International Journal of Research
Available at https://edupediapublications.org/journals

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

Heavy Metal Pollution of Holy River Ganga: A Review

Mahipal Singh Sankhla[1], Mayuri Kumari[2], Kirti Sharma[3], Ravindra Singh Kushwah[4], Rajeev Kumar[5]

[1]Junior Research Fellow, Department Chemical Engineering, Malaviya National Institute of Technology-MNIT, Jaipur.

[2]M.Sc. Forensic Science, Division of Forensic Science, Galgotias University, Greater Noida.

[3] M.Sc. Forensic Science, Department of Biotechnology, Baba Saheb Bhimrao Ambedkar University, Lucknow, India.

[4]Student of M.Sc. Chemistry, College of Basic and Applied Sciences, Pacific University, Udaipur.

[5]Assistant Professor, Division of Forensic Science, Galgotias University Greater Noida.

Abstract

The present Review focus on the heavy metal pollution in holy river Ganga. The Ganga river water is a source of life but contamination of water is the major threat in today's India. Multiplicity of heavy metals, some of them are potentially toxic and are relocated to the surrounding Water environment through different pathways. Water quality has become a major issue due to growing industrial development, urban development, E-Waste, wastewater irrigation and Sewage. The concentrations determined were more than the maximum admissible and desirable limit when compared with the National and International organizations like WHO, USEPA. Exposure to heavy metals has been linked to chronic & acute toxicity developing retardation, neurotoxicity, kidney damage, various cancers, liver damage, lung damage, and fragile bones and even death in instances of very high exposure. These 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.

Key-Words:- River, Pollution, Toxic, Water, Heavy Metals, etc.

Introduction

Ganga is the largest riverine system of India with well-developed ecosystem and has several important cultural, economic and environmental values. It provides water for approximately 450 million people with an over 550 individuals per square kilometer [1]. Therefore, the river water is being utilized for fishing, aquaculture, irrigation and domestic purposes, river basin for cultivation of vegetables and cereals. These activities are indispensable for the nutritional requirement and uplift of economic status of the millions of households. Ganga water is continuously degrading due to direct discharge of industrial wastes, agricultural run of and anthropogenic activity along the river bank. Such activity culminate into the accumulation of domestic, industrial and agricultural wastes in the river. These wastes contain health hazard chemicals like salts of chromium, copper, cadmium, arsenic, mercury and lead which interact with aquatic environment and affect the river ecosystem. Aquatic ecosystem of river Ganga is suffering a huge loss in terms of aquatic biodiversity. Heavy metal containing pollutants accumulate into water column, sediment and organisms like plant and animals [2]. The pollution of aquatic ecosystem by heavy metals has assumed serious proportions due to their toxicity and accumulative behavior. Unlike organic pollutants, natural processes of decomposition do not remove heavy metals. 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 [3]. 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 [4]. During latter part of the twentieth century, India witnessed rapid urban–industrial growth and increased food production to meet the requirements of rapidly growing population. As a result, the surface water bodies receive massive amount of pollutants including heavy metals. The input of heavy metals in surface waters has particular concern due to their toxic nature. After entering to water bodies, metals accumulate in water, sediments, and biota. Sediments are regarded as ultimate sink and indicator of changes in water column as well as the influence of anthropogenic activities in air and watersheds [5]. Heavy metals of anthropogenic origin enter into the rivers as inorganic complexes or hydrated ions, which are easily adsorbed on surface of sediment particles and constitute the labile fraction [6]. Environmental and ecosystem variables such as turbulence, water pH, redox potential, seasonal flooding, and storms cause periodic remobilization of contaminated surface and thereby making the bottom sediments a potential source [7]. Previous studies have shown that 30–98 % of heavy metals in rivers are transported in sediment-associated forms [8]. The length of the main channel from the traditional source of the Gangotri glacier in India is about 2550 km. 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 entersWest 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 [9]. The mean annual water discharge is the fifth highest in the earth with a mean of 18,700 m3/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 [10]. The freshwater flow in the river system is mostly from the tributaries and therefore, the water availability greatly varies from 59,000 million m3 at Allahabad, before the confluence with the Yamuna, to 459,000 million m3 at Farakka in the lower stretch [11]. 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 [12].

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 Km2 and covers a long distance about 2,525 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 CPCB's (2013) report from these cities about 2,723 million litres per day (MLD) of domestic sewage is discharged into the river8. 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 [13,14]. Although the physical appearance of river water is generally good in quality before it reaches the Ghatiya Ghat, Farrukhabad. From Ghatiya ghat (Farrukhabad) to Menhadi ghat (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 Ganga11. 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 [2].

