Heavy metal pollution and potential ecological risks in the riverine ecosystem: a review

Siddharthasankar Banerjee,
Department of Zoology, Burdwan Raj College, Post- Rajbati, Dist.- Purba Bardhaman, PIN-713104, West Bengal, India.

Abstract:

Assessment of hydrochemical characteristics of the riverine ecosystem is very much significant for water resources protection and sustainable utilization. The natural processes as well as anthropogenic activities and industrialization in the catchment area influence water quality. Heavy metals are well-known environmental pollutants due to their huge toxicity, persistence in the environment, and are dangerous because they tend to bio accumulate. Many of them have their toxic effects on man and aquatic environment and further which can affect the biological and ecological cycles. Monitoring and analysis of heavy metal concentrations in the reverine environment are necessary for pollution assessment and control in this ecosystem. This study would provide an illumination highlighting the impacts of levels of these metals in the water, sediment and aquatic environment contributing to the effective monitoring both quality and the health of the organisms inhabiting the riverine ecosystem. This article comprehensively reviews the different aspects of these metals as hazardous materials with special focus on their effect as pollutant and potential risk in the reverine ecosystem.

Key words: Heavy metals, risk, impact, reverine ecosystem.

1. Introduction

The chemistry of the river waters and sediments depends upon both natural processes as well as anthropogenic activities. The natural processes including precipitation, weathering of rocks, and sediment transport as well as anthropogenic activities like urban development and industrialization in the catchment area influence water quality. Increasing industrial activity has continuously introduced pollutants along with heavy metals into the riverine system and various workers have attempted to assess chemical nature of metals and inorganic toxicants in this regard (Silveira *et al.,* 2006; Farkas *et al.,* 2007). Such types of anthropogenic activities can alter the relative contributions of the natural causes of variations and also introduce the effects of pollution. The impact of point source pollution from industrial activities in rivers can be localized and well-defined, whereas the influence of non-point pollution from agricultural activities is less obvious because of the poorly defined origins, volume, and frequency of loading. Regardless of origin, both the source loads typically find their way to the rivers and streams potentially leading to substantive environmental pollution (Carpenter, 1998; Fytianos, 2002).

The mobility, transport, and partitioning of metallic and metalloid elements in natural aquatic and terrestrial systems is a function of the chemical form of the element which, in turn, is controlled by the physicochemical and biological characteristics of that system. When metals are reaching the sediment, they could be bound on to hydrated oxides of iron and manganese, organic compound, clay minerals, etc. and may be associated with them in different ways. Generally, heavy metals may represent a threat to the aquatic organisms because of their toxicity, persistence and bioaccumulation (Tekin-Ozan and Kir 2006). Therefore, monitoring of the heavy metal is important for safety assessment of the riverine environment in general and human health in particular. The poor quality of water can also adversely affect the plant growth and human health and can cause various environmental consequences.

2. Evolution of heavy metals in the riverine system

2.1.Natural input of heavy metals:

Natural waters, having a contact with heavy metals along with different chemical variations of rocks, inevitably gain a specific composition. Different types of chemical processes occur during rock-water interaction, includes dissolution/ precipitation, ion exchange processes, oxidation and reduction. Various minerals present in the rocks will completely or partially dissolve in water according to the resistance of chemical weathering and makes the chemical composition of the river water. The study of environmental geochemistry of the natural river water gives significant information on chemical weathering of rock as well as soil, chemical and isotopic compositions of drainage and even of the upper continental crust (UCC), and on the elements cycled in the continent–river–ocean system (Stallard and Edmond 1983; Zhang *et al.,* 1995). Generally, weathering and the geochemical processes controlling solute acquisition in the riverine system. Metals are associated with sediments in the river systems largely due to processes of adsorption onto mineral surfaces, absorption into organic matter, ion-exchange in riverine environments.

