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Pollution in river Ganga due to heavy metal toxicity and various mitigation plans- A Review

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ABSTRACT

India is blessed with most holy and worshiped rivers of the world. These rivers have enormous importance not only to the people who lives in the nearby areas but also to those also who lives far from them. Because of rapid industrialization and urbanization various rivers of India including river Ganga, are under immense pressure of water pollution. Discharge of toxic elements like Pb, Cd, Cr, and As etc. in various water resources has been increased simultaneously. Heavy metals are founded to be carcinogenic and prove toxic not only to humans but also to aquatic life and also damages river ecosystem. Municipal waste water and industrial waste water are considered as major source of pollution of River Ganga. A number of plans has been started by Government of India, but still the condition of water remains unsatisfactory. This review mainly gives an idea about the presence of various toxic elements in water bodies, their toxic effect on human health and strategies and plan to mitigate them from river Ganga.

***Key words**: Heavy metal, Ganga river, Toxic, Contamination, Bioremediation, Environment, Health effect.*

Introduction

Water is considered as the one of the most important parameter for the survival of all organisms including human being, plants and animals, etc. About 71% of the earth's surface is covered with water and Asiatic continent alone contributes 36% of the total water share (Gaikwad and Kamble, 2014). Rivers, lakes, reservoirs, swamps, streams and ponds, etc. are considered as fresh water source. Water found great importance in agricultural purposes, industrial purposes, hydropower generation and in domestic purposes that includes; drinking, cooking, washing etc. India is a country where Rivers are treated as a goddess or Devi. River Ganga is considered as the most holy river of the country. Water from this river has found great importance in almost all the possible ways, i.e. for religious, domestic, industrial, and agricultural purposes etc. Water, in modern days, on the basis of its availability and quality is considered as main threat to human existence. The condition worsen in case of developing country as these are the regions where nearly 3.1% of world total death is caused due to consumption of bad quality water. As per WHO, countries who do not follow the drafted water quality parameters have around 80% of diseases related to consumption of bad quality of water. There are various factors that are mainly responsible for the issues related to water quality and quantity, one of such most important issue is industrialization (Dixit *et al.*, 2015). Economic growth related hunger have not only caused pollution related to water but also to soil, air and sound.

India is a developing country, rapid urbanization and industrialization around the bank of rivers have deteriorated the quality and quantity of various water resources including river Ganga. River Ganges covers around 2506 km and gives life to 29 cities, 7 towns and hundreds of thousands of villages. But, settlements around river bank are contaminating the river water by the discharge of polluted water over 1.3 billion litres per day (Khan *et al.,* 1998). The quality of water near cities like Kanpur, Varanasi and Allahabad etc. has become much more worsen. Out of various water pollutants, heavy metals are considered to be one of the most important group of contaminant because of their toxicological effects. Heavy metal includes; chromium, iron, cobalt, lead, copper, manganese, zinc, and nickel etc. and these are founded to have degradability issue (Coral *et al.,* 2005; Nagajyoti *et al.,* 2010; Gupta *et al.,* 2014). Some metal like Zn, Co, Cu, Ni contains important nutrient and can be served as micronutrient to plants. These are used for redox process to stabilize molecules through electrostatic interaction while many other metals like Cr, Cd, Pb, have no known physiological activity (Marchner, 1995).

Metals are classified to be heavy metal if their specific weight is greater than 5 g/cm^3. Concentration of heavy metals in higher concentration in water body leads to have toxic effect on living and non-living organism because of their non-biodegradable nature and more often founded to cause biological magnification through trophic levels (Lenntech, 2004; Deeb and Altahali, 2009; Jain, 1978). May deadlier disease including edema of eyelid, tumar, congestive of nasal mucous membrane and genetic malfunction, etc. are caused by some of these heavy metals even at very low concentration (Atlas and Bartha, 1993; Nies, 1999; Johnson, 1998; Tsuji and Karagatzides, 2001; Abbasi *et al.,* 1998).

