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A Review on Heavy Metal Pollution of Holy River Ganga

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Abstract- The Ganga, is one of the most sacred and worshipped river of India, is regarded as the cradle of Indian civilization. Ganga River is a source of life but contamination of water is the major threat in today's India. The industrial, municipal and agricultural wastes contain large amount of organic and inorganic materials and itleads to water pollution, which contains, variable amounts of heavy metals, some of them are potentially toxic and may affect human health and health of aquatic system. Many natural and anthropogenic sources caused heavy metal pollution into water. The concentrations of heavy metals determined were more than the maximum admissible and desirable limit when compared with the National and International organizations like CPCB (Central Pollution Control Board), ISI (Indian Standard Institution), ICMR (Indian Council of Medical Research), WHO (World Health Organization) and USEPA (United States Environmental Protection Agency). Exposure to heavy metals has been linked to chronic & acute toxicity developing retardation, neurotoxicity, kidney damage, various cancers, liver damage, lung damage, fragile bones and even death in instances of very high exposure. The major objective of this review paper is the finding of the work carried out by the many scientists, environmentalists and researchers in the past on the heavy metal pollution of holy river Ganga.

Keywords- India, Environment, River Ganga, Pollution, Water, Heavy Metals, Sediment etc.

I. INTRODUCTION

The Ganga River is one of the most utilized rivers in the world with well-developed ecosystem and has several important cultural, economic and environmental values. Due to abundant availability of water throughout the year, it has played an important role in the development of Indian civilization and economy [1]. It accounts for 25% of India's water resources [2]. The Ganga is the 30th longest river in the world, covering a basin area of 8, 61,404 km^2. The Ganga basin is among the most heavily populated areas in the world with an average density of 520 persons/km^2. The basin sustains more than 300 million people in India, Nepal, and Bangladesh [3-4].

The basin of river Ganga, which has very rich heritage, culturaland religious values, drains about 10,60,000 km^2 area and it is the 5th largest in the world [5]. The river system drains about one-fourth of the Indian sub continents. In India, the river Ganga passes along 29 class-I cities, 23 class-II cities and approximately 50 towns because of which different types wastes such as industrial, agricultural, sewage etc. are released into this mighty river eco-system [6-7].

These wastes contain health hazard Heavy Metals like Chromium (Cr), Copper (Cu), Arsenic (As), Cadmium (Cd), Mercury (Hg) and Lead (Pb) which interact with aquatic environment and affect the river ecosystem [8]. Metals are introduced into the aquatic system as a result of weathering of soil and rocks, from volcanic eruptions and from a variety of human activities involving mining, processing use of metals or substances containing metal contaminants [9].

Trace metals entering natural water become part of the water-sediment system and their distribution processes are controlled by a dynamic set of physical-chemical equilibria. The metal solubility is principally controlled by pH, concentration and type of ligands and chelating agents, oxidation-state of mineral components and the redox environment of the system [10]. The pollution of aquatic ecosystem by heavy metals has assumed serious proportions due to their toxicity and accumulative behavior. Therefore, aquatic ecosystem of river Ganga is suffering a huge loss in terms of aquatic biodiversity. Unlike organic pollutants, natural processes of decomposition do not remove heavy metals [11].

The increased use of metal based fertilizer in agriculture revolution of the government could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Metal in water occur as complex and mixture of soluble and insoluble form, such as ionic species, inorganic and organic complexes associated with colloids and suspended particulate matter. Metals are probably the most harmful pollutants because of their non-biodegradable nature and their potential to cause adverse effects to human beings, if their concentration is higher than the permissible limits. The industries, which emits the metals in electroplating industries, paint and pigment industries, ceramic pulp and paper industries, cotton textile, steel plant, galvanization of ion product, iron and mining industries. Various environmental factors such as temperature, pH, water hardness, dissolved oxygen light, salinity and organic matter can influence the toxicity of the metals in the solution. As a result, metals shift from one compartment within the aquatic environment toanother with detrimental effects, through sufficient bioaccumulation.

As a result of adsorption and accumulation the concentration of metals in bottom sediments is expected to be higher than in the water above and this sometimes can causes secondary pollution problems, therefore, bottom sediments are repository of heavy metals. Metals in natural waters can exist in truly dissolved colloidal and suspended forms. The proportion of these forms varies with metals and for different water bodies. Consequently, the toxicity and sedimentation potential of metals change depending on their forms [12].