2.2.Anthropogenic input of heavy metals:

The anthropogenic inputs of industrial wastewater, without prior treatment, in aquatic environments, affect the geochemical composition of receiving water bodies. Besides the growth of industrial technologies the population and water usage has increased the stress upon the river water resources. Anthropogenic activities in a river basin results in input pollutants via point and non-point sources which may degrade the quality of surface water and impair their use for potable supply, industrial, agricultural or other purposes (Simeonova *et al.,* 2003; Kepner *et al.,* 2004). Fresh water contamination with a wide range of pollutants has become a matter of concern (Dirilgen, 2001; Vutukuru, 2005). Improper disposal of industrial effluents and other wastes may contribute greatly to the poor quality of the receiving water bodies. Various Indian rivers carry effluents from sewage, industries, agricultural and urban areas (Jameel and Hussain 2007; Rani and Sherine 2007).

Rapid urbanization and industrialization have resulted in increased waste loads which are discharged into rivers without any prior treatment. River water contamination due to wastewater discharge is a major environmental concern. Indiscriminate and unscientific disposal of municipal sewage has also severely deteriorated the aquatic environment leading nutrient enrichment of the receiving waterbody (Akpan, 2004) which in turn affects environmental health worldwide. Nutrient enrichment of lakes, reservoirs, wetlands, rivers and streams is also one of the most prevalent environmental concerns responsible for freshwater quality degradation on a world-wide scale (Smith *et al.*, 1999). Anthropogenic activities at basin scales may cause increased waterborne pollution from point and diffuse sources, affecting aquatic ecosystems.

3. Potential risks of heavy metals in the riverine system

In the natural aquatic system metals can undergo a variety of transformations including in dissolved speciation, precipitation and oxidation/reduction and all of these processes can drastically alter the mobility of the metals. According to Miao *et al.*, 2006 changes in sediment oxidation/reduction state and pH influence the solubility of both metals and nutrients. Singh *et al.*, (2005) studied on distribution and fractionation of heavy metals in Gomti river sediments—a tributary of the Ganges, India. From this study it was observed that there was a considerable variation in the concentration of heavy metals in water and sediments and this variation may be due to the change in the volume of industrial and sewage waste being added to river at different sampling stations. According to Risk Assessment Code (RAC) the concentrations of Cd and Pb at Neemsar (57 and 51% respectively) are posing a very high risk.

3.1.Exposure routes for heavy metals to the riverine system

The main sources of lead entering into the riverine ecosystem are atmospheric lead (primarily from automobile emissions), lead containing industrial wastewater, paint chips, fertilizers and pesticides and lead-acid batteries or other industrial products. Leaded gasoline is one of the major sources of dispersing lead into the riverine environment. During the burning of leaded gasoline, huge small particles of lead emits into the air, where they remain for extended periods of time. Arsenic can be found naturally on earth, it occurs in soil and minerals and it may enter air, water and land through wind-blown dust and water run-off. Arsenic is released into the environment by the anthropogenic activities also, like smelting process of copper, zinc, and lead, as well as the manufacturing of chemicals and glasses. Arsenic occurs in various organic and inorganic forms in the riverine environment. Generally, inorganic compounds of arsenic are regarded as more toxic than most organic forms which are less toxic (Andrianisa et ai, 2008). According to Reimer *et al*, (2010) inorganic arsenic and its compounds, upon entering the food chain, are progressively metabolized to a less toxic form of arsenic through a process of methylation. The toxicity of arsenic depends on various factors like, its species, the pH, and redox conditions, surrounding mineral composition, and microbial activities affect the form (inorganic or organic) and the oxidation state of arsenic.