In recent years the problem related to toxic metals along with other pollutants got increased immensely. These pollutants caused various types of contamination in the surface water, ground water, soil, and air. Out of these pollutants some are persistent in nature and hence needed to be addressed more carefully. Through studies it has been founded there is need of development of new method besides the convention treatment method as these leads to discharge of some secondary waste product (Asha and Sandeep, 2013; Dixit *et al*., 2015). Bioremediation is one such process by which these toxic and hazardous metals can be degraded by using naturally occurring microorganisms and gets converted into less toxic or non-toxic form (Patel *et al*., 2019; Patel *et al*., 2019; Patel *et al*., 2020).

Hence it becomes prime area of concern to conduct a study related to various heavy metals their source of occurrence, possible routes of their entrance to the environment and their health effect to humans, flora, and fauna and further their biodegradation.

Occurrence and distribution of various heavy metal in environment

Two types of sources, i.e. natural and anthropogenic sources, are mainly responsible for the presence of heavy metals in our environment. Occurrence and distribution of heavy metals depends; on hydrology, local geology, and geochemical characteristics in case of natural source, while rapid globalization and industrialization in case of anthropogenic source (Dhal *et al.,* 2013; *Yadav et al.*, 2017; Barkat, 2011; Mani and Bharagava, 2016; Wang and Mulligan, 2006). Cr metals are mainly released from the tannery industry as Cr salts are used in large quantity during chrome tanning process (Mishra and Bharagava, 2016). Paint and electroplating industries are the major source of contamination related to lead contribute. Metals in soil mainly gets distributed due to application of pesticides, fungi-

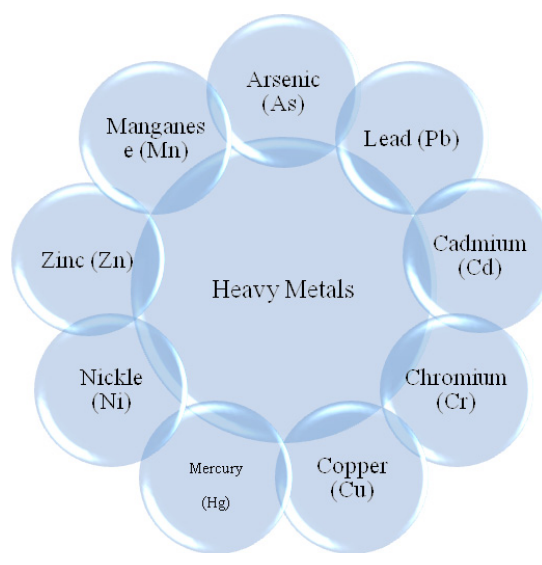
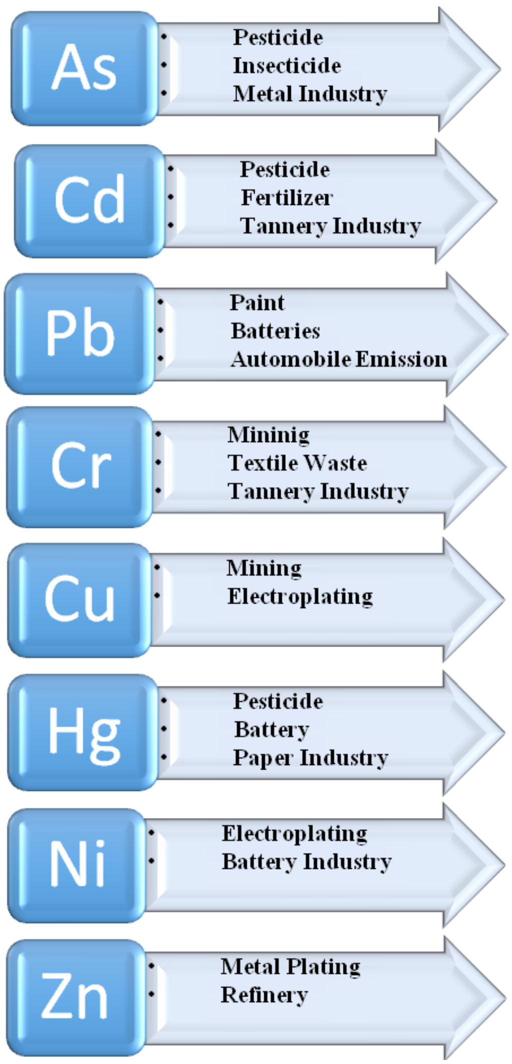


Fig. 1. Various types of heavy metals

cides, and fertilizers (Yadav *et al.*, 2016). The fertilizers contains of As, Cr, Cd, Pb, Zn, Ni, Fe, Mo, and Mn that are useful for plant growth but excessive use of these lead to toxic effect in soils (Reeves and Baker, 2000; Blaylock and Huang, 2000). Concentration of these toxic elements are increasing day by day because of the lack of proper guidelines and management. Table 1 shows the permissible limit of these heavy metals in drinking water. Moreover, some of the heavy metals along with their occurrence, distribution and health related issues are discussed below;



Heavy metal discharge from different sources

Cadmium

The average concentration of cadmium in the earth crust is about 0.1 mg/kg. Sedimentary rocks and marine phosphates are considered to have highest concentration of cadmium in environment containing about 15 mg cadmium/kg. Cadmium is frequently used by industries for producing alloys, pigment, batteries and electroplating works (Wilson, 1988). In recent decades Cd emission, production and utilization has increased immensely (Järup *et al.*, 1998). Other sources of Cd exposure are incineration of Cd containing waste and cigarette smoking. However, there concentration in the body is founded to be founded in low concentration (Hossny *et al.*, 2001).

Health effect

Prime route for the Cd exposure are mainly by inhalation and ingestion of food (Yedjou and Tchounwou, 2007). Cadmium enters in human body through several ways; eating contaminated food, smoking cigarettes, and working in Cd contaminated work places (Prodan *et al.*, 2014; Järup *et al.*, 1998; Hossny *et al.*, 2001; Paschal *et al.*, 2000). Many food stuffs like vegetable, potatoes, mushroom, cocoa powder, dried sea weed, and shellfish are rich in Cd. An important distribution route is the circulatory system where is gets distributed through blood vessel and hence blood becomes prone to Cd toxicity. Pulmonary function and chest radiography that is consistent with emphysema gets change due to chronic inhalation exposure of Cd (Prodan *et al.*, 2014; Seidal *et al.*, 1993; Davison *et al.*, 1998). Chronic

Table 1. Permissible limits set by various organizations for heavy metals in drinking water.

Heavy metal (µg/L)	Permissible limit			
	WHO	USEPA	ICMR	CPCB
Mercury	1	2	1	No relaxation
Cadmium	5	5	10	No relaxation
Arsenic	50	50	50	No relaxation
Lead	50	-	50	No relaxation
Zinc	5000	-	100	15000
Chromium	100	-	-	No relaxation

Cd inhalation also suspected to be a possible cause of lung cancer (IACR, 1976). Itai-itai or ouch-Ouch are caused due to excessive level of Cd exposure. Kidney failure is principle organ that gets enormously affected by chronic exposure to Cd (Järup *et al.,* 2000).

Cd gets accumulated in renal cortex and has the ability to damages it even at low concentration. (Prozialeck and Edwards, 2012). Prostate, ovary, and placenta (reproductive organs) along with others like pancreas, lung and kidney also gets affected on exposure to them (Bonithon-Kopp *et al.,* 1986; Bridges and Zalups, 2005). They lead to male infertility by decreasing the sperm count (Xu *et al.,* 2001).

