of water (CPCB, 2006). It's not only the industrial sector that needs to be blamed, but the residents of slums and rural areas that live around the river wash their clothes, utensils, cattle, even defecate also in or around the river.

Sources of Yamuna river pollution

The river Yamuna is polluted through geogenic (Natural) and anthropogenic activities and it is widely accepted that anthropogenic activity makes a significant contribution to the total aquatic burden of toxic metals by both point source and non- point source contamination (Figure 3) can occur (Gupta and Singh, 2011).

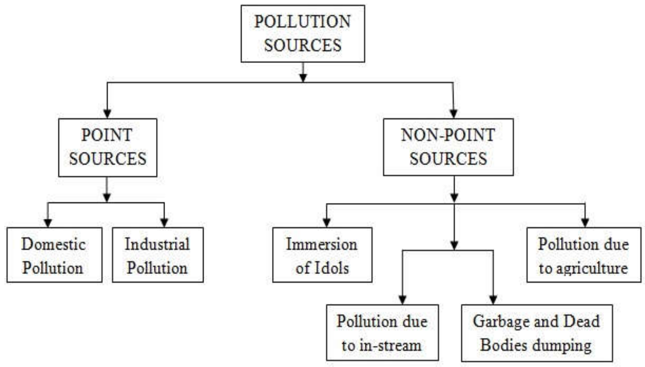

Figure 3. Sources of Pollution (Source: Christopher *et al.,* 2012)

Major threats to river Yamuna

There are several major threats that affecting the ecological integrity of river Yamuna, include:

Industrial effluent and Sewage

The river carries highly toxic wastes, containing high level of heavy metals and pesticides indiscriminately discharged by about half a million industrial units. The water of river Yamuna continues to be polluted by domestic sewage and industrial effluents (Zaffar and Alappat, 2004).

Siltation and degradation of wetlands

All the segments of river Yamuna have been subjected to siltation, encroachment of river beds and the flood plains. This has resulted in a change in land use pattern hindering the ecological functions of the wetlands in the Yamuna basin (The Hindu, 2002).

Alien species

Introduction of exotic species is also a major problem in water resources. Outside their normal environment, they have no natural predators, so they rapidly run wild, crowding out the usual animals or plants that thrive there (http://www.explainthatstuff.com/waterpollution.html). For example, alien fish species are now dominating the 950-km stretch of the river Yamuna and affecting yields, according to a new study by the National Bureau of Fish Genetic Resources (India Today, 2014).

Sand mining

Sand mining is adding to the plight of the Yamuna River in the National Capital Region. It has not only changed the course of the river but also made its riverbed unstable, causing damage to the river's banks, thus disturbing the biodiversity of the region (http://www.dailymail.co.uk/indiahome/indianews/article-2386267/Illegal-sand-mining-changed-course-Yamuna-River-experts-claim.html#ixzz3dVgwCwAv).

Disposal of Carcasses

Dead bodies of human beings and animals are either directly disposed off into river or cremated on the river banks (ENVIS, 2008).

Religious and social practices

People do many religious activities like Asthi visarjan (ashes immersion), Murti visarjan (Idol immersion) Deh visarjan (dead bodies of human beings immersion) on the bank of the river Yamuna. Poly bags filled with different holy material are immersed into the river (Anonymous, 2009).

Industries and their effluents

Development process, industrialization, anthropogenic activities and population explosion have affected environmental quality in many ways, with attendant negative impacts on the environment and human health. Various devastating ecological and human disasters of the last four decades implicate industries as a major contribution to environmental degradation and pollution (Ademoroti and Sridhar, 1979; Asia and Ademoroti, 2001 and Abdel-Shafty and Abdel-Basir, 2001). By mixing of Industrial effluents and domestic wastes into water bodies not only affects the water quality of fresh water bodies but also has the deleterious impact on the aquatic ecosystems and soil micro flora (Abida *et al.,* 2009; Islam et al., 2010; Baskaran *et al*., 2009; Kaur *et al.,* 2010 and Sirohi *et al.,* 2014). It has been realized that discharges of untreated or incompletely treated wastes containing algal nutrients, non-biodegradable organics, heavy metals and other toxicants will hasten the deterioration of receiving water bodies. There has been growing awareness of the need for effective treatment of various effluents before discharging into any public water body (Olaniyi *et al.,* 2012).

Heavy metals

Rapid population growth, increasing urbanization and the increasing appearance of townships as a consequence of poor planning coupled with increasing industrial activities have resulted in overwhelming production of waste without adequate disposal systems (Fasinu and Orisakwe, 2013) and enter into aquatic system through drains, leaching of rocks, airborne dust, forest fires and vegetation (Fernandez and Olalla, 2000 and Ogoyi *et al.,* 2011). Existence of poisonous heavy metals in lakes, reservoir and river water disturbs the lives of native people that rely on these water bodies for their regular supply of water (Rai *et al.,* 2002) causing devastating effects on the ecological balance of the aquatic environment, and the diversity of aquatic organisms becomes limited with the extent of contamination (Ayandiran *et al.,* 2009). Uptake of these toxic metals by plants and subsequent accumulation along the food chain is a potential threat to humans and through various exposure pathways causing adverse affects on human health and environment concern (Qishlaqi *et al.,* 2008; Khan *et al.,* 2009 and Wong and Selvam, 2006).

