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Heavy metals in Yamuna river: A Review

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Abstract

Water is vital for everyone whether they are plants, animals or humans. 70% of earth is made up of water but few percent are fresh water which is fit for drinking or irrigation purpose. Rivers are major source of fresh water. Due to easy availability of water, people allure to settle down near any river. Even industries require water for their various functions and strangely to dump off the waste. River is the best option they can think of for these activities because of rapid urbanization and industrialization, waste disposal is becoming a major problem. These effluents contain hazardous heavy metals. The amount of these effluents released through industries and domestic households are also multiplying tremendously. Hence, river in urban area are suffering to a large extent. Yamuna is one of the major rivers of India that is almost dried up or almost a sewer at various places. This article attempts to review the assessment of heavy metals in Yamuna river from its origin to Allahabad where its confluences with Ganga.

Keywords: Industrialization, wastewater, urbanization, Yamuna river, pollution, heavy metals

1. Introduction:

Water is indispensable resources for sustaining life. The major part of the earth is marine water which is not fit for human consumption. As population increases, the stress on water resources also increases because surface water is limited and is being depleted day by day due to anthropogenic activities such as mining, irrigation, dumping religious or household waste into rivers etc. Yamuna is one of the sacred rivers of India and a tributary of river Ganges; originates from Yamunotri glacier near the peak name Banderpoonch (38o 59`N 78o 27`E) which is approx. 6387 meters above sea level in district Uttarkashi (Uttrakhand) (CWC,2018). As per CPCB report the total catchment area of Yamuna river is 345848 sq. km as per CPCB Report 1980-81 In CPCB (1999-2015), Yamuna River has been classified into five different segments that are Himalayan Segment, Upper Segment, Delhi Segment, Eu-triphicated Segment and Diluted Segment.

Table 1. Segments of Yamuna river by Mishra,2010

River Segments	Segment Area	Approx. Length
Himalayan Segment	From origin to Tajewala Barrage	172 km
Upper Segment	Tajewala Barrage to Wazirabad Barrage	224 km
Delhi Segment	Wazirabad Barrage to Okhla Barrage	22 km
Eutriphic-ated Segment	Okhla Barrage to Chambal Confluence	490 km
Diluted Segment	Chambal Confluence to Ganga Confluence	468 km

Since the beginning of life, rivers have been the lifeblood of any region. Hence, whole civilizations had been set up on the banks of the rivers whether the Nile river or Indus river. As water is the main source of socio-economic wellbeing and productivity of a region, most of the communities build alongside of the river. Today river pollution is becoming a grave issue in many developing nations. In less developed countries, many rivers and streams are heavily polluted due to anthropogenic activities. Kibria and co-workers (2015) reported that reasons of polluting a river name Buriganga in Dhaka are expansion of population, dumping of domestic and solid waste, encroachment of land, industries like tanneries.

With industrialization, disposing of industrial effluents become another problem. Disposing of waste in river is an easy and inexpensive way so industries as wells sewer containing households' waste is dumped into the river. Polluted river water contains heavy metals that endangers aquatic ecosystem and degrades water quality (Sen et al.,2011; Nongburi and Syiem,2012; Bhattacharya et al.,2008). The parameters to check water quality are categorized into three groups: physical, chemical and bacteriological. Physical parameters include total solids, suspended solids, dissolved solids, colour, odour, taste and turbidity. In chemical parameters, the assessment of heavy toxic metal, biocides, pH, BOD, COD is done whereas bacteriological parameter consist total bacterial count, coliform, E.Coli and Salmonella (FAO, nd). When toxic elements containing water is used for drinking or irrigation purposes; these metals transfer into food chain that ultimately affects human health (Achary et al.,2017; Kacholi and Sahu, 2018)

2. Heavy metals

The term "heavy metals" is defined as group of metals and metalloids of relatively high density in comparison with water that means the atomic density of heavy metals is greater than 4g/cm cube (Fergusson, 1990; Hawke 1997). In 1990, according to Apprenhoth: heavy metals are 1. All transition elements except Actinides and Lanthanides. 2. Rare earth metal c. heterogenous group includes Bismuth (Bi), Aluminium (Al), Galium (Ga), Indium (In), Lead (Pb), Antinomy (Sb), and metalloids Arsenic (As), Germanium (Ge) and Tellurium (Te). According to Raone, on the basis of biological functions and effects of metals, they are classified into three categories: 1. The essential metals: It includes Potassium (K), Calcium (Ca), Manganese (Mn), Iron (Fe), Sodium (Na), Cobalt (Co), Copper (Cu), Zinc (Zn) etc. 2. The toxic metals: It include Cadmium (Cd), Mercury (Hg), Lead (Pb), Aluminium (Al), Silver (Ag) etc and metalloids includes Antimony, Selenium (Se), Arsenic (As), Germanium 3. The nonessential metal: It includes Titanium (Ti), Rubidium (Rb), Caesium (Cs), Strontium (St). On the basis of the coordination chemistry, heavy metals are class B metals that falls into the category of the non- essential trace elements (highly toxic) such as silver, lead, nickel (Ni) and mercury (Nieboer and Richardson,1980) and Class A metals consist Sodium (Na), Magnesium (Mg), Calcium (Ca), Barium (Ba) etc (Silva & Williams,1993).

2.1 Sources of heavy metals

Natural and anthropogenic activities are responsible for deposition of heavy metals (Kar et al., 2008). Many natural events degrade the quality of water like hurricanes, torrential rain falls and mudflow. Natural factors such as climate, watershed characteristics, and wild fires could have substantial impacts on the quality of water (Danquah,2010). Heavy precipitation increases turbidity, metal, microbial loading, colour etc. Industrial pollution, agricultural pollution and urbanization are the prime man-made causes of increasing heavy metals in environment (Liu et al.,2014). According to CPCB 2006, fertilizers and pesticides used in agriculture, agricultural residue, domestic waste, slaughtered waste, dairy waste, carcass of animals, dead bodies of animals and human dumped into the Yamuna river; immersion of idols; industrial waste etc. are the sources of pollution to river (Krishna and Govil.,2004). The practicing of dumping waste from all above sources lead to enhancement of heavy metals in the river water (Li et al.,2015; Silambarasan et al., 2012; Varol and Sen.,2012).

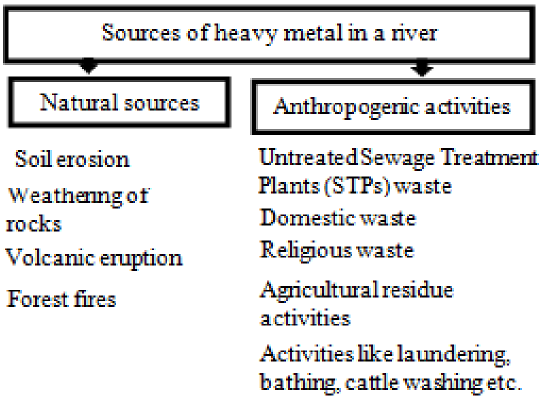

Fig 1. Sources of heavy metal in a river

2.2 Effect of heavy metals

In limited amount, some heavy metals are required by humans and plants for functioning of life but in large quantity, they are toxic to human and plants both (Mahurpawar,2015; Nath et al., 2008; Malik and Khan, 2006; Rehman et al.,2011; Chaves et al.,2011). Many diseases like cholera and typhoid can spread through drinking contaminated water (Haque, nd; Pande et al.,2015). Some waterborne diseases caused by polluted drinking water: are hookworm, typhoid, ascariasis, amoebiasis, and giardiasis. According to a report named "Pollution effects on Human, Animals, Plants, and the Environment", the problems associated with polluted water through chemicals like hydrocarbons, pesticides, heavy metals etc are cancer, lymphoma, hormonal problems, damage of liver and kidney, damage of the nervous system, and damage of the DNA. Essential heavy metals are required for physiological as well as biological functions of the plants. Through soil or irrigation water, plants absorb heavy metals. Some heavy metals are required by plants for their germination, development and growth (Gurmani et al.,2012; Patil et al.,2008; Kazemi,2013). Excess as well as deficiency of heavy metals affects the plants negatively. Exceeding concentration of heavy metals in plants negatively affects plants directly or indirectly (Wang et al.,2017; Ashagre et al.,2013).