Arsenic (As)

Based on their metallic and nonmetallic properties, As has been called as metalloid and are found in the environment mainly due to anthropogenic activities includes fungicides, pesticides, herbicides, algaecides, sheep dips, wood preservative, dye stuffs and natural phenomenon; weathering, and volacanic emission etc. are the main components of environment through which As gets distributed widely (Nriagu and Azcue, 1994; Reis and Duarte, 2019; Tchounwou, 1999). Arsenic can be detected even at low concentration and can be examined by collecting samples from urine, hairs or nails (WHO, 2011). As have great ability to combine with carbon and hydrogen present in animals and plants to form organic compound whereas can combine with oxygen, chlorine and sulphur to form inorganic arsenic (Atsdr, 2007). Once incorporated into soil, water, plants, animals and human beings beyond assimilation capacity create various problems. Use of food resources grown in soil having rich As content leads to As poisoning (Nriagu and Azcue, 1990). Beside food cycle As may enter human body through inhalation or through skin (Lauwyers and Hoet, 2001).

Health effect of arsenic compound

Arsenic behavior can be controlled by mainly two parameters that includes; redox potential and pH (Smedley and Kinniburgh, 2002). Oxidation numbers, physical state, particle size, absorption rate into cell and elimination rate are the factors on which toxicity of As is dependent (Mandal and Suzuki, 2002; Bhattacharya and Ghosh, 2015). The effect of arsenic depends primarily upon the route of entry, chemical composition, age, sex, dose and exposure duration (Reis and Duarte, 2019). According to WHO report; vomiting, diarrhea, abdominal pain are the acute effect of as poisoning whereas skin, lung, and bladder cancer are its chronic effects (Yoshida *et al.,* 2004; WHO, 2010). Through a research conducted by Maull *et al.* (2012) has founded that ingestion of even small quantity causes effect in half to one hour (within short duration) (Maull *et al.*, 2012). As exposure leads failure to Central Nervous System (CNS) that further cause patients death with in short duration of time (Civantos *et al.*, 1995).

As exposure leads to disorders related visibility, speech and further causes low verbal intelligence in children (Rosado *et al.,* 2004; Calderon *et al.,* 2001). Through various studies conducted on As effect on blood pressure have founded that As leads to damage the production of endothelial nitric oxide, that in turn leads to high systolic blood pressure that further causes cardiovascular disease associated deaths (Kumagai and Pi, 2004; Lee *et al.,* 2003; Pi *et al*., 2003).

Lead

Lead is a naturally occurring bluish gray, soft and malleable metal distributed in very small concentration in the earth crust in between 10 to 30 mg/kg (USDHHS 1999). These are present in form of ions, oxyanion, hydroxide and oxides, in the environment. Among these forms, Pb (II) is considered to be the most reactive. Various anthropogenic activities like burning of fossil fuel, manufacturing of lead acid batteries, metal producing, and printing industries are the major source of lead enter into the environment in high concentration (Paula *et al.,* 2014). Vehicular and railways emission are one of the emerging contributor of Pb in to the environment. These metals has been categorized as toxic as consumption of these leads to several health issues (Zahra, 2012).

Health effect

Human beings gets exposure to lead mainly via inhalation and ingestion of contaminated dust particles, water, food, paints, and toys etc. (ATSDR, 2007; ASTDR, 1992). Toys and other useful goods for children are considered to have high quantity of lead and have the ability to cause Pb poisoning. Lead enters into the body, predominantly affects central nervous system; generally damages the developing brain and this is more common in case of children, hence children suffer more neurotoxic effects than adult (Rehman *et al.,* 2018). Pd exposure leads to damage to various organs that includes; skeletal, reproductive system, pulmonary system, and gastrointestinal tract etc. (Akil and Ahmad, 2011). Pb also have negative impact on plant as it leads to effect the chlorophyll content that in turn effects the photosynthesis process and hence inhibits its growth (Najeeb *et al*., 2017; Yongsheng *et al.,* 2011)

Chromium (Cr)

Cr are found naturally on earth crust, with oxidation state ranging from Cr III to Cr VI (Jacobs and Testa, 2005). Hexavalent Cr are considered to be more toxic than trivalent Cr, because hexavalent form of chromium is found to be soluble in water as compared to trivalent (Monalisa and Kumar, 2013). Coal, oil fuel, and pigment oxidants are some of the natural sources of chromium existence. Anthropogenic sources of Cr are metallurgical, refractories and leather industries (Kotaœ and Stasicka, 2000; Ghani, 2011).