Non-essential metals often exerts their action through their chemical similarity to essential elements e.g. Cd with Cu or Zn. However, the effects of toxicity are usually additive and or synergistic. Essential heavy metals are less toxic than non-essential metals. Metal such as cadmium, chromium, copper, iron, nickel, lead and zinc exhibits aquatic toxicity when present above recommended standard in that they can contaminate surface and ground water bodies, soil, plant, aquatic life and man, through bioaccumulation.

The heavy metals pollution is one of the five major types of toxic pollutants commonly present in surface and ground water. The environmental pollutants tend to accumulate in organisms and become persistent because of their chemical stability or poor biodegradability and those they are readily soluble and therefore, environmentally mobile [13]. Heavy metals form one of the major contributors to the pollution of natural aquatic ecosystem [14-15].

II. OBJECTIVES OF THE STUDY

This review paper presents all the findings of the work carried out by the many researchers in the past on the heavy metal pollution of holy river Ganga. The present paper is an effort to discuss a number of critical issues due to heavy metal pollution in river Ganga.

III. METHODOLOGY

1. Nature of Study:
The present paper is a macro level and descriptive study in nature, based on secondary data collected from the published records, reports and contributions of several institutions, organizations and individuals in India.

2. Secondary Data:
Secondary data was collected from Annual Reports of CPCB, Economic Survey, websites, various articles, books and other journals.

Limitation of the study:

3. Lack of primary data.
As the research mainly depends on secondary data, it may not be 100% accurate.
The study is restricted to India only.

IV. GEOGRAPHICAL JOURNEY OF RIVER GANGA

The river Ganga originates from the Gangotri glacier at Gomukh (30°36′ N; 79°04′ E) in the Uttar Kashi district of Uttarakhand province in India, at an altitude of about 3800 m above mean sea level in the Garhwal Himalaya [16]. The length of the main river/channel from the traditional source of the Gangotri glacier in India is about 2,550 km.

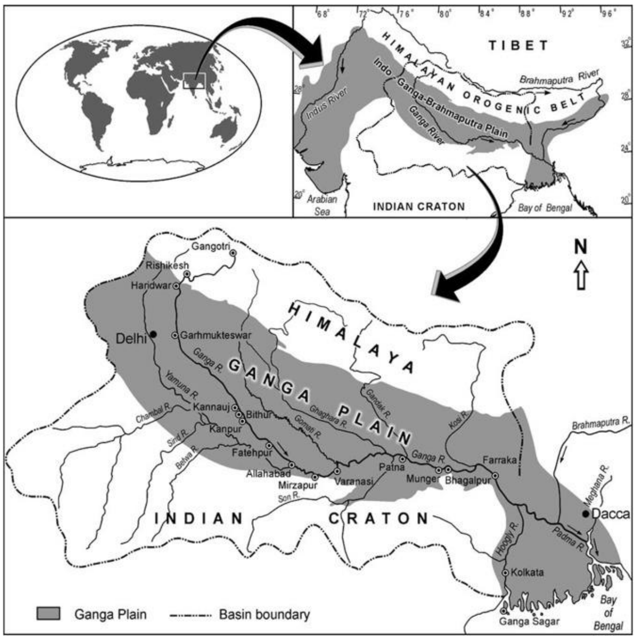

Fig 1. Geographical Journey of River Ganga.

After flowing through the Sivalik hills, it enters plains at Haridwar. Then it flows southwards, passing through the plains of Uttar Pradesh. After leaving Uttar Pradesh, the Ganga enters Bihar in the Rohtas district. From Bihar, it enters West Bengal province and starts flowing south. Nearly 40 km below Farakka, it is divided into two arms.

The left arm flows eastwards into Bangladesh and the right arm, called Bhagirathi, continues to flow south through West Bengal. The Bhagirathi flowing west and south-west of Kolkata is known as Hooghly. After reaching Diamond

Harbour, it attains a southward direction and is split into two streams before reaching the Bay of Bengal [17] (Figure-1).