Table 2. Permissible limit of heavy metal for drinking water given by various agencies

Heavy metals (MG/l)	BIS 10500,2012		WHO, 2011	European standard, 1980
	Acceptable	Permissible		
As	0.01	1.5	0.01	0.05
Cd	0.003	NR	0.003	0.005
Cr	0.05	NR	0.05	0.005
Cu	0.05	1.5	2	>3
Fe	0.3	NR	0.3	0.2
Pb	0.01	NR	0.01	0.05
Ni	0.02	NR	0.07	0.05
Zn	5	15	-	> 5
Mn	0.1	0.3	0.1	0.005

For example, zinc is required for the growth of roots and shoot of plants whereas in excess zinc causes chlorosis by reducing chlorophyll (Gurmani et al.,2012; Kazemi,2013). and inhibit the growth and yield of the plant(Mediouni et al.,2006; Vassilev et al.,2011; Vijayarengan and Mahalakshmi, 2013).

According to Ministry of water resources, water quality standard in India is divided into five classes – A,B,C,D,E (Mishra,2010)

Table 3 Categorization of river water quality into classes based on its purpose

Class	Uses
A	Drinking purpose without treatment
B	Outdoor bathing
C	Drinking water with treatment
D	Wildlife and fisheries
E	Irrigation, controlled waste disposal, industrial cooling

Class A category water is fit for drinking purposes without any treatment, while Class C is fit but with treatment. Class E water can be used only for Irrigation, controlled waste disposal, and industrial cooling purposes.

2.3 Heavy metal contamination in Yamuna river**:**

Yamuna river is originated from Yamunotri, Uttrakhand. Due to less human population in Yamuntori, river Yamuna is considered to be clean. According to (Kansal et al.,2013), Iron was found to be in Yamuna river in Yamunotri itself but it was below the permissible limit of BIS and WHO. Presence of iron in Yamunotri could be due to lithological weathering. Downstream to Yamunotri there is a village named Kalsi settled near Yamuna river, where Cd and Ni were found in to be more than the permissible limit of BIS in the river. Zn and Cr were also found in water, though below the permissible limit. Zinc concentration was found to be exceed in the water of Yamuna river in upstream of Dakpathar as well as in Dakpathar (Kansal et al.,2013 and Ishaq and Khan,2013), which may be due to dumping of industrial effluents and untreated sewage. Although Zn concentration was found to be lower than permissible limit. Lead concentration reported was more than permissible limit. As per (Ishaq and Khan,2013), Ni concentration is higher than permissible limit at Kalsi, Dakpathar and even at Asan barrage. Copper is mainly sourced by industrial waste hence at Yamunotri copper was not detectable but from Upstream of Dakpathar it was there in water and more than permissible limit of BIS. At Asan barrage all heavy metals were higher in quantity in comparison to above mentioned areas near of river Yamuna. Yamuna river after passing Uttarakhand and enters into Haryana where all heavy metals concentration reported to increase. Cu, Pb and Cd level were found to be higher than the permissible limit whereas Ni and Zn were below than permissible limit (Juned and Arjun, 2010). High concentration of heavy metal may be due to the fact that Haryana is an agricultural state and industrialization is also surging. In 2001, Kaushik and others, studied Delhi and Haryana area to find out how heavy metals is related to the anthropogenic activities. Yamuna crosses Haryana and at Wazirabad it enters into Delhi. A research was conducted by Toxic link on Yamuna river of Delhi to monitor heavy metal concentration and reported high amount of heavy metals in the river. Wazirabad is a major contributor in surging heavy metal concentration in Yamuna river; could be due to discharge of drains and industrial effluents. Main industrial areas of Haryana and Delhi were taken to find out the causes of water contamination especially whether it is due to industries. Fe level was higher in Yamunanagar industrial area; in Panipat it drastically reduced and surged in Sonipat again while in Delhi Fe level was shockingly high and reduced to some extent in Faridabad. Higher concentration of Fe in Delhi is due to the iron related industries in this area; when its effluent dumped into the river Fe level increases. Pb concentration was high in Haryana but decreased after Yamuna entered into Delhi contrary to this Cd concentration was within permissible limit in Haryana and vice versa. Zn was below the permissible limit in Delhi as well as in Haryana. Similarly, Ali & Jain in their research selected industrial areas of Delhi and tried to assess change in heavy metal contamination in Yamuna river as per season. They found that each metal was above the permissible limit except zinc and copper. Concentration of heavy metals vary, it depends on the nature of industry from which effluents released. Heavy metal concentration increases during post-monsoon rather than pre-monsoon. Seven sites of Delhi were taken to find out the mean concertation of heavy metals present in Yamuna river in Delhi and the result was Fe > Cu > Zn > Ni > Cr > Pb > Cd (Bhardwaj et al.,2017). Untreated effluents from STPs, domestic effluents, untreated industrial waste, immersion of idols etc could be the reason of surging of heavy metal concentration. When Yamuna leaves Delhi to enter Uttar Pradesh, it remains nothing but a sewer containing chemical and biological waste (Mishra,2010). In Etawah region of Uttar Pradesh, the mean concentration of heavy metals was tried to find out during two seasons, summer and in post rainy season. This time, the mean concentration of heavy metals was: Fe> Pb> Zn> Cd> Cr> Cu during summer and Fe> Zn> Cr> Pb> Cd> Cu during post-rainy season. After monsoon, there was decrement in concentration of Cu, Cr, Cd, Pb while increment in concentration of Zn and Fe. Pb, Fe, Zn and Cu were within permissible limit during both season (Pal et al.,2017). Concentration of iron in river starts from original point of the river i.e. Gangotri. It increases with river pollution along the way. Cd, Cr, Cu, Ni, Pb were found to be highly increasing except Zn that is only heavy metal to be found within the permissible limit. In Mathura, concentration of all heavy metals decreases except Cd, Cu, Ni, Pb as their concentration was above the permissible limit (Paul et al.,2014). In Mathura region, mean concentration of heavy metal was Zn > Fe > Pb> Cd > Mn> Cu >Ni > Cr (Pal et al.,2017). In Allahabad, heavy metal concentration in Yamuna river was Fe > Ni > Cd > Cr> Pb> Mn. After confluence with Ganga at Sangam, concentration Of Fe and Mn increased at Sarawati Ghat otherwise levels of Cr, Cd, Ni and Pb level were found to be reduced (Naushad et al.,2014). In 2013, Kumar and his co-workers, conducted a research to find out the concentration of heavy metal in water, sediments and fishes of Yamuna river of Allahabad area. It was concluded that Pb, Cu and Zn were above the permissible limit set by WHO for drinking water. Yamuna water and even fishes living in Yamuna river were reported to be unsuitable for consumption. Zn, Ni and Cu were reported to be mostly accumulated in gills and muscles of fishes that is toxic for human consumption. Pb is found to be highly accumulated in the muscles of fishes. Many researches were carried out by different authors on different rivers and found similar results (Ayas et al.,2007; Bhattacharya et al.,2008; Sen et al.,2011). A study was done by Ambedkar and Muniyan (2012) in a river of Tamilnadu and came to know that the distribution of heavy metals in water and sediment of river were as follows Cd > Cr > Cu > Pb > Fe > Zn > Mn. Heavy metals were found to be accumulated mostly in liver > Kidney > Gill > Intestine > Muscle of fishes.