Health effect

In Cr compounds, Cr III is considered as an essential nutrient as it plays a role in glucose, fat and protein metabolism by enhancing the action of insulin in humans and animals (Goyer and Clarkson, 1996). Cr IV gets absorbed in to human body more easily than Cr III. Occupational exposure to these are becoming a major concern for high risk of Cr induced diseases (Guertin, 2004). Toxicity of Cr exposure in the body depends on the dose and generally caused by a mixture of Cr III and Cr IV ions (Graham, 1999). Many health issues like effect respiratory challenges obstruction of airways, chronic effect of pulmonary irritation, asthma, chronic bronchitis etc are mainly caused due to exposure with chromim (Zhang, 2011; Guertin, 2004). Chronic toxicity causes cancer often occurs in respiratory track mainly in lungs, nasal, and sinus cancers (Guertin, 2004).

Status of heavy metal in Ganga

Extensive studies were done by several researchers regarding heavy metal pollution in sediments of river Ganga in UP and other states. These studies suggested enormous variation in the concentration of heavy metals from one sampling station to another (Ajmal *et al*., 1984). River Ganga have immense catchment area of about 8,61,404 square km and covers near about 2506 km before joining to Bay of Bengal. River Ganga has many tributaries including Ramganga, Kali, Yamuna and Gomati among these Yamuna, kali and Ramganga are founded to have undesirable quantity of heavy metals (Sanklaet, 2018). About 2723 million litre of wastewater along with other industrial effluent gets discharged into it (Sanklaet, 2018). Out of total 78 monitoring stations set up for the study of water quality, stations at Kanpur, Gola-ghat Varanasi , Allahabad, Ghajipur, Buxur, Patna, Bhagalpur, Hawrah, Shivpur in West-Bengal were founded to be unfit for drinking and bathing purposes. The heavy metals are generally associated with chemical part of sediments of river Ganga and were analyzed at different ecological district zones at its run which includes; Diamond harbor, Ganga- Babughat, Gangasagar in West-Bengal, for detection of level of heavy metal dissolution in river Ganga (Purushothaman and Chakrapani, 2007). Bioaccumulation and occurrence of heavy metals like Cu, Cr, Cd, Pb, Zn in muscles of two catfish species and sediments from river Ganga has been studied at Allahabad and accumulation of Zn was found to be maximum followed by Pb, Cu, Cr, and Cd (Sarkar *et al.,* 2007). Pulp and paper manufacturing industry were found to have high values Hg and Pb in their effluents (Gupta *et al.,* 2009). Sample were collected at Kanpur and Varanasi for analysis of chemical composition, energy transformation rate and level of heavy metals. The study concluded that the concentration of heavy metal was very high at the discharge point and it improves with increase in mixing length (Paul, 2017). The Ganga river quality has been evaluated on the basis of physicochemical and biological parameters of water, i.e. turbidity, color, total dissolve solids, pH, BOD, COD, Alkalinity, presence of heavy metals and coliform bacteria (Gupta *et al.,* 2017). Concentration of various heavy metals present at various sites by various researchers has been summarized in Table 2.