Sources of heavy metal

"Heavy metals" is a collective term, which applies to the group of metals and metalloids with a atomic density greater than 4 g/ cm3, or 5 times or more, greater than water [15]. Heavy-metal contamination is not a modern problem arising out of industrialization e it began when humans started processing ores [16,17]. Since then the use of metals and their impacts on the environment have accelerated, with a major increase during the 19th and 20^{th} centuries [18]. Generally, most of the heavy metals enter the in river from different sources, it be can be either natural by erosion and weathering and or anthropogenic [19,20]. (Fig. 1). 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 [21,22]. [32e34]. 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 [23-24]. 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 [25,26]. These heavy metals have accumulative effect at the low level in drinking water and ground water [27].

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

Arsenic (As)	• Pesticides, fungicides, metal smelters
Cadmium (Cd)	• Welding, electroplating, pesticides, fertilizer, batteries, nuclear fission plant
Chromium (Cr)	• Mining, electroplating, textile, tannery industries
Copper (Cu)	• Electroplating, pesticides, mining
Lead (Pb)	• Paint, pesticides, batteries, automobile emission, mining, burning of coal
Manganese (Mn)	• Welding, fuel addition, ferromanganese production
Mercury (Hg)	• Pesticides, batteries, paper industries
Nickel (Ni)	• Electroplating, zinc base casting, battery industries
Zinc (Zn)	• Refineries, brass manufacture, metal plating, immersion of painted idols

Fig. 1. Sources of different heavy metals [28].

Heavy Metal position in river Ganga water and sediments

Status of heavy metal in river Ganga water and sediments Extensive studies have been carried out by several researchers on heavy metal pollution of river Ganga. 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 [29]. A similar study was also conducted in upper Ganga [30]. Heavy metals distribution in the sediments and sewer-river confluence points of river Ganga in Varanasi-Mirzapur region were also studied [31]. Studied the heavy metal pollution of River Ganga in the Mirzapur region and came to the conclusion that the riverwas polluted [32]. A similar study was also conducted at Kanpur by several researchers [33,34]. 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; 50e75% 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 [35]. 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

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

Co, Cr, Fe, and Ni, and enhances the contents of Cd, Sn and Zn in sediments of post-monsoon period [36]. Studied Ganga river water and sediments pollution due to tannery industries at Kanpur [37]. 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 [38]. 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 [39]. Assessed the impact of lead on water quality of river Ganga in West Bengal [40]. Analyzed physicochemical 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 [41]. 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) [42]. The overall study reveals that the Ganga River is moderately polluted. Assessed the heavy metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, and Pb) associated with different chemical fractions of sediments of the river Ganga [43]. 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 [44]. 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 [45]. 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-fold higher than in upstream sediment and its concentration was above the probable effect level [46]. 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 2006e2007. 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. The concentrations of heavy metals follow the trend: Zn > Cr > Cu > Cd > Pb [47]. 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 [48]. Gupta et al. [85] 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, Cr, Cu, and Cd [49]. 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, 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 [50]. 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 [51]. Assessed the impact of various parameters including heavy metals, polluting Ganga water in Kolkata region [52]. 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 [53]. Assessed the waste metal pollution at Ganga Estuary via the East Calcutta Wetland areas [54]. 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 [55]. 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) [56].

Heavy Metal Toxicity

Humans have evolved in the presence of metals and are adapted to various levels of essential and non-essential metals. Metals from dietary intake and environmental exposure eventually reach their target organs (brain, liver and kidney). The fate of metal inside the body is determined by its ability to modify these systems. Excess metals in body are excreted through urine and faeces or accumulated in various tissues. At higher concentrations metals become toxic. Some metals act additively when they are present together, others act independently of each other, and still others are antagonistic or synergistic [57]. In general, lipophilic metal species are absorbed more readily than hydrophilic ones. Absorption may vary dramatically for different forms of the same metal, for the same form of metal in different matrices, among different species, and across different routes of exposure [58]. The distribution of metals reflects their transport and accumulation in the body within tissues, blood or plasma, or other extracellular space. Retention in tissues of metals or metal compounds generally is related to formation of inorganic complexes or metal protein complexes Metal binding to proteins is capacity-limited, and toxicity to target organs occurs when the binding capacity is exceeded [59].