2.4 Strategies taken to improve condition of Yamuna river:

The enhancement of heavy metals in Yamuna river with time is becoming a serious issue. Hence, researchers and scientists are doing continuous tests to know level of heavy metals in water of Yamuna river to monitor the contamination level. Then only necessary steps can be taken to lessen the side effects of river pollution. In India, Central and many state governments are concerned about continuous increase of Yamuna river pollution. In 1978, CPCB report (1978) concluded that domestic waste was the main cause of Yamuna pollution. It also mentioned that two-third of the pollution discharged into the Yamuna river came from domestic households while one-third was contributed by agricultural and industrial effluents. In 1993, Yamuna Action Plan (YAP Phase-I) was implemented by Government of India (GOI) with the help of Government of Japan with the objective to enhance the river water quality level to desired bathing level. Steps such as construction of sewages, provision of improved crematoria, low cost toilets, diversion of sewages, providing awareness through education activities etc were taken under this plan. Again in 2000 to 2002, this plan was implemented under the name of Yamuna action plan II (YAP Phase-II) (Nakamura,2004). According to PIB report, 2015 it was mentioned that there are no separate schemes for Yamuna rejuvenation as being tributary of Ganga it comes under Namami Gange programme. To upgrade the existing STPs and trunk sewer, Rs.1650 crore approximately had been approved under YAP Phase-III. In 2016, Delhi Jal Board (Govt. Of NCT Of Delhi) came out with the report "ACTION PLAN FOR CLEANING THE RIVER YAMUNA" reported that 70% of the pollution in Yamuna comes from Delhi; the reason is that in Delhi 22 drains are directly discharged into the river. There is the dumping of solid, industrial effluents in drains that are also discharged into river. Slums are settled on the bank of the river. Sewerage Master Plan 2031 was mentioned to follow for unsewered areas in Delhi. Various steps regarding urban waste management and bio remediation were also mentioned under the plan. In 2017, Maily Se Nirmal Yamuna Revitalization Plan 2017, Phase-I was implemented and Finance Ministry sanctioned Rs, 344 crores approximately for working on STPs of Najafgarh Drain (PIB report, 2017). There are schemes made by GOI but results are not as per their expectation. In an article by Srivastav mentioned that ministry of India had

