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Heavy Metal Pollution in River Ganga: A Review

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ABSTRACT

River Ganga is considered sacred by people of India for providing life sustenance to environment and ecology. Anthropogenic activities have generated important transformations in aquatic environments during the last few decades. Advancement of human civilization has put serious questions to the safe use of river water for drinking and other purposes. The river water pollution due to heavy metals is one of the major concerns in most of the metropolitan cities of developing countries. These toxic heavy metals entering the environment may lead to bioaccumulation and biomagnifications. These heavy metals are not readily degradable in nature and accumulate in the animal as well as human bodies to a very high toxic amount leading to undesirable effects beyond a certain limit. Heavy metals in riverine environment represent an abiding threat to human health. Exposure to heavy metals has been linked to developmental retardation, kidney damage, various cancers, and even death in instances of very high exposure.

KEYWORDS: heavy metal, pollution, ganga, river, human, civilization, exposure

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INTRODUCTION

To assess the risk on human health, heavy metal contamination was analysed from surface water in the Upper Ganga river, India. Spatial and seasonal distribution of Fe, Mn, Zn, Cr and Pb was evaluated at eight sites during pre-monsoon and post-monsoon season of 2017. Average concentration of heavy metals was high, often exceeding the limits prescribed for surface water by Bureau of Indian Standard (BIS) and the World Health Organization (WHO). Based on heavy metal pollution index (HPI), 87% of the river stretch was classified as medium to highly polluted. Simultaneous assessment of the health risk employing chronic daily intake (CDI) and hazard quotient (HQ) indicates that exposure through ingestion and dermal pathways currently poses no serious threat to human health (CDI < 1, HQ < 1). For the two population groups analysed, $HQ_{Ingestion}$ values for Cr (adults 0.51, child 0.55) and Pb (adult 0.31, child 0.34) were significantly higher as compared with other heavy metals. $HI_{Ingestion}$ varied from 0.85 to 1.64 for adult and 0.92 to 1.77 for child group, indicating health risk to both groups with child group being more risk prone from either of the exposure pathways. In addition, HI values revealed an increased risk to health for both groups during the post-monsoon season. Higher hazard index (HI) values (> 1) in the Upper Ganga river indicate an ever-increasing non-carcinogenic risk to the exposed population within the riverine landscape. The study highlights the impact of heavy metals in degrading the water quality of the Upper Ganga river and also advocates immediate attention towards reducing human health risk.[1]

Twelve sampling stations were selected along a 20 km long stretch of the river. Mid stream sub-surface water samples collected at fortnightly intervals from all the sites were acid digested and analyzed for Cd, Cr, Cu, Ni, Pb and Zn. The data revealed that the mid-stream water of river Ganga at Varanasi is invariably contaminated by heavy metals. Highest concentrations of Cd, Cr, Cu, Ni and Pb were recorded during winter and that of Zn during summer season. The overall concentration of heavy metals in water showed the trend : Zn > Ni > Cr > Pb > Cu > Cd. Concentrations of all the heavy metals were high in down - stream sampling stations. Correlation analysis showed that heavy metal concentration in mid-stream water had significant positive relationship with rate of atmospheric deposition at respective sites. Although the concentrations of these metals in water remained below the permissible limits of Indian standards for drinking water, levels of Cd, Ni and Pb at three stations, were above the internationally recommended (WHO) maximum admissible concentrations (MAC). These observations suggest that use of such water for drinking may lead to potential health risk in long-run.

Understanding how dissolved trace elements chemically evolve in the Ganga River from source to sink is important to understand subcatchment contributions and chemical variability across space and time but remains poorly constrained. What exists is site-specific data sets that are focused on capturing contamination “hotspots.”[2] Here, we present riverine trace element concentrations of 38 targeted locations in the Ganga Basin. Samples in the headwater and the upstream segments of the river were collected during the premonsoon, monsoon, and postmonsoon seasons of 2014, 2015, and 2016, and the downstream samples were collected in 2016. In addition, monthly time-series samples were collected at a downstream site to capture the geochemical variability at a higher temporal-resolution. To evaluate the geogenic contributions, groundwater, rainwater, snow, glacier-ice, and sediment samples were also analyzed. We find that the river chemistry displays a wide spatio-temporal variability. Headwater samples are characterized by high concentrations of trace elements that are primarily controlled by ice meltwater, intense weathering, and interactions with glacial flour and are therefore geogenic in nature. Moreover, high concentrations of trace metals were also observed in a few localized downstream sites. However, such enriched signals are not persistent further downstream as they get diluted by the joining of large tributaries.[3] We show that the dissolved trace element concentrations in the Ganga River are low compared to existing datasets and are comparable to the global average river water composition

A study on the heavy metal pollution of River Ganga in the Mirzapur region, India has revealed that the river is polluted. The samples were collected from both the confluence of sewers and the river and from midstream points. The river is the dumping ground for domestic, municipal and industrial effluents. All the samples were analysed for certain physiochemical parameters i.e. temperature, pH, chloride content, alkalinity, dissolved oxygen and chemical oxygen demand.

On analysis, the concentrations of most of the heavy metal ions were found to be above the prescribed limits for potable waters in the samples collected from confluence points. Cadmium and cobalt were in the range 13.37–32.73 µg/L and 10.50–26.77 µg/L respectively. Copper, iron and manganese were found in the range of 38.0–157.80 µg/L, 19.75–72.77 /ug/L and 34.25–105.55 yug/L respectively. Nickel was recorded to be in the range 67.25–176.13 mg/L while lead and zinc were in the range of 34.25–185.75 µg/L and 94.25–423.75 µg/L. Concentrations of all these ionic species were within the prescribed limits in the samples collected from midstream points, revealing the river to be almost free from pollution at these points. The data obtained have been examined statistically[4] to explain metal-metal association by using the Pearson correlation coefficient. Cobalt, manganese, nickel, lead and zinc reflected positive correlations with most of the species. However cadmium, copper and iron show very weak or negative association with metal ions.

Discussion

The Ganga, is one of the most sacred and worshipped river of India, is regarded as the cradle of Indian civilization. The major objectives of the present study were to investigate heavy metal's concentration in water and sediments of the River Ganga along the different locations of patna city viz gai ghat, kali ghat, naujar ghat. Water and sediments collected from four locations were analysed for Iron (Fe), Chromium (Cr), Cadmium (Cd), Lead (Pb) and Manganese (Mn) with Atomic Absorption Spectrophotometer. Contamination Factor (CF), Contamination Degree (CD), Pollution Load Index (PLI) were used to assess the degree of accumulation of heavy metals in sediments. Anthropogenic activities have generated important transformations in aquatic environments during the last few decades. Human civilization has put serious questions to the safe use of river water for drinking and other purposes. The river Ganga water pollution due to heavy metals is one of the major concerns in most of the metropolitan cities of developing countries. [5]

The Ganga is the largest river in India with an extraordinary religious importance for Hindus. Situated along its banks are some of the world's oldest inhabited cities like Kanpur and Varanasi. The total stretch is 2525 km from Gangotri up north to Kolkata on east provides water to about 40% of India's population across 11 states serving an estimated population of around 500 million people, which is larger than any other river in the world in terms of dependence of natural source. It provides ecosystem services which are of vital importance for the inhabitants of the Ganges river basin. Anthropogenic activities have generated important transformations in aquatic environments during the last few decades.[6] Advancement of human civilization has put serious questions to the safe use of river water for drinking and other purposes. The water quality of the Ganges River deteriorates downstream. The river water pollution due to heavy metals is one of the major concerns in most of the metropolitan cities of developing countries. Indian cities, e.g., Kanpur and Varanasi, are local hotspots of pollution and poor water quality. Downstream of these cities the river's water quality improves, but never restores to its original state. These toxic heavy metals entering the environment may lead to bioaccumulation and biomagnifications. These heavy metals are not readily degradable in nature and accumulate in the animal as well as human bodies to a very high toxic amount leading to undesirable effects beyond a certain limit. Heavy metals in riverine environment represent an abiding threat to human health. Exposure to heavy metals has been linked to developmental retardation, kidney damage, various cancers, and even death in instances of very high exposure.[7]

The samples of Ganga canal water were collected from five sampling sites namely Bhimgoda Barrage, Haridwar (origin point); Premnagar Ashram Ghat, Haridwar; Pathari Power Plant, Bahadrabad; Rail Bridge, Roorkee and Uttam Sugar Mills Limited, Narsan (exit point). The samples were analyzed for seven metals viz., copper, manganese, cadmium, lead, zinc, chromium and iron in Ganga canal water monthly during March, 2014 to August, 2014. The concentration of manganese was found greater than its desirable limit (0.1 mg/L), while iron was observed more than its permissible limit (0.3 mg/L) according to Bureau of Indian Standards (BIS) specifications. The water quality data was further analyzed using analysis of variance (ANOVA) for monthly and spatial variations. The ANOVA analysis revealed that the contents of different metals such as copper, manganese, lead, zinc, chromium and iron were found statistically significant ($P \leq 0.05$) as per temporal study. These monthly variations in Ganga Canal water quality parameters might be ascribed due to the anthropogenic and hydro-geological activities. However, none of the metals showed significant site variation at any of the sampling site of Ganga Canal.

Water quality assessment and regular monitoring of Ganga canal water between origin and exit points at Uttarakhand is essential in order to determine level of metals in its water and subsequently, to adopt corrective and preventive actions to avoid from further deterioration of its quality. Out of seven metals, only one metal i.e. manganese exceeded its desirable limit (0.1 mg/L), whereas iron was found more than its respective permissible limit (0.3 mg/L) as per BIS standards. This might be ascribed due to geo-genic activities and discharge of untreated/ partially treated consumer waste into Ganga canal water. ANOVA showed that any of the analyzed water quality parameter does not show significant site variation at any site of Ganga Canal. Contrary to this, a total of eight metals such as calcium, copper, magnesium, manganese, lead, zinc, chromium and iron were found statistically significantly ($P \leq 0.05$) different as per monthly investigation. These variations in water quality parameters of Ganga canal might be attributed mainly due to the anthropogenic and hydro-geological activities. Therefore, anthropogenic and hydro-geological activities should be prevented to avert the contamination of heavy metals in the water of Ganga canal at Haridwar Parameter (Uttarakhand), India.[8]

The entry of contaminants into the environment due to human and natural activities is one of the most important issues facing today's communities. Due to the industrial and economic growth and the production of a variety of compounds and chemicals followed by increased consumption man makes some unwanted pollutants, many of which cause serious problems and risks for the environment and for man himself. The most important natural resources of environmental pollution are soil and rock weathering and natural events such as earthquakes and floods. The term "heavy metal" is not altogether clearly defined, but in the case of water pollution, these are metals such as arsenic, cadmium, iron, cobalt, chromium, copper, manganese, mercury, molybdenum, nickel, lead, selenium, vanadium and zinc. While heavy metals do tend to have a high atomic mass, and so are heavy in that sense, toxicity seems to be a further defining factor. Heavy metals occur in he earth's geological structures, and can therefore enter water resources through natural processes. For example, heavy rains or flowing water can leach heavy metals out of geological formations. Such processes are exacerbated when this geology is disturbed by economic activities such as mining. These processes expose the mined-out area to water and air, and ca n lead to consequences such as acid mine drainage (AMD). The low pH conditions associated with AMD mobilise heavy metals, including radio-nuclides where these are present. Mineral processing operations can also generate significant heavy metal pollution, both from direct extraction processes (which typically entail size reduction - greatly increasing the surface area for mass transfer - and generate effluents) as well as through leaching from ore and tailings stockpiles. mining activity poses significant risks for heavy metal pollution, this sector is not the only culprit in the industrial sector. Many industrial processes can generate heavy metal pollution, and in a large number of ways. Clearly, some industries will be more likely to pollute than others. Hence the electroplating industry,[9] which can produce large volumes of metal-rich effluents, will naturally be a more likely polluter than the food processing industry, for example. This is not to say that players in this industry will necessarily pollute, and it is in fact in the electroplating industry's best economic interests to minimise metal discharges, since these are inversely proportional to resource efficiency. Reducing losses by minimising drag-out from plating baths leads to reduced metal discharges, for example. The lead-acid battery manufacturing industry is another example of an industry which can generate metal-rich effluents as well as airborne lead pollution which can subsequently be deposited in surface water resources (and of course on land). So clearly, where an industry uses heavy metals as key input materials, pollution risks increase. An example of a large non-point source of heavy metal pollution is coal-fired power generation, which can contaminate water resources through aerial deposition of mercury emitted from boiler flues. Technologies such as wet scrubbing are available to remove much of this mercury, but of course the effluents produced have to be safely handled to prevent subsequent pollution. Some of these processes have the primary goal of removing sulphur dioxide, with heavy metal removal a welcome by-product of the scrubbing process

Results

The results of the analysis of water and sediment samples in upstream and downstream of the river revealed that the mean concentration of Cd, Cr, Cu, Fe Mn, Pb, and Zn in the downstream water was higher than that in the upstream water in different seasons. the effect of the entry of sewage untreated municipal sewage, runoff, abattoir wastewater, and leachate of solid wastes around the river ganga the concentration of Cd, Cr, Mn, and Ni in this ganga river is higher than the stated standard level for it, and that its water is harmful to the human health . These results show the effect of dry seasons and water evaporation on concentration increase of heavy metals in water. Their research that dry seasons affect the accumulation of heavy metals in water and its reared fish. The seasonal distribution of Cd, Cr, Cu, Ni, and Pb varies seasonally. heavy metals in the River ganga water with the standard value in drinking water and those in the water used for agriculture for aquatic life and surface water standards suggests that the mean concentration of Cu within the standard range for drinking water and the mean concentrations of Mn and Cd within the standard range of agricultural water. the mean concentrations of Zn within the standard range for all three kinds of water. In River ganga water is not suitable for drinking and aquatic life. Mean concentrations of Cd, Cr, Mn, and Pb were higher than surface water standards. [6] The River ganga downstream have increased in comparison with those in its upstream. The maximum and minimum levels of concentration are related to Mn in downstream and Cd in upstream areas, respectively. Regarding the rise in the concentrations of these metals in downstream water, the higher concentrations in downstream sediment are very reasonable. In fact; increased heavy metals concentration in water in downstream lead to increasing of their concentration in sediment in downstream. The sediments of the river upstream, where the sewage enters River Ganga, changes similarly in four seasons. The average concentration of metals in sediments in Autumn and Winter is lower than that in Summer. These amounts rise again when Summer starts. The amounts of heavy metals in sediment varied seasonally as follows:

Summer season>Winter season> Spring season

The cause of these changes was high rain in rainy season and Winter season which gives rise to flow of the water in the river ganga. Due to the turbulence created by increase of flow, some sediments and heavy metals inside them are displaced and carried away from the river bed. As Summer starts, the rise in temperature and evaporation and the end of the rain period cause the rise in heavy metals concentration in water and finally in sediments because metal ions transfer from water to sediment. The seasonal variation of distribution of Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in the sediment, these metals with the standards for fresh water sediments indicates that, except Zn, the mean concentrations of Cd, Cr, Cu, Ni, and Pb were higher than the standards for fresh water sediments while only the mean concentrations of Cd in marine sediments were higher than the standards. The levels of various heavy metals in the river

Ganga water and sediment are far above the acceptable concentrations. The metals enter the environment through aquatic life systems and plants and animals surrounding the river. The hazard of bioaccumulation and bio-magnification of the heavy metals make them a big risk to human health.[7]

Conclusions

Pollution of the Ganges, the largest river in India, poses significant threats to human health and the larger environment. The river, which is severely polluted with human waste and industrial contaminants, provides water to about 40% of India's population across 11 states, serving an estimated population of 500 million people, which is more than any other river in the world.Today, the Ganges is considered to be the fifth-most polluted river in the world. Raghubir Singh, an Indian photographer, has noted that no one in India spoke of the Ganges as being polluted until the late 1970s. However, pollution had been an old and continuous process in the river by the time people were finally acknowledging it. Stretches of over 600 km (370 mi) were essentially ecologically dead zones.

A number of initiatives were undertaken to clean the river, but failed to deliver significant results. After getting elected, India's Prime Minister Narendra Modi affirmed to work on cleaning the river and controlling pollution. Subsequently, the Namami Ganga project was announced by the government in the June 2014 budget. An estimated Rs 3,000 crores (US$460 million) had been spent by July 2016 in various efforts to clean up the river. Because of the establishment of a large number of industrial cities on the bank of the Ganges like Kanpur, Prayagraj, Varanasi and Patna, countless tanneries, chemical plants, textile mills, distilleries, slaughterhouses, and hospitals prosper and grow along with this and actively play a role in polluting the Ganges by dumping untreated waste into it. One coal-based power plant on the banks of the Pandu River, a Ganges tributary near the city of Kanpur, burns 600,000 tons of coal each year and produces 210,000 tons of fly ash. The ash is dumped into ponds from which a slurry is filtered, mixed with domestic wastewater, and then released into the Pandu River. [8] Fly ash contains toxic heavy metals such as lead and copper. The amount[2] of parts per million of copper released in the Pandu before it even reaches the Ganga is a thousand times higher than in uncontaminated water. Industrial effluents are about 12% of the total volume of effluent reaching the Ganges. Although a relatively low proportion, they are a cause for major concern because they are often toxic and non-biodegradable. Plastic and industrial waste, such as wastewater from the factories that sit on the banks of the Ganga, is another cause of pollution. The most worrying problem facing the river is its increasing lack of water. Water for irrigation is being removed faster than the rainy season can replenish it.[9]

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