Recommendations

a. Don't release things which are made up of plaster or any other non biodegradable waste.
b. Implicating a restriction of the use of toxic chemicals in product formulation.
c. Adopting protective measures to prevent leaching of contaminants from sites.
d. Redirecting industrial wastes into containers and then dispose of those containers in special waste treatment plants.
e. For cleaning up the pollution, the rational mind of people and emotional, cultural and religious beliefs is essential.

Table 3. Heavy metals, sources and their toxicological effects on human health

Heavy Metals	Major Sources	Effect on Human health
Arsenic	Pesticides, fungicides, metal smelters, Geogenic/natural processes, thermal power plants, fuel.	Bronchitis, dermatitis, irritation in stomach and intestine, skin, lung, liver and lymphatic cancer, damage of brain and nervous system.
Cadmium	Welding, electroplating, pesticides, fertilizers, Cd, Ni batteries, nuclear fission plant, TV phosphors.	Kidney and liver damage, Bronchitis, gastrointestinal disorder, bone marrow, cancer, renal dysfunction
Lead	Paints, pesticides, batteries, smoking, crystal glass preparation, automobile emission, mining, burning of coal, E-waste, smelting operations, coal-based thermal power plants.	Liver, kidney, gastrointestinal damage, behavioral changes, lower IQ, miscarriages and subtle abortions, peripheral neuropathy in adults, Mental retardation and cognitive impairment in children, developmental delay, coma and even death.
Mercury	Pesticides, fertilizers, Fungicidal sprays, batteries, paper industry, mining, painting, petrochemicals, thermal power plants, fluorescent lamps, hospital waste (damaged thermometers, barometers, sphygmomanometers), electrical appliances etc.	Mental retardation, cerebral palsy, deafness, blindness, memory loss, vision loss, numbness of fingers and toes, damage to the nervous system, protoplasm poisoning.
Fluoride	Food, Drugs, Industrial exposure etc.	Dental and skeletal fluorosis, muscle fibre degeneration, low haemoglobin, deformities in RBC's, excessive thirst, headache, skin rashes, nervousness, neurological manifestations, depression, gastrointestinal problems, urinary tract malfunctioning, abdominal pain, reduced immunity, repeated abortions or still births, male sterility.
Zinc	Refineries, Smelting, electroplating, brass manufacture, metal plating, plumbing, immersion of patent idols	Zinc fumes have corrosive effect on the skin, damage nervous membrane, diarrhoea, liver and kidney damage.
Copper	Water pipes; Copper water heaters; Alcoholic beverages from copper brewery equipment; Pesticides. insecticides; fungicides; Copper jewelry; Copper cooking pots, mining, smelting operations, electroplating, mining	Mental disorders, Anemia, Arthritis, Hypertension, diarrhea, Hyperactivity, Schizophrenia, Insomnia, Autism, Stuttering, Postpartum psychosis, Inflammation and enlargement of liver, kidney malfunctioning, heart problem, Cystic fibrosis.
Chromium	Steel and textile industry, mines, electroplating, industrial coolants, leather tanning, chromium salts manufacturing.	Skin rashes, respiratory problems, hepatic damage, neuronal damage, haemolysis, acute renal failure, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer.
Nickel	Stainless steel manufacturing units, electroplating, Smelting operations, Thermal power plants, Silver refineries, zinc base casting and storage battery industries.	Neurotoxic, Genotoxic, Dermatitis, Myocarditis, Encephalopathy, pulmonary fibrosis, cancer of lungs, nose and bone, headache, dizziness, nausea and vomiting, chest pain, rapid respiration.

(Source: Alluri *et al.,* 2007; Malik *et al.,* 2014; Sharma and Chhabra, 2015; Meenakshi and Maheshwari, 2006; Tangahu *et al.,* 2011 and Bhattacharya *et al.,* 2014)

f. There is a sincere need to punish the polluters and defaulters through a system of fines with adequate bonus to the fine collectors to keep them duty bound and honest.
g. In order to support ecologically and socially sustainable development, necessary to formulate effective plans and policies for industries and develop guideline values and regulations to monitor concentrations of heavy metals in surface water of all rivers.
h. Individually, there is a need to be aware of the pollution and reconsider the basic and real value of the river and spontaneously participate to the plans for cleaning up the river. Small steps can make a big change, so action must be taken from individual level for themselves as well as environmental protection.

Conclusion

This review article summarizes the current situation and most prominent reasons of pollution in the water of river Yamuna, and demands for adopting certain easily feasible and effective measures and approaches that can prevent worsening of water quality of river Yamuna and ensuring better river water quality and quantity. The desired quality of river Yamuna at diverse sites is a very multifaceted striving. The river receives sewage and industrial effluents from huge industrial clusters at Faridabad which is 9th biggest industrial City of Asia (Punia and Cheema, 2013) and Palwal district of Haryana, state. Yamuna River pollution cannot be lessened simply by launching more sewage treatment plants and diversion of waste water drains. To restore the wholesomeness of ecosystem, monitoring of physico-chemical parameters, prediction and detection of ecological effect of river Yamuna is necessary. Besides these, the protection and conservation of rare and endangered species in an aquatic ecosystem cannot be overlooked. It's time to awake, realize the need for cleaning and protecting and take some important steps to reduce the biological and metallurgical effluent load deposited into the river. However, for healthy river ecosystem detailed studies needs to be carried out to in between Faridabad and Palwal district of Haryana state to confirm these observations properly to resolve this complex environmental problem and protect the environment and ecological health.

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