TABLE 5: Approximate concentration of heavy metals in Yamuna river, India

Study area				Approximate Concentration of heavy metals (mg/l)									References
				Cd	Cr	Cu	Fe	Ni	Zn	Pb	Mn	As	
Uttrakhand	**Yamunotri**		Jan	-	-	ND	0.11	-	ND	ND	-	-	Kansal et al.,2013
			April	-	-	ND	0.09	-	ND	ND	-	-	
	Dakpathar (upstream)		Jan	-	-	0.8	0.18	-	ND	0.09	-	-	
			April	-	-	0.92	0.17	-	0.08	0.11	-	-	
	Yamuna Vikasnagar (downstream)		Jan	-	-	0.91	0.23	-	0.08	0.26	-	-	
			April	-	-	1.22	0.25		0.14	0.51	-	-	
Uttrakhand (Dehradhun)	**Kalsi**			0.004	0.0049	-	-	0.0045	1.25	-	-	-	Ishaq & Khan,2013
	Dakpathar			0.008	0.006	-	-	0.0041	1.4	-	-	-	
	Asan barrage			0.005	0.006	-	-	0.0069	1.45	-	-	-	
Haryana	**Yamuna nagar**	**Upstream of river**	Summer	0.003	-	0.001	-	0.0022	0.0227	0.0038	-	-	Malhotra et al.,2014
			Monsoon	0.005	-	0.001	-	0.0008	0.0364	0.0024	-	-	
			Post monsoon	0.004	-	0.002	-	0.001	0.029	0.0051	-	-	
			Winter	0.009	-	0.001	-	0.0007	0.0336	0.0031	-	-	
Haryana	**Yamuna nagar**	**Middle**	Summer	0.004	-	0.0016	-	0.0014	0.0342	0.0041	-	-	
			Monsoon	0.002	-	0.0014	-	0.0006	0.0404	0.0032	-	-	
			Post monsoon	0.007	-	0.0011	-	0.0011	0.0406	0.0059	-	-	
			Winter	0.005	-	0.0009	-	0.0016	0.0365	0.0042	-	-	
Haryana	Yamuna nagar	downstream	Summer	0.005	-	0.002	-	0.001	0.02	0.005	-	-	
			Monsoon	0.006	-	0.002	-	0.0007	0.034	0.002	-	-	
			Post monsoon	0.004	-	0.001	-	0.0008	0.036	0.002	-	-	
			Winter	0.005	-	0.002	-	0.0009	0.0341	0.0051	-	-	
Haryana	**Hathnikund**			0.01	-	-	-	0.12	-	0.15	-	-	Kaushik et al.,2001
	Kalnor			0.01	-	-	0.79	0.06	0.4	0.15	-	-	
	Kundaghat			0.01	-	-	0.76	0.17	0.2	0.13	-	-	
	Manglora bridge			0.01	-	-	0.39	0.18	0.5	0.15	-	-	
	Kairana			0.01	-	-	0.08	0.1	0.3	0.13	-	-	
	Khojkipur			0.01	-	-	0.07	0.15	0.2	0.13	-	-	
	Mimarpur Ghat			0.0	-	-	0.0	0.1	0.3	0.1	-	-	

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			1			9	8		3			
		Ghar bridge	0.01	-	-	0.87	0.14	0.8	0.15	-	-	
		Bairabakipur	0.01	-	-	0.24	0.25	0.4	0.13	-	-	
Delhi		**Palla Ghat**	0.01	-	-	0.94	0.21	0.4	0.12	-	-	Kaushik et al.,2001
		Wazirabad	0.02	-	-	0.57	0.07	0.2	0.03	-	-	
		Okhla	0.02	-	-	3.33	0.02	0.05	0.04	-	-	
		Dadasiya	0.02	-	-	3.48	0.06	0.2	0.04	-	-	
		Chhaynsa	0.02	-	-	1.12	0.06	0.13	0.04	-	-	
		Mohana	0.02	-	-	2	0.08	0.15	0.05	-	-	
		Hassanpur	0.02	-	-	0.13	0.05	0.1	0.04	-	-	
Delhi		**Wazirabad**	0.017	0.02	2.25	11.26	0.053	0.449	0.031	-	-	Bhardwaj et al.,2017
		Najafgarh	0.016	0.75	5.93	21.57	0.2244	2.3159	0.12	-	-	
		ITO barrage	0.127	0.026	1.79	5.7	1.04	0.71	0.04	-	-	
		Okhla barrage	0.015	0.024	1.083	6.54	0.06	0.4136	0.0978	-	-	
Delhi	**Wazirabad**	Pre -monsoon	0.013	0.008	0.04	0.2	-	0.05	0.03	0.05	-	Ali & Jain, 2001
		Post -monsoon	0.007	0.03	0.16	0.8	-	0.3	0.11	0.09	-	
Delhi	**Okhla Barrage**	Pre -monsoon	0.013	0.003	0.04	1.2	-	0.08	0.01	0.22	-	Ali & Jain, 2001
		Post -monsoon	0.005	0.04	0.16	1.8	-	0.28	0.05	0.4	-	
Uttar Pradesh	**Etawah,**	**Summer**	0.176	0.139	0.0725	1.23	-	0.316	0.356	-	-	Pal et al.,2017
		Post rainy	0.046	0.092	0.017	1.6	-	0.468	0.063	-	-	
Uttar Pradesh		**Agra**	0.243	7.914	1.4	-	0.256	1.56	0.082	-	-	Paul et al.,2014
Uttar Pradesh		**Mathura**	0.088	0.003	0.916	-	0.097	0.868	0.036	-	-	Paul et al.,2014
Uttar Pradesh		**Mathura**	0.254	0.07	0.116	1.222	0.096	1.86	0.656	0.158	-	Pal et al.,2017
Uttar Pradesh		**Allahabad**	-	-	17.64	-	5.71	79.92	15.26	-	-	Kumar et al.,2013
Uttar Pradesh	**Allahabad**	Old bridge	0.29	0.29	-	1.223	0.234		0.254	0.01	-	Naushad et al.,2014
		Arail ghat	0.33	0.16	-	1.939	0.345		0.284	0.013	-	
		Sangam	0.027	0.13	-	0.536	0.094		0.248	0.036	-	
		Saraswati ghat	0.02	0.003	-	1.109	0.06		0.166	0.055	-	

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set up an authority named "National Ganga River Basin Authority (NGRBA) in 2009 to curb the discharge of untreated industrial and municipal waste in river Ganga and its tributaries by 2020. But, The Parliamentary Committee on Environment and Forests listed the reason of failing NGRBA in its task is encroachment of nearby area of river, and no involvement of people living around the river (Shrivastav,2015). To get better idea regarding current scenario of heavy metals in Yamuna river, there is a need to have more field testing in this regard with ground realities. More realistic and pragmatic schemes are needed to revive Yamuna river. Rather than investing funds again and again, more sustainable and cost-effective ways need to be adopted. To enhance the involvement of people, more awareness should be raised amongst them.

3. Conclusions

This review article summarizes about the current scenario of river Yamuna pollution in terms of heavy metals. Iron is the only heavy metal that is found in the Yamunotri (Uttrakhand) but its concentration increases with pollution level in water along the way. With increasing industrialization and urbanization, concentration of heavy metals also increases in river water. Through polluted water, heavy metals enter into the food cycle and negatively affect human, animal and plants. Heavy metals being accumulative in nature, remain in body. Haryana being industrial area contributes large amount of heavy metals in Yamuna; after crossing Wazirabad, Delhi Yamuna become a river full of chemical constituents. After passing Delhi, it remains nothing but a sewer. Many steps are being taken by Government of India for the betterment of the condition of Yamuna river but strict implementation procedure needs to be followed. This review suggests that various sources of heavy metals in water of Yamuna river should be monitored closely; domestic and industrial waste should be treated before dumping in river and people should be made aware about all these issues and while implementing any programme they should be involved actively

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