Discussion

These Review paper 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. The Toxic of waste in contained in water and Sediment heavy metals make them a big risk to human health. Heavy metals scattering showed different points of toxic pollution and a consistently rising trend downstream, representing strong impact of local sources including agricultural and natural urban–industrial wastewater. may be due to the other sources such as pharmaceutical industries waste & stabilizing dyes used in the paint industry.

Concussion

The review study we conclude that holy river Ganga water is maybe 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 causes 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.

References

[1] Behera S., Areendran G., Gautam P. and Sagar V. (2011). For a living Ganga–working with people and aquatic species. New Delhi, WWF-India, 1-84.

[2] Varsha Gupta et.al; "Risk assessment of heavy metal pollution in middle stretch of river Ganga: an introspection", International Research Journal of Environment Sciences, ISSN 2319–1414 Vol. **6(2),** 62-71, February **(2017).**

[3] Suresh Prasad and D. C. Ruapanwar, Separation of Selected Heavy Metals from Bank Sediment of River Ganga by Solvent Extraction, Pollution Research, **9(1-4)**, 15-21 (1990).

[4] K. R. Beg and S. Ali, Chemical Contamination and Toxicity of Ganga River Sediment from up and Down Stream Area at Kanpur, American J. Environ. Sci., **4(4)**, 362-366 (2008).

[5] Ramesh R, Subramanian V, Grieken RV (1990) Heavy metal distribution in sediments of Krishna River basin. Environ Geol Water Sci 15:207–216.

[6] Vukovic D, Stankovic SJ, Vukovic Z, Jankoviv K (2014) Transport and storage of heavy metals in the Sava River Basin in Serbia. J Serbian Chem Soc 79(3):379–387.

[7] Osakwe JO, Adowei P, Jnr MH (2014) Evaluation of heavy metal species in bottom sediments from Imo River system, Southeastern Nigeria. Res J Chem Sci 4(6):23–30.

[8] Wang Y, Yang Z, Shen Z, Tang Z, Niu J, Gao F (2011) Assessment of heavy metals in sediments from a typical catchment of the Yangtze River, China. Environ Monit Assess 172(1–4):407–417.

[9] M.M. Rahaman, Integrated Ganges basin management: conflict and hope for regional development, Water Policy 11 (2009) 168e190.

[10] U.K. Sarkar, A.K. Pathak, R.K. Sinha, R. Sivakumar, A.K. Pandian, A. Pandey, V.K. Dubey, W.S. Lakra, Freshwater fish biodiversity in the river Ganga (India): changing pattern, threats and conservation perspectives, Rev. Fish. Biol. Fish. 22 (2012) 251e272.

[11] D.M. Joshi, A. Kumar, N. Agrawal, Assessment of the irrigation water quality of

river Ganga in Haridwar district, Rasayan J. Chem. 2 (2009) 285e292.

[12] K.K. Vass, S.K. Mondal, S. Samanta, V.R. Suresh, P.K. Katiha, The environment and fishery status of the River Ganges, Aquat. Ecosyst, Health Manag. 13 (2010) 385e394.

[13] Tare V., Yadav A.V.S. and Bose P. (2003). Analysis of photosynthetic activity in the most polluted stretch of river Ganga. *Water Res.*, 37(1), 67-77.

[14] Singh M., Muller M.G. and Singh I.B. (2003). Geogenic distribution and baseline concentration of heavy metals in sediments of the Ganges River Indian. *J. of Geochem. Exp.,* 80(1), 1-17.

[15] J.S. Hawkes, What is a “heavy metal”, J. Chem. Educ. 74 (1997) 1374.

[16] I. Renberg, M.W. Persson, O. Emteryd, Pre-industrial atmospheric lead contamination detected in Swedish lake sediments, Nature 368 (1994) 323e326.

[17] M. Sharma, H. Tobschall, I. Singh, Environmental impact assessment in the Moradabad industrial area (rivers Ramganga-Ganga interfluve), Ganga Plain, India, Environ. Geol. 43 (2003) 957e967.

[18] U. F €orstner, G. Wittman, Metal Pollution in the Aquatic Environment, Springer-Verlag, New York, 1983.

[19] N. Gupta, K.K. Yadav, V. Kumar, D. Singh, Assessment of physicochemical properties of Yamuna river in Agra city, Int. J. Chem. Tech Res. 5 (2013) 528e531.

[20] V. Sheykhi, F. Moore, Environmental risk assessment of heavy metals pollution in aquatic ecosystem-a case study: sediment of Kor river, Iran, Hum. Ecol. Risk. Assess. 22 (2016) 899e910.

[21] A. Kabata-Pendias, Trace Elements in Soils and Plants, CRC Press, Boca Raton, Florida, USA, 2001.

[22] R. Dixit, D. Malaviya, K. Pandiyan, U.B. Singh, A. Sahu, R. Shukla, B.P. Singh, J.P. Rai, P.K. Sharma, H. Lade, D. Paul, Bioremediation of heavy metals from soil and aquatic environment: an overview of principles and criteria of fundamental processes, Sustainability 7 (2015) 2189e2212.

[23] Y. Wang, Z. Yang, Z. Shen, Z. Tang, J. Niu, F. Gao, Assessment of heavy metals in sediments from a typical catchment of the Yangtze river, China, Environ. Monit. Assess. 172 (2011) 407e417.

[24] R.Y. Capangpangan, N.K. Pagapong, C.P. Pineda, P.B. Sanchez, Evaluation of potential ecological risk and contamination assessment of heavy metals in sediment samples using different environmental quality indicesea

case study in Agusan river, Caraga Philippines, J. Biodiver. Environ. Sci. 8 (2016) 1e16.

[25] S. Suthar, A.K. Nema, M. Chabukdhara, S.K. Gupta, Assessment of metals in water and sediments of Hindon river, India: impact of industrial and urban discharges, J. Hazard. Mater 171 (2009) 1088e1095.

[26] S. Sindern, M. Trem€ohlen, L. Dsikowitzky, L. Gronen, J. Schwarzbauer, T.H. Siregar, F. Ariyani, H.E. Irianto, Heavy metals in river and coast sediments of the Jakarta Bay region (Indonesia)-geogenic versus anthropogenic sources, Mar. Pollut. Bull. 110 (2016) 624e633.

[27] S. Prabha, P. Selvapathy, Toxic metal pollution in Indian Rivers, Indian J. Environ. Prot. 17 (1997) 641e649.

[28] Dipak Paul, "Research on heavy metal pollution of river Ganga: A review", B-7/21(S), Kalyani 741235, West Bengal, India, Annals of Agrarian Science 15 (2017) 278e286.

[29] M. Ajmal, A.A. Nomani, M.A. Khan, Pollution in the ganges river, India, Water Sci. Technol. 16 (1984) 347e358.

[30] D.K. Saikia, R.P. Mathur, S.K. Srivastava, Heavy metals in water and sediments of upper Ganga, Indian J. Environ. Hlth 30 (1988) 11e17.

[31] S. Prasad, A. Mathur, D.C. Rupaniwar, Heavy metal distribution in the sediment and river confluence points of river Ganga in VaranasieMirzapur region, Asian Environ. 11 (1989) 73e82.

[32] Y.C. Sharma, G. Prasad, D.C. Rupainwar, Heavy metal pollution of river Ganga in Mirzapur, India, Int. J. Environ. Stud. 40 (1992) 41e53.

[33] N. Garg, N. Mathur, D.P. Modak, K.P. Singh, R.C. Murthy, S. Ahmed, S.V. Chandra, P.K. Ray, Trace metals trend analysis in river Ganges at Kanpur, Environ. Int. 18 (1992) 297e305.

[34] R.P. Singh, G. Dayal, A. Taneja, C.K. Kapoor, Enrichment of Zn, Cd, Pb, and Cu, in the surface micro layer of river Ganga along Kanpur city, Poll. Res. 12 (1993), 261e165.

[35] A.A. Ansari, I.B. Singh, H.J. Tobschall, Status of anthropogenically induced metal pollution in the Kanpur-Unnao industrial region of the Ganga Plain, India, Environ. Geol. 38 (1999) 25e33.

[36] A.A. Ansari, I.B. Singh, H.J. Tobschall, Role of monsoon rain on concentrations and dispersion patterns of metal pollutants in sediments and soils of the Ganga Plain, India, Environ. Geol. 39 (2000) 221e237.

[37] A.R. Khwaja, R. Singh, S.N. Tandon, Monitoring of Ganga water and sediments vis-a-vis tannery pollution at Kanpur (India): a case study, Environ. Monit. Assess. 68 (2001) 19e35.

[38] M. Singh, G. Müller, I.B. Singh, Heavy metals in freshly deposited stream sediments of rivers associated with urbanisation of the Ganga plain, India, Water Air Soil Poll. 141 (2002) 35e54.

[39] M. Singh, G. Müller, I.B. Singh, Geogenic distribution and baseline concentration of heavy metals in sediments of the Ganges River, India, J. Geochem. Explor 80 (2003) 1e7.

[40] S. Dutta, R.K. Kole, S. Ghosh, D. Nath, K.K. Vass, Impact assessment of lead on water quality of river Ganga in West Bengal, India, Bull. Environ. Contam. Toxicol. 75 (2005) 1012e1019.

[41] J. Chaturvedi, N.K. Pandey, Physico-chemical analysis of river Ganga at Vindhyachal ghat, Curr. World Environ. 1 (2006) 177e179.

[42] A.K. Nath, S. Banerrjee, In-situ accumulation of heavy metals in the Ganga river system-an overview, Ecol. Environ. Conserv. 12 (2006) 435e440.

[43] P. Purushothaman, G.J. Chakrapani, Heavy metals fractionation in Ganga river sediments, India, Environ. Monit. Assess. 132 (2007) 475e489.

[44] S.K. Sarkar, M. Saha, H. Takada, A. Bhattacharya, P. Mishra, B. Bhattacharya, Water quality management in the lower stretch of the river Ganges, east coast of India: an approach through environmental education, J. Clean. Prod. 15 (2007) 1559e1567.

[45] R.K. Sinha, S.K. Sinha, D.K. Kedia, A. Kumari, N. Rani, G. Sharma, K. Prasad, A holistic study on mercury pollution in the Ganga river system at Varanasi, India, Curr. Sci. 92 (2007) 1223e1227.

[46] K.R. Beg, S. Ali, Chemical contaminants and toxicity of Ganga river sediment from up and down stream area at Kanpur, Am. J. Environ. Sci. 4 (2008) 362e366.

[47] A.K. Bhattacharya, S.N. Mandal, S.K. Das, Heavy metals accumulation in water, sediment and tissues of different edible fishes in upper stretch of Gangetic West Bengal, Trends Appl. Sci. Res. 3 (2008) 61e68.

[48] D. Kar, P. Sur, S.K. Mandai, T. Saha, R.K. Kole, Assessment of heavy metal pollution in surface water, Int. J. Environ. Sci. Technol. 5 (2008) 119e124.

[49] A. Gupta, D.K. Rai, R.S. Pandey, B. Sharma, Analysis of some heavy metals in the riverine water, sediments and fish from river Ganges at Allahabad, Environ. Monit. Assess. 157 (2009) 449e458.

[50] A. Kumar, D. Jaiswal, G. Watal, Studies on chemical composition and energy transformation in river Ganga at Kanpur and Varanasi due to environmental degradation, J. Environ. Biol. 30 (2009) 445e450.

[51] J. Pandey, K. Shubhashish, R. Pandey, Metal contamination of Ganga river (India) as influenced by atmospheric deposition, Bull. Environ. Contam. Toxicol. 83 (2009) 204e209.

[52] S. Purkait, M. Ganguly, M.W. Aktar, D. Sengupta, A. Chowdhury A, Impact assessment of various parameters polluting Ganga water in Kolkata region: a study for quality evaluation and environmental implication, Environ. Monit. Assess. 155 (2009) 443e454.

[53] M.W. Aktar, M. Paramasivam, M. Ganguly, S. Purkait, D. Sengupta, Assessment and occurrence of various heavy metals in surface water of Ganga river around Kolkata: a study for toxicity and ecological impact, Environ. Monit. Assess. 160 (2010) 207e213.

[54] S. Chatterjee, B. Chattopadhyay, S.K. Mukhopadhyay, Monitoring waste metal pollution at Ganga estuary via the East Calcutta wetland areas, Environ. Monit. Assess. 170 (2010) 23e31.

[55] J. Pandey, K. Shubhashish, R. Pandey, Heavy metal contamination of Ganga river at Varanasi in relation to atmospheric deposition, Trop. Ecol. 51 (2010) 365e373.

[56] P.K. Rai, A. Mishra, B.D. Tripathi, Heavy metal and microbial pollution of the river Ganga: a case study of water quality at Varanasi, Aquat. Ecosyst. Health. Manag. 13 (2010) 352e361.

[57] Khan RR (2001). Environment and Metal Pollution, ABD Publishers, Jaipur, India. Pp 66-67.

[58] Walker CH, Hopkin SP, Sibly RM and Peakall DB (2001). Principles of Ecotoxicology, Taylor and Francis, London. Pp 62-85.

[59] Newman MC (2010). Fundamentals of Ecotoxicology, CRC Press, New York. PP.73-96.