Management and strategies to clean river Ganga

It's been almost 35 years for first Ganga action plan, launched in year 1985 by CPCB (Central Pollution Control Board, India) to abate the increasing pollution. The main aim was to control pollutants to reach to river water and hence improving the water quality to acceptable limits. The main objective laid in the first Ganga action plan was modified in year 1987, and new objectives drafted with aim to make water quality to at least bathing standard (NRCD,

Table 2. Quantity of heavy metals (μg L^{-1}) present at different sampling sites in the river Ganga

Study Area	Concentrations of different heavy metals (μg L^{-1})										
	As	Cd	Cr	Cu	Co	Fe	Hg	Mn	Ni	Pb	Zn	Ref.
Haridwar	–	–	43 to 196	101–178	–	–	–	28.7 to 16	–	108 to 690	113 to 219	(Rai *et al.*, 2012)
Rishikesh-Allahabad	–	600 to 13100	–	ND to 36000	–	–	–	–	–	2400 to 26900	ND to 106300	(Goswami, and Sanjay, 2014)
Allahabad	–	ND to 10	ND to 18	ND to 30	–	–	–	–	–	18 to 86	26 to 122	(Gupta *et al.*, 2009)
	–	–	5 to 68	8 to 46	–	6300 to 11,900	–	18 to 94	–	9 to 181	4 to 79	(Kumar *et al.*, 2014)
Varanasi	–	100 to 160	160 to 1090	1700 to 2000	–	120 to 150	–	–	100 to 900	–	500 to 600	(Chaturvedi and Pandey, 2006)
	–	ND to 8.4	1.2 to 29.6	2.4 to 18.1	–	–	–	–	1.6 to 60.8	–	31.2 to 185.2	(Pandey *et al.*, 2010)
	–	ND to 51	17 to 72	47 to 168	–	342 to 1981	–	23 to 67	–	36 to 86	15.8 to 217	(Singh, 2011)
	–	11.41 to 39.24	41.8 to 70.16	19.42 to 43.72	–	83.17 to 117.7	–	40.62 to 68.83	31.28 to 61.11	80.55 to 134.8	31.73 to 71.37	(Pandey *et al.*, 2015)
Mirzapur 1992)	–	13.37 to 32.73	–	38.0 to 157.80	10.50 to 26.77	19.75 to 72.77	–	34.25 to 105.55	67.25 to 176.13	34.25 to 185.75	94.25 to 423.75	(Sharma *et al.*,
Kaushambi	–	–	–	ND to 1000	–	ND to 600	–	–	–	ND to 9	ND to 980	(Chaudhary *et al.*, 2017)
Kanpur	–	–	ND to 390.8	0.6 to 52.1	–	59.3 to 27,956	–	17.7 to 272.6	ND to 63.7	4.3 to 57.5	0.1 to 49.49	(Garg *et al.*, 1992)
Rishra-Konnagar	–	0.043 to 0.088	0.281 to 0.391	0.155 to 0.322	–	–	–	–	–	0.041 to 0.058	0.545 to 0.691	(Bhattacharya *et al.*, 2008)
Bhagalpur	–	ND	BDL to 1090	ND to 120	–	–	–	–	BDL to 120	–	BDL to 870	(Leena *et al.*, 2012)
Berhampore	–	1 to 2	10 to 18	3 to 7	–	365 to 1744	–	181 to 712	41 to 84	8 to 21	65 to 95	(Ker *et al.*, 2008)
Kolkata	–	–	–	1 to 49	–	90 to 420	160 to 950	90 to 490	–	17 to 76	20 to 280	(Sarkar *et al* 2007)
	–	5 to 6	ND	3 to 33	–	13 to 5490	–	22 to 1780	45 to 240	50 to 530	5 to 293	(Aktar *et al.*, 2010)

BDL- Below detection limit; ND- Not detected

2009). CPCB conducted several studies and concluded that industrial and domestic waste are the two important reasons responsible for pollution in the river. Gap I (Ganga Action Plan I) and GAP II were implemented one after another with the main agenda to clean river Ganga but the quality of Ganga kept deteriorating even after executing these plans. The main reason behind the failure of GAP I was the lack of incorporation of integrated river basin management approach as it focused only on effluent from major cities and towns (Ostrom, 2009). Lack of public participation was also the major failure of these schemes. Up flow anaerobic sludge blanket technology (UASBR) was adopted by the authorities without understanding the criteria of suitability hence low bacterial removal efficiency was observed using it (Menon, 1988). Moreover, under these plans only 45% of industries have installed effluent treatment plant, out of which only 27% were able to meet the prescribed standards.

After analyzing these past failures, Government of India (GOI) has set up an authority for basin wide and multi-sectoral approach named National Ganga River Basin Authority (NGRBA) in the year 2009, (Environment Protection Act, 1986). Planning, financing, monitoring and coordinating body between center and states was the main of function of NGRBA. Responsibility of plan preparation for Ganga River Basin Management Plan (GRBMP) was given to 7 Indian Institute of Technology byMinistry of Environment and Forests (MoEF) in year 2010, so as to make long term commitment towards monitoring program (IIT-Consortium, 2015). In 2016, NGBRA was diluted to National Council for Rejuvenation, Protection, and Management of River Ganga.

In the year 2014, an enthusiastic plan was launched by GOI with budget of nearly $3 billion USD, named it as Namami Ganges Mission (NGM), also known as the "Namami Gange". The main objective was to improve the quality of water by 2020 without disturbing its geological and ecological integrity. NGM plan has been divided in to three levels; activities which have instant visible impact are placed in entry level, further, activities that has to be executed within timeframe of five years were clubbed in medium term, and long term activities includes the activities that has to be implemented within 10 years (Ministry of Water Resources, 2016). Construction of sewage treatment plants, development of riverfront, afforestation along the river banks, industrial effluent monitoring, and public awareness programs were main activities that were proposed under this plan.

World Bank, Japan International Cooperation Agency (JICA), German International Cooperation (GIC), and International Water Management Institute (IWMI), along with other international agencies have also supported India both financially and technological in order solve the problem related to river pollution (Ministry of Water Resources, 2016, IWMI, 2015).

Besides all these programs, recent reports by CAG of India on Namami Gange has reported some serious shortfalls in the program. They have mentioned that even after number of notification from almost a decade by NGRBA, NGM is still missing basin management plan. Total coliform level were found to be higher than prescribed limits in all the cities of West Bengal, Bihar, and Uttar Pradesh during 2016-2017 (CAG, 2017). World Bank in its report namely "Implementation Status and Results Report" released in May 2018 has mentioned the objectives and implementation related to program to be "moderately unsatisfactory". Study conducted by CPCB in tannery industry areas of Kanpur has found that all the common effluent treatment plants (CETPs) to be ineffective in treating the effluents (CPCB 2016a, 2016b). Heavy metals such as Hg has been underreported even after various reports related to presence of Hg in higher concentration in the sediments and water of industrial areas of Kanpur (Beg and Ali, 2008; Bhatnagar *et al.*, 2013).

Though after failure of several programs and plans,concerned authorities have learnt a little. It is one of the most important steps to reassess all the programs that has been implemented so far to develop much better understanding related to failure (SANDRP, 2018). A better governance along with more accountable, transparent, and participatory plan at every level is needed to be established. A better pollution control plan is needed to be adopted at the known pollution points. Periodic monitoring and evaluation mechanism along with continuous sample collecting and analyzing unit is needed to be established. Some help can be taken from the other similar projects like remediation of Hudson River that flows in the US (Michaels and Oko, 2017). Each individual needs to understand their role for protection and prevention of the sacred river Ganga.

Conclusion

This review article will give an overview about the recent status of heavy metals in the river Ganga. Through various studies, it has been found that the water of river Ganga contains enormous amount of heavy metals and that too in high concentration. These metals are responsible to several health effects. Though after implementing several plans by Government of India, still the water pollution level of river Ganga remains pathetic. Therefore, there is need of serious and urgent steps to be taken for betterment of sacred river Ganga and hence helping human beings. This review suggested that different sources of heavy metals in water along with other plans to rejuvenate river Ganga should be monitored closely, along with other improvement of conditions and effluents both from industries and domestic is needed to be minimized.

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