A number of industries, petrochemicals and also the agricultural sources like fertilizer and fungicidal sprays have a great impact in the riverine system. The household bleach, acid, caustic chemicals (e.g., battery acid, household lye, muriatic acid, hydrochloric acid), instrumentation containing mercury like medical instruments, thermometers, barometers and manometers, batteries, electric lighting (fluorescent lamps, incandescent wire filaments, mercury vapor lamps, ultraviolet lamps), pesticides, pharmaceuticals (e.g., nasal sprays, cosmetics, contact lens products), household detergents and cleaners, laboratory chemicals, lubrication oils, wiring devices are also some of the more common sources for mercury. The dispersion of atmospheric mercury across the globe also takes place by wind, which returns to the earth through rainfall and leads to its bio-accumulation in the aquatic food chains. Cadmium is a toxic and hazardous substance may introduced into the riverine environment from mining and smelting operations, industrial operations, paints and pigments, plastic stabilizers, electroplating, reprocessing cadmium scrap and incineration of cadmium containing plastics. Cadmium can be found in soils because insecticides, fungicides, sludge, and commercial fertilizers that contain cadmium are used in agriculture. It may enters into the river as a result of surface runoff and can persist in sediments for decades.

3.2.Effect of heavy metals on the aquatic life

Once heavy metals are released into the riverine systems they persist and can bioaccumulate, reaching concentrations in the aquatic ecosystem, particularly in the sediment, that could be harmful to humans and other organisms. The chemical analysis of metals in sediments, water, and biota is considered to be an appropriate and suitable method for evaluating the bioavailability of heavy metals in water and for estimating the biological and ecological effects caused by heavy metal exposure. Eventually the sediments generally contaminates with different toxic heavy metals from different sources. Afterwards under certain environmental conditions, these metals from contaminated sediments are released into the water column that brings about their dispersion and accumulation in a number of plants and animals. The environmental impact of heavy metals is depends on the fact whether the metals are dissolved in water and therefore, transported with water mass or adsorbed in suspended sediment and hence capable of settling out of solution in localized areas. Both these forms of transportation of heavy metals have a significant impact on aquatic life members of which the second one brings about hazardous problems on bottom dwellers. Bhattacharyay *et al.*, (2005) revealed that the metals are also responsible for causing morphological deformities of antennae and other parts of chironomid larvae. The transfer of metals through the aquatic food chain generally leads to accumulation of certain metals to a high concentration enough that may bring about a number of harmful effects.

4. Conclusion:

Rivers play a significant role in human development and are important natural potential sources of different usage. Discharge of industrial effluents along with heavy metals and toxic compounds into riverine systems represents an ongoing environmental problem and possess a potential threat to human health. Rapid urbanizations have resulted an increased waste loads which are discharged into rivers without any prior treatment. River water contamination due to wastewater discharge is also a major environmental concern. Surface sediment acts as a metal pool that can release metals to the overlaying water through natural and anthropogenic processes and possess potential adverse effects in the riverine ecosystem. The anthropogenic inputs of industrial wastewater, without prior treatment, in aquatic environments, affect the geochemical composition of receiving water bodies. Like other toxic pollutants, heavy metals have been of great concern due to their environmental persistence, toxicity, and ability to be incorporated into food chains. Therefore, assessment of heavy metal in the river and sediments is important in order to estimate the extent of pollution or to identify the pollution sources. Massive amount of wastewater from different industries and municipal sewage if treated properly that can certainly be used for fish production, irrigation, aquaculture and for many other developmental purposes.

References:

Akpan, A. 2004. The water quality of some tropical fresh water bodies in Uyo (Nigeria) receiving municipal sewage effluents, slaughter house washing and agriculture land drainage. *The Environmentalist, 24*, 49–55.

Andrianisa H. A. Ito, A. Sasaki A. Aizawa J. and Umita T. 2008. Biotransformation of arsenic species by activated sludge and removal of bio-oxidised arsenate from wastewater by coagulation with ferric chloride. *Water Research*, 42(19):4809-17.

Bhattacharyay, G. Sadhu, A. K. Mazumdar, A. and Chaudhuri, P. K. 2005.Antennal deformities of chironomid larvae and their use in biomonitoring of heavy metal pollutants in the river Damodar of West Bengal, India. *Environmental Monitoring and Assessment,108*,67–84.

Carpenter, S. Caraco, N. Howarth, R. Shawley, A. and Smith, V. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, *8*, 559–568.

Dirilgen, N. 2001. Accumulation of heavy metals in freshwater organisms: Assessment of toxic interactions. *Turkish Journal of Chemistry, 25(3),* 173-179.

Fytianos, K. Siumka, A. Zachariadis, G. A. and Beltsios, S. 2002. Assessment of quality characteristics of Pinios River, Greece.*Water Air and Soil Pollution*, *136*, 317–329.

Farkas, A. Erratico, C. and Vigano, L. 2007. Assessment of the environmental significance of heavy metal pollution in surficial sediments of the River Po.*Chemosphere*.*68,* 761–768.

Jameel, A. A. and Hussain, A. Z. 2007. Assessment of ground water on banks of Uyyakondan channel of River Cauvery at Tiruchirappalli. *Indian Journal of Environmental Protection, 27(8),* 713-716.

Kepner, G. W. Semmens, J. D. Bassett, D. S. Mouat, A. D. and Goodrich, C. D. 2004. Scenario analysis for the San Pedro River, analysing hydrological consequences of a future environment.*Environmental Monitoring and Assessment, 94*, 115–127.

Miao, S. DeLaune, R. D. and Jugsujinda A. 2006. Influence of sediment redox conditions on release/solubility of metals and nutrients in a Louisiana Mississippi River deltaic plain freshwater lake. *Science of the Total Environment*.371(1-3):334-43.

Rani, S. A. F. and Sherine, H. B. 2007. A study on measure of pollution load of well waters in Trichy area. *Indian Journal of Environmental Protection 27(8)*, 721–723.

Reimer, K.J. Koch, I. and Cullen, W.R., 2010. Organoarsenicals. Distribution and transformation in the environment. In: Sigel, A., Sigel, H., Sigel, R.K.O. (Eds.), Metal Ions in Life Sciences. RSC Publishing, London, p. 165

Silveira, M. L. Alleoni, L. R. F. O'Connor, G. A. and Chang, A. C. 2006. Heavy metal sequential extraction methods—a modification for tropical soils. *Chemosphere, 64*, 1929–1938

Simeonova, V. Stratisb, J. A. Samarac, C. Zachariadisb, G. Voutsac, D. and Anthemidis, A. 2003.Assessment of the surface water quality in Northern Greece. *Water Research, 37*, 4119– 4124

Singh, K. P. Mohan, D. Singh, V. K. and Malik, A. 2005.Studies on distribution and fractionation of heavy metals in Gomti river sediments—a tributary of the Ganges, India. *Journal of Hydrology, 312*, 14–27.

Smith, V. H. Tilman, G. D. and Nekola, J. C. 1999. Eutrophication: Impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution, 100*, 179-196.

Stallard, R. F. and Edmond, J. M. 1983.Geochemistry of the Amazon 2.The influence of geology and weathering environment on the dissolved load. *Journal of Geophysics Research,88*, 9671–9688.

Tekin-Ozan, S. and Kir, I. 2006. Concentrations of some heavy metals in organs of two fish species from the Bey¸sehirlake, Turkey. *Fresenius Environmental Bulletin*, *15(6)*, 530-534.

Vutukuru, S. S. 2005. Acute effects of Hexavalent chromium on survival, oxygen consumption, hematological parameters and some biochemical profiles of the Indian Major carp, *Labeorohita*.*International Journal of Environmental Research and Public Health, 2(3)*, 456-462.

Zhang, J. Takahashi, K. Wushiki, H. Yabuki, S. Xiong, J. M. and Masuda, A. 1995. Water geochemistry of the rivers around the Taklimakan Desert (NW China): crustal weathering and evaporation processes in arid land. *Chemical Geology*, *119*, 225-237.