INTERNATIONAL JOURNAL OF ENVIRONMENT

Volume-5, Issue-2, March-May 2016 **ISSN 2091-2854**

Received:14 March *Revised:24 March* *Accepted:08 May*

HEAVY METAL ASSESSMENT IN WATER AND SEDIMENTS AT JAIKWADI DAM (GODAVARI RIVER) MAHARASHTRA, INDIA

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Abstract

The indiscriminate release of industrial effluents, domestic sewage, agricultural runoff have resulted in extensive contamination of water and soil with heavy metals thereby causing hazard to flora and fauna and the aquatic ecosystem. Therefore, there is a need for biological monitoring studies to evaluate the toxic concentrations of various chemical compounds so that certain preventive measure can be taken to ensure the safety of the environment. Therefore, this study was focused at investigating few of the important heavy metals like zinc, chromium, cadmium, mercury and lead, in water along with sediments of the Jaikwadi dam. It has been found that the content of mercury was the highest in both water (15.24 - 18.21 µg/L) and sediments, it is followed by lead (14.31 - 18.38 µg/L), cadmium (1.95 - 2.29 µg/L), chromium (0.68 - 4.00 µg/L) and finally zinc (0.88 - 1.77 µg/L). High concentrations particularly of mercury and lead warrant studies for their remediation so that the concentration remains safe for the populace dependent on the water.

Keywords: heavy metal, water, sediments, Jaikwadi dam, assessment

Introduction

Heavy metals such as Hg, Cu, Cd, Zn, Ni etc. generally exist within the earth crust in trace concentrations. In traces these metals are necessary for normal metabolism of the living organisms as these facilitate physiological functioning and also form part of structural components. However, anthropogenic activities such as industrial processing and use of metals, alloys and metallic compounds result in environmental contamination (Dar, 2002). Discharge of such metal containing effluents into the aquatic environment and drainage of residues of mining, there is manifold increase in the contents of these metals in the aquatic media (Kelkar, 2001) such as ponds, lakes, rivers and dams of India. According to a survey report of ATSDR (2001) almost 70% of the Indian available water has been reported to be extensively contaminated by heavy metals and other categories of chemicals. Heavy metal pollution in freshwater bodies assumes considerable significance because these are stable compounds and hence, not readily disposed off by the processes of oxidation, precipitation etc and adversely affect the activity of the animals. Heavy metals have a unique property of accumulation in organisms from very low concentration in water from lakes, rivers and dams (Kulkarni, 2000). Higher metal concentrations in natural waters might cause various deleterious effects in aquatic organisms (Lohar, 2000). Sublethal concentrations have equally serious effect on the aquatic biota drastically altering growth, reproduction, fecundity and other biological phenomenon (Chen and Yang 2001).

High sedimentation in dams and reservoirs adversely affects aquatic organisms by modifying their biochemical conditions, habitat space, food resources and respiratory gradients. It has been found that obstructing the flow of running water commonly by means of dams and reservoirs has unfavorably impacted almost all of the world's major river systems (Shinde, 2006). Contamination of sediment is a serious issue particularly in a densely populated country as India. Rapid and indiscriminate pace of urbanization and industrialization have severally augmented the growing burden of chemical contaminants in the soil. Major classes of organic contaminant of aquatic and terrestrial ecosystems are polycyclic aromatic hydrocarbons (PAHs). These compounds affect micro-flora and are potentially a grave threat to human health owing to their genotoxic, mutagenic and or carcinogenic potential (Raj and Sharma, 1995). The U.S.E.P.A has highlighted 16 PAHs as pollutants of high concern. The PAHs are highly recalcitrant and their biological transformation mediated by bacteria and fungi represents a potential route for their ultimate removal from the soil environment. The biodegradation of PAHs is reported to be influenced significantly by various environmental factors (Fatima and Ahmad, 2005).

The unsystematic discharge of effluents those are organic or inorganic in nature changes the physico-chemical parameters of water and soil thereby causing irreparable damage to flora and fauna as well as the aquatic ecosystem. In India, many industries have been established on the bank of rivers where hazardous waste effluents are being discharged into these systems thereby causing severe pollution problems (Eja et al, 2003; Gopal et al, 2002; Davydova, 2005). Thus, there is a need for biological monitoring studies to evaluate the toxic concentrations of various chemical compounds so that certain preventive measure can be taken to ensure the safety of the environment. In this background the present study was aimed at investigating few important heavy metals like Zinc, Chromium, Cadmium, Mercury and Lead, in the water as well as sediments of the Jaikwadi dam.