The mean annual water discharge is the fifth highest in the earth with a mean of 18,700 m^3/s. High variation in flow exists within the catchment area, to the extent that the mean maximum flow of the river Ganga is 468.7 × 109 m3 which is 25.2% of India's total water resources [18]. The fresh water flow in the river system is mostly from the tributaries and therefore, the water availability greatly varies from 59,000 million m^3 at Allahabad, before the confluence with the Yamuna, to 4,59,000 million m^3 at Farakka in the lower stretch [19]. The source of water is the melting of snow in the Himalayas and monsoon rains.

The river system covers cool upland streams and warm water stretches, including deltaic habitats [20]. Ganga river water is used routinely for drinking and outdoor bathing by millions of people who take a holy dip at least once a year throughout the course of the river, from Gangotri to Ganga Sagar, owing to its socio-religious significance (Figure-2).

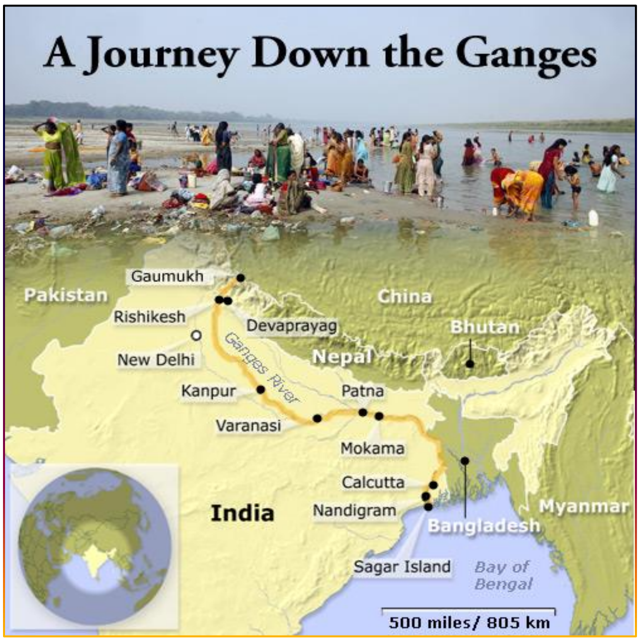

Fig 2. Journey of river Ganga through different places.

V. POLLUTION STATUS IN MIDDLE STRETCH OF RIVER GANGA

The Ganga river basin is the largest inland river basin of India draining a catchment of about 8,61,404 km^2 and covers a long distance about 2,550 km from Gangotri to Bay of Bengal. Ganga has many tributaries like Ramganga, Kali, Yamuna and Gomati around the middle stretch from Haridwar to Varanasi.

Among these tributaries Ramganga, Kali and Yamuna are loaded with huge amount of heavy metals containing organic and inorganic pollutants. There are several major cities such as Haridwar, Farrukhabad, Kannauj, Kanpur, Allahabad and Varanasi are located close to the river bank in the middle stretch and their waste waters directly discharged into the river. According to the Survey of Economic Times (2020) and CPCB's report, from about 37,000 million litres per day (MLD) of domestic sewage is discharged into the Ganga river. The monitoring of river Ganga in between Rishikesh to Varanasi indicated that the middle stretch of river Ganga from Kannauj to Kanpur and Varanasi are the most polluted region [21].

Although the physical appearance of river water is generally good in quality before it reaches the Ghatiya Ghat, Farrukhabad. From Ghatiya ghat (Farrukhabad) to Menhadighat (Kannauj) the water quality of river gradually decreases due to discharge of approximately 500 MLD toxic wastes from domestic sewage and Kali and Ramganga Rivers. Industrial wastes with organic and inorganic chemical constituents change the physical appearance of river water.

Therefore, physical appearance of the river water gradually becomes brown to blackish colour around Kanpur city where approximates 1000 MLD toxic effluents of about 400 tanneries, untreated municipal waste and industrially polluted Pondu river discharge their waste to river Ganga. The Ganga river water quality has been evaluated on the basis of pollution indicators like pH, alkalinity, DO, BOD, COD, coliform bacteria and presence of heavy metals [22].

VI. SOURCES OF HEAVY METALS

"Heavy metals" is a collective term, which applies to the group of metals and metalloids with an atomic density greater than 5 g/cm^3, or 5 times or more, greater than water [23]. It means, a toxic heavy metal is any relatively dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts. The term has particular application to cadmium, mercury, lead and arsenic, all of which appear in the World Health Organization's list of 10 chemicals of major public concern. Other examples include manganese, chromium, cobalt, nickel, copper, zinc, selenium, silver, antimony and thallium.

Heavy-metal contamination is not a modern problem arising out of industrialization; it began when humans started processing ores [24]. Since then the use of metals and their impacts on the environment have accelerated, with a major increase during the 20th and 21st centuries. Generally, most of the heavy metals enter in the river from different sources, it can be either natural or by erosion and weathering or anthropogenic [25] (Figure-3).

In view of the intense human activity, natural sources of heavy metals from leaching and weathering of rocks in the environment, are usually of little importance. The presence of heavy metals in sediments is due to precipitation of their carbonates, hydroxides and sulfides, which settle down and form the part of sediments. The most important anthropogenic sources of heavy metal are various industries and domestic sewage.

The practice of discharging waste from industries and untreated domestic sewage into the aquatic ecosystem is continually going on that leads to the increase in the concentration of heavy metals in river water [26]. The industries which attribute heavy metals in river water are generally metal industries, paints, pigment, varnishes, pulp and paper, tannery, distillery, rayon, cotton textiles, rubber, thermal power plant, steel plant, galvanization of iron products and mining industries as well as unsystematic use of heavy metal-containing pesticides and fertilizer in agricultural fields [27]. These heavy metals have accumulative effect at the low level in drinking water and ground water.

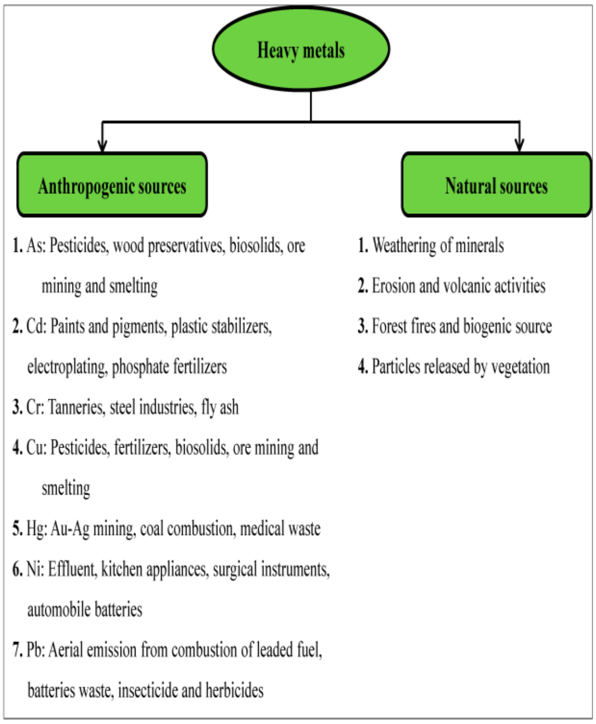

Fig 3. Different sources of Heavy metals.

VII. HEAVY METAL STATUS IN RIVER GANGA WATER AND SEDIMENTS

Extensive studies have been carried out by several researchers on heavy metal pollution of river Ganga that are given below:

Ajmal et al. studied the concentrations of cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead and zinc in the water and sediments of the river Ganga in Uttar Pradesh and reported that there was considerable variation in the elements from one sampling station to the other [28].
A similar study was also conducted in upper Ganga by Saikia et al [29].
Heavy metals distribution in the sediments and sewer-river confluence points of river Ganga in Varanasi-Mirzapur region was studied by Prasad et al [30].

Sharma et al. studied the heavy metal pollution of River Ganga in the Mirzapur region and came to the conclusion that the riverwas polluted [31]. A similar study was also conducted at Kanpur by several researchers [32-33].

Ansari et al. determined the concentrations of Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sn and Zn in sediments of the river Ganga in the Kanpur-Unnao industrial region. According to them about 90% of the contents of Cd, Cr, and Sn; 50-75% of organic carbon, Cu and Zn; and 25% of Co, Ni and Pb in sediments are derived from the anthropogenic input in relation to the natural background values [34].

Ansari et al. also studied the role of monsoon rain on concentrations and dispersion patterns of metal pollutants in sediments of the river Ganga in the Kanpur-Unnao industrial region and reported that the monsoon rain reduces the contents of Co, Cr, Fe, and Ni, and enhances the contents of Cd, Sn and Zn in sediments of post-monsoon period [35].

Khwaja et al. studied Ganga river water and sediments pollution due to tannery industries at Kanpur [36]. Singh et al. studied the heavy metals in freshly deposited stream sediments of rivers associated with urbanization of the Ganga Plain in Lucknow, Kanpur, Delhi and Agra urban centers and classified by the proposed Sediment Pollution Index as highly polluted to dangerous sediments [37].

Singh et al. studied the geogenic distribution and baseline concentration of heavy metals (Cr, Mn Fe, Co, Ni, Cu, Zn, Cd, and Pb) in the sediments of the Ganga river [38].

Dutta et al. assessed the impact of lead on water quality of river Ganga in West Bengal [39].

Chaturvedi et al. analyzed physico-chemical parameters as well as few toxic metals of river Ganga at Vindhyachal Ghat of Varanasi. According to their study, this site was polluted and the water is not suitable for domestics, irrigation and other purposes [40].

Nath and Banerjee assessed pollution of Ganga River considering the heavy metals (Cu, Pb, Cd, and Zn) in water, soil, benthic macro invertebrates (Thiara lineate) and fish (Rita rita). The overall study reveals that the Ganga River is moderately polluted [41].

Purushothaman et al. assessed the heavy metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, and Pb) associated with different chemical fractions of sediments of the river Ganga [42]. Sarkar et al. also analyzed the level of dissolved heavy metals such as Fe, Zn, Mn, Cu, Pb, Hg at three ecologically distinct zones along the course of the river Ganga- Babughat, Diamond Harbour and Gangasagar in West Bengal and reported high values for Hg and Pb which can be attributed to the discharge from pulp and paper manufacturing units and to atmospheric input and runoff of automobile emission [43].

Sinha et al. studied mercury pollution in the Ganga River system at Varanasi. Their study on mercury describes its presence and variation in different biotic and abiotic components of the river system [44].

Beg et al. studied the sediment quality mainly trace metals from upstream and downstream area of Ganga river at Kanpur city where effluents from tannery industries are discharged and reported that Cr in downstream sediment was 30% higher than in upstream sediment and its concentration was above the probable effect level [45].

Bhattacharya et al. studied the accumulation of heavy metals in water, sediment, and tissues of different edible fishes at Rishra-Konnagar region situated on the upper stretch of Gangetic West Bengal during 2006-2007. According to them the concentration of Zn, Cr, Cu, Cd, and Pb in sediment and water as well as in commercially edible fish samples at the sampling station exhibited a unique seasonal oscillation [46]. The concentrations of heavy metals follow the trend: Zn > Cr > Cu > Cd >Pb.

Kar et al. analyzed various heavy metals such as Fe, Mn, Zn, Cu, Cd, Cr, Pb and Ni from the surface water samples of river Ganga in West Bengal and found a significant seasonal variation for Fe, Mn, Cd, and Cr. The presence of different studied heavy metals in the surface water of the river Ganga followed the sequence: Fe >Mn> Ni > Cr >Pb> Zn >Cu >Cd [47].

Gupta et al. studied the occurrence and bioaccumulation of several heavy metals (Cu, Cr, Cd, Pb, Zn) in the river water, sediment, and the muscles of two catfish species procured from the river Ganga at Allahabad. According to them the order of occurrence of different heavy metals to be Zn >Pb> Cu > Cr > Cd, respectively. The heavy metals analysis in sediment indicated that among the five heavy metals, Zn was maximally accumulated followed by Pb, Cu, Cr, and Cd [48].

The impact of effluents discharged in Ganga through various sources on chemical composition, energy transformation rate and level of heavy metals was studied at Kanpur and Varanasi by Kumar et al. According to them the level of heavy metals (Cu, Cr, Cd, Pb and Zn) showed higher values in the effluents, at the discharged point and considerable improvement was observed below the discharge zone [49].

Pandey et al. investigated heavy metal contamination of Ganga river in relation to atmospheric deposition and revealed that although levels of Cr and Cu remained below their maximum admissible concentrations, levels of Cd and Pb in mid-stream waters at five out of six sampling stations were higher than their respective maximum admissible concentration [50].

Purkait et al. assessed the impact of various parameters including heavy metals, polluting Ganga water in Kolkata region[51].

Aktar et al. analyzed the heavy metal concentrations (Fe, Mn, Cu, Zn, Pb, Cd, Cr, and Ni) of surface water at four different locations of the river Ganga around Kolkata and evaluated that the studied heavy metals showed no significant variation with respect to sampling sites as well as discharge points. However, those metals concentration varied with season, being a higher in rainy season and lower in winter season [52].

Chatterjee et al. assessed the waste metal pollution at Ganga Estuary via the East Calcutta Wetland areas [53]. Pandey et al. investigated the midstream water quality of river Ganga as influenced by aerially driven heavy metals at Varanasi. They reported that the concentrations of all the heavy metals were high in downstream sampling stations and The overall concentration of heavy metals in water showed the trend: Zn > Ni > Cr >Pb> Cu > Cd [54].

Rai et al. analyzed water samples from three sewage treatment plants which frequently release into the river Ganga at Varanasi and reported a very high concentration of heavy metals (Zn, Cu, Cd, Pb, and Cr) [55].

Sharma et al. studied the distribution of non-radioactive heavy metals (Zn, Cd, Cu, and Pb) in water of river Ganga from Rishikesh to Allahabad. Their investigation reported that at some locations concentrations of measured heavy metals were exceeding the standard limits which correspond to more anthropogenic activities [56].

Singh et al. measured the concentration of five heavy metals i.e. Cu, Cr, Zn, Ni, and Cd in water and sediments samples of river Ganga for a period of two years in Bhagalpur starting from Champanala Nathnagar to Burning ghat Barari. Based on their findings, the Ganga river sediments from Champanala to Barari can be considered as unpolluted with respect to the concentration of Cd, Cu, and Ni, whereas the concentration of Cr and Zn exhibit their pollutional status which may be harmful to the rich biodiversity of the river segment [57].

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Bhatnagar et al. studied the effect of tannery effluents on sediments of river Ganga in special reference to heavy metals at Jajmau, Kanpur and found that the heavy metal such as Cr, As, Co, Fe, Cu, Mn, Zn, Pb, Cd, and Ni were present in significantly higher concentrations. Heavy metal concentrations in sediment collected from downstream Jajmau area were higher than upstream area [58].
Pandey et al. also determined the concentration of several heavy metals such as Cr, Cu, Fe, Ni, Pb, and Zn in the water of river Ganga at Allahabad and reported that all the heavy metals at all the sampling sites were found above the permissible levels. The high concentration of these heavy metals in the study area indicated that the river is highly polluted [59].

Singh et al. investigated geochemical environment of the river sediment in the middle stretch of the river Ganga at Ghazipur, Buxar and Ballia urban centers. According to them the percentage of anthropogenic and lithogenic values of heavy metal concentration showed that Cd receives the highest value of anthropogenic addition into river water and it is followed by Cr, Cu, Zn and Co [60].

Vaseem and Banerjee investigated the heavy metal (Fe, Cr, Zn, Cu, Mn, Ni and Pb) contamination of the river Ganga and its toxic implication in the blood parameters of the major carp Labeorohita (Ham) [61].

Goswami and Sanjay determined the concentration of heavy metals viz. cadmium, copper, lead and zinc ions in the different matrices of the river Ganga from Rishikesh to Allahabad through differential pulse anodic stripping voltammetry. Their study suggested that the contamination of water and sediment at Narora Barrage and Jajmau Kanpur is alarming where the pollutants accumulated due to the point source discharges from tannery industries [62].

Kumar et al. investigated the seasonal variation of the heavy metals (Cr, Mn, Fe, Cu, Zn, and Pb) concentration in water of the river Ganga at five sites of Allahabad city and its possible effect on fish fauna. It has been observed from their study that all the parameters have more or less fluctuations mainly with seasons and sites [63].

VIII. HEAVY METAL TOXICITY

Heavy metals can bind to vital cellular components, such as structural proteins, enzymes, and nucleic acids, and interfere with their functioning [64]. Symptoms and effects can vary according to the metal or metal compound, and the dose involved. Broadly, long-term exposure to toxic heavy metals can have carcinogenic, central and peripheral nervous system, and circulatory effects.

For humans, typical presentations associated with exposure to any of the "classical" toxic heavy metals [65], or chromium (another toxic heavy metal) or arsenic (a metalloid), are shown in the table [66].

Element	Acute Exposure (usually a day or less)	Chronic Exposure (often months or years)
Chromium (Cr)	Gastrointestinal Hemorrhage (Bleeding) Hemolysis (Red Blood Cell Destruction) Acute Renal Failure	Pulmonary Fibrosis (Lung Scarring) Lung Cancer
Arsenic (As)	Nausea Vomiting Diarrhea Encephalopathy Multi-organ effects Arrhythmia Painful Neuropathy	Diabetes Hypopigmentation/Hyperkeratosis Cancer
Cadmium (Cd)	Pneumonitis (Lung Inflammation)	Lung Cancer Osteomalacia (Softening of Bones) Proteinuria (Excess protein in urine; possible kidney damage)
Mercury (Hg)	Diarrhea Fever Vomiting	Stomatitis (Inflammation of gums and mouth) Nausea3 Nephrotic Syndrome (Non-specific kidney disorder) Neurasthenia Parageusia(Metallic Taste) Pink Disease (Pain and pink discoloration of hands and feet) Tremor
Lead (Pb)	Encephalopathy (Brain dysfunction) Nausea Vomiting	Anemia Encephalopathy Foot drop/wrist drop (Palsy) Nephropathy (Kidney Disease)

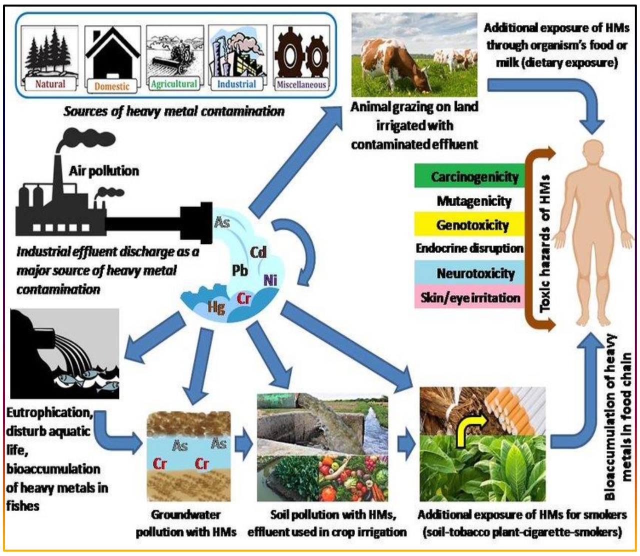

Fig 4. Different sources and effects of Heavy Metals.

IX. DISCUSSION

This review paper aimed to through light upon the present state of extent of pollution in the river Ganga due to the presence of heavy metals. Studies show that holy river Ganga is overloaded with heavy metal pollutants. Their quantities are far above the permissible levels according to national guidelines of drinking water and WHO, USEPA standards.

Ganga river water quality is not fit for daily use purpose such as drinking, bathing and Aquatic Environment. Numerous researches conducted on heavy metal pollution on this river show that the concentration of heavy metals in this river and sediment are exceeding the permissible concentrations, which penetrates the stream, through straight discharges of municipal, industrial and mining effluents as discussed in this paper.

The toxic metals are not only badly affecting the human health by causing severe diseases but also creating the imbalance of the aquatic ecosystem of river Ganga.

Since protection and management plan of River Ganga is going on a large scale by Government of India but still there is a need of attention towards other the current position of heavy metal pollution in river Ganga.

Therefore the conservation and supervision strategies are suggested for the contaminated sites of river Ganga as well as there is an urgent needed to implement the preservation and awareness plan of River Ganga at all the mentioned sites. Therefore, this river should be monitored closely and necessary actions should be taken which undoubtedly are the blessings for whole mankind especially for all the citizens of India.

X. CONCLUSION

The review study we conclude that holy river Ganga water is not fit for drinking and its basic requirement to be treated to reduce the pollutions specific heavy metals. Heavy metals extraction is a serious problem as well as very costly. Heavy metals in water cause many serious Biochemical problems in human health. Most components of electronic equipment's are made up of heavy metals.

The crude way of recycling them releases much more of the heavy metals into both the soil and the water environment. There is a need to maintain control on disposal of industrial waste in water bodies and to bio-monitor the trace elements in the water and other eatables.

The practice of trace element detection should be continued to avoid possible consumption of contaminated eatables. It is recommended that awareness should be spread among the people regarding the hazards on consumption of polluted water and related eatables.

XI. ACKNOWLEDGEMENT

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