Site description: Jaikwadi Dam is a man- made reservoir constructed in the year 1975 on the upper reaches of the river Godavari. It is situated at Paithan (50 km from the south of Aurangabad city) at a longitude of 75 0 17' and latitude of 19 0 29'. The main purpose for construction of this dam was to meet the irrigation and widespread drinking water scarcity in the drought prone areas of the Marathwada region. The dam's abounded water body is spread in overall length of 102'10 meters long and consists of 610 meters long masonry over dam. Godavari River is considered as "Ganges of Deccan" and the "Gate of Hari". It serves as source of water and plays an important role in improving socio-economic life of population residing on its bank. The Jaikwadi water body receives the untreated sewage residues from small scale industries, automobile waste and surface runoff from the adjoining areas. The fishing activity established in the sewage fed dam has a great importance for the economic well being of locals and used for agriculture. In addition the dam water is being used for irrigation of the nearby agricultural fields of Paithan region (Matkar, 2008).

Material and Methods

In order to estimate the heavy metals within water and sediments, sampling was undertaken in three different seasons. Water samples were collected in clean and dry plastic containers. For collecting sediment samples a pre-cleaned and acid washed PVC corer was used. Subsequent to collection the samples were placed in clean poly-bags and were transported to the laboratory for further analysis. Firstly the samples were washed using distilled water and were then dried at 110 ^{0}C for 5 - 6 hours in an oven and then grinded to powder with the help of a mortar and finally stored for analysis in cleaned polythene sample bags. 500 mg sample quantity (sediment sample) was taken and digested using Conc. H_2SO_4 (1-2ml). Few drops of HF were also added for facilitating complete digestion. Upon completion of the process of acid digestion the sample was filtered and used for the estimation of Zn, Cr, Cd, Pb and Hg using Atomic Absorption Spectrophotometer, model Elico SL 167 manufactured in 2006 (APHA, 1992; Matkar, 2008).

Results

Metal content in water

Zinc: Zinc is an essential element for human body. Zinc enters the domestic supply from deterioration of galvanized Fe and de-zincification of brass, besides industrial waste. In the study it has been found that in monsoon the zinc content in water ranged between 1.19 - 1.23 µg/L. In winter season for the study period the zinc content in water ranged between 0.88 - 0.90 µg/L. During summer the concentration of zinc in Jaikwadi water varied from 1.68 - 1.77 µg/L. In the present study in both the years zinc content reported was higher in summer and lower in winter

(Table1). In summer, the water volume of the dam gets reduced substantially; therefore, it is likely that the heavy metal concentration increases (Dons and Beck 1993). Shanthi and Ramanibai, 2011 estimated the seasonal variation of zinc content in the estuarine water they recorded the maximum amount in summer and rainy season while minimum in winter.

Chromium: In monsoon, chromium content in water varied from 3.97- 4.00 µg/L. While during winter, its concentration ranged from 1.76 - 1.78 µg/L. In summer the chromium content in water was low ranging between 0.68 - 2.03 µg/L. In the present study the chromium content was recorded higher in monsoon during both the years but it was lower in summer and winter during 2009-10 (Table 1).

Cadmium: In monsoon, during the study period cadmium content in water ranged between 2.28 - 2.29 µg/L. The cadmium content in winter was quite close to the levels found in monsoon ranging between 2.25 - 2.27 µg/L. While in summer, cadmium content was recorded in the range 1.95 - 2.04 µg/L. It is evident that the cadmium content was higher in monsoon and lower in summer season.

Table 1: Seasonal variations in heavy metal content of Jaikwadi dam water

Heavy Metal	Season 2009-10	Seasonal Mean values (µg/L)	CV	Season 2011-12	Seasonal Mean values (µg/L)	CV
Zn	**Monsoon**	1.19 ± 0.02	2.10	**Monsoon**	1.23 ± 0.02	1.68
	Winter	0.88 ± 0.20	23.65	**Winter**	0.90 ± 0.21	23.35
	Summer	1.68 ± 0.02	1.31	**Summer**	1.77 ± 0.05	3.22
Cr	**Monsoon**	4.00±0.02	0.68	**Monsoon**	3.97±0.03	0.83
	Winter	1.76±0.11	6.27	**Winter**	1.78±0.11	6.66
	Summer	0.68±0.17	0.01	**Summer**	2.03±0.08	4.20
Cd	**Monsoon**	2.29± 0.01	0.79	**Monsoon**	2.28± 0.02	1.03
	Winter	2.25±0.19	8.43	**Winter**	2.27± 0.01	7.70
	Summer	1.95±0.02	1.06	**Summer**	2.04± 0.02	1.29

Pb	**Monsoon**	18.37±70.01	0.09	**Monsoon**	18.38±0.05	0.30
	Winter	16.31±11.34	8.23	**Winter**	16.31±1.30	7.99
	Summer	14.31±0.04	0.30	**Summer**	14.36±0.05	0.38
Hg	**Monsoon**	15.30±0.22	1.46	**Monsoon**	15.24±0.08	0.54
	Winter	17.52±0.43	2.48	**Winter**	17.48±0.46	2.68
	Summer	18.19±0.02	0.11	**Summer**	18.21±0.02	0.08

± - Mean value & Standard Deviation, C.V.-Coefficient of variation

Lead: In monsoon, the lead content in water was high and the concentration was 18.37 µg/L. In winter, the lead content was 16.31 µg/L for both the years. In summer, however the metal concentration in water was lower than the other two seasons ranging between 14.31 - 14.36 µg/L.

Mercury: In monsoon season the mercury content in water ranged between 15.24 - 15.30 µg/L. In winter, the mercury content in water was higher and ranged between 17.48 - 17.52 µg/L. However, in summer the mercury content in water was highest ranging between 18.19 -18.21 µg/L. Thus, the mercury content was recorded higher in summer and lower in monsoon (Table 1). From the results of metal concentration in Dam water it is clear that the concentration of zinc and mercury was highest in summer while for chromium, cadmium and lead the highest concentration was reported in monsoon.

Metal content in sediments

Sediments are key sources in the assessment of anthropogenic contamination within the aquatic environments (Gaur et al, 2004). It is important to note that the contamination of sediment causes serious impacts on the entire ecosystem (Jardim, 2004). An assessment of heavy metal concentrations within the aquatic system assists in a better understanding of the processes that are involved in these ecosystems. It also facilitates in the planning and implementation of environmental management plans. It is also important to consider that a strong relationship exists between water and sediment, as characteristics of water have a significant influence over the sediment (Isidori et al, 2004).

Zinc: In monsoon, the zinc content in sediment ranged between 0.65 - 0.66 µg/g. In winter, it ranged between 0.52- 0.53 µg/g. In summer, the zinc content in sediment ranged between 1.55 - 1.56 µg/g. Therefore, the zinc content in sediment was recorded highest in summer and lowest in winter compared to two other seasons (Table 2).

Chromium: During monsoon, average chromium content in sediment ranged between 10.14 - 10.16 µg/g. In winter, chromium content in sediment ranged between 6.35 - 6.42 µg/g. In summer, it was ranged between 9.64 - 9.66 µg/g. Chromium content in sediment was reported in higher in monsoon while lower content was recorded in winter. Higher chromium content in sediment was attributed to discharge of industrial wastes, domestic waste and the runoff from agricultural fields of the nearby villages (Nicolau et al, 2006).

Cadmium: During monsoon cadmium content in sediment ranged between 4.37 - 4.39 µg/g. In winter, the cadmium content in sediment was recorded in the range between 4.24 - 4.25 µg/g. In summer cadmium content in sediment ranged between 1.42 - 1.52 µg/g. Hence, cadmium content in sediment was reported higher in monsoon and lower in summer.

Lead: When observed lead content in sediment during monsoon, the concentration in sediment was high ranging between 24.37 - 24.38 µg/g. In winter, the lead content in sediment varied between 16.86 - 16.87 µg/g. During the summer season, the lead content ranged between 19.39 - 19.41 µg/g. The lead content in sediment was recorded highest in monsoon and lowest in winter.

Mercury: In monsoon the mercury content in sediment varied from 11.06 - 11.10 µg/g. In winter, the mercury content ranged between 10.26 - 10.40 µg/g. However, in summer the mercury content in sediment was highest ranging between 13.30 - 13.31 µg/g. The mercury content in sediment was recorded highest in summer and lower in the other two other seasons (Table 2).

Table 2: Seasonal variations in heavy metal content of sediments from Jaikwadi dam

Heavy Metal	**Season 2009-10**	**Seasonal Mean values (µg/g)**	**CV**	**Season 2011-12**	**Seasonal Mean values (µg/g)**	**CV**
Zn	**Monsoon**	0.66±0.01	2.74	**Monsoon**	0.65±0.02	3.99
	Winter	0.53±0.01	2.37	**Winter**	0.52±0.08	1.56
	Summer	1.56±0.01	1.10	**Summer**	1.55±0.02	1.28
Cr	**Monsoon**	10.14±0.02	0.19	**Monsoon**	10.16±0.01	0.15
	Winter	6.35±0.03	0.47	**Winter**	6.42 ±0.04	0.63
	Summer	9.64±0.03	0.31	**Summer**	9.66± 0.02	0.15
Cd						

	Monsoon	4.39±0.01	0.34	**Monsoon**	4.37±0.01	0.38
	Winter	4.24±0.01	0.45	**Winter**	4.25±0.01	0.52
	Summer	1.52±0.03	2.10	**Summer**	1.42±0.01	0.65
Pb	**Monsoon**	24.38±0.01	0.05	**Monsoon**	24.37±0.02	0.09
	Winter	16.86±0.01	0.04	**Winter**	16.87±0.03	0.18
	Summer	19.39±0.08	0.04	**Summer**	19.41±0.02	0.11
Hg	**Monsoon**	11.10±0.02	0.18	**Monsoon**	11.06±0.02	0.18
	Winter	10.40±0.02	0.25	**Winter**	10.26±0.01	0.14
	Summer	13.30±0.04	0.36	**Summer**	13.31±0.04	0.37

Discussion

Metal contents in water and sediment:

In aquatic environments, metals have been termed as conservative pollutants because once added to the environment, they prevail for a long time in absence of removal by processes of oxidation, precipitation etc (Besada et al, 2002). Hence, heavy metal contamination of fresh water environments is a major cause of concern as it may worsen the natural habitats by diminishing eco-sensitive species or by elimination of the commercial species (Eja et al, 2003) and also pose a significant health hazard to humans. Increase in heavy metal concentration in water results in histological, biochemical, morphological and physiological changes as well as behavioral changes (Kulkarni, 2000). In aquatic water bodies such as dams and lakes, bivalves usually serve as bio-monitor organisms in areas that are suspected of pollution. Assessment of metals in water and sediments become necessary for drawing certain baseline information for monitoring metals like Zn, Cr, Cd, Pb and Hg which are toxic to aquatic life (Mohan et al, 1996).

The sources of zinc are metallurgical and galvanic industries, mines, incineration plants and anti corrosive products which through effluent and wastewater discharges find way into water sources (Chindah and Braide, 2003). In the present study, the zinc level in water sample ranged between 0.88 - 1.77 µg/L. The lower level was recorded in winter and higher level was reported in summer. The zinc content was higher in summer. Zinc content in sediment ranged between 0.52 - 1.56 µg/g. The trend for sediments was similar to that in water, zinc content being lower in winter and higher in summer. The higher metal content in summer in water and sediment may be attributed to the fact that during summer the water volume of dam gets reduced substantially, therefore it is likely that the heavy metal concentration increases with the anthropogenic input or it may be due to the agricultural runoff, domestic activities, wastewater discharges, effluent discharges and another non-point sources opened into water bodies. Wadhawan et al, (1991) carried out the analysis of zinc content in the lakes Kailana, Bulsamand and Ranisar near Jodhpur and observed high metal content ranging from 70- 250 µg/L. Similar values were also reported by Rashed (2001). While the trend was similar for both zinc content in water and sediment however, it was the sediment that accumulated lesser heavy metal as compared to water (Besada et al, 2001; Chindah and Braide, 2003; Eja et al, 2003).

Chromium contamination is frequently studied and there are many research reports which assume significance owing to the existence of several anthropogenic sources (such as industrial effluents, domestic wastewaters) of chromium that result in environmental contamination (Rashed, 2001). In the present study, the chromium content in water sample ranged between 0.68 - 4.00 µg/L. It was lower in summer and higher in monsoon. Chromium's major sources include electroplating industries, treatment plants, inorganic chemical plants, iron and steel foundries and discharge from urban and residential areas (Gaur et al, 2004). Nicolay et al, (2006) observed that rivers serve as important pathway for transport of metals and presence of metals in aquatic environments results in serious concerns regarding their impact on plant and animal life. In the present study, the chromium content in sediment ranged 6.35 - 10.16µg/g. The chromium content was higher in monsoon and lower in winter. High chromium content in sediment was attributed to industrial wastes and domestic waste dumping and agricultural runoff from the nearby villages (Obire et al 2003; Nicolay et al, 2006). Davydova (2005) concluded that metals exert harmful effects on human health as well as that of the whole environment. Clearly, rivers serve as sensors of different anthropogenic activities that exist around.

During the present study, it was observed that the cadmium content in water ranged from 1.95 - 2.29 µg/L. The lower content of cadmium was recorded in summer and higher content was recorded in monsoon. Sources of cadmium resulting in contamination in river water system may include release from industrial activities, discharge of domestic wastewater, application of agrochemicals along the river bank and local air pollution due to open burning (Pondhe and Jadhav 2002; Patil et al, 2005). It has been proposed that the major quantity of the cadmium entering water from industrial effluents may be readily adsorbed by particulate matter and therefore, sediment may serve as an important sink in the aquatic environment for cadmium (Isidori et al, 2004). Benthic organisms remain attached to the ocean floor and therefore, these are most likely to be impacted by the presence of metals in the sediment. A very significant factor is the relation between cadmium partitioned which is in adsorbed form in sediment state and that which is dissolved in water. It is this relation that determines whether the cadmium present in water is available to penetrate the food chain and adversely impact human health. Water bodies such as rivers, lakes and ponds, dams that contain cadmium in excess have potential to contaminate surrounding land by means of dumping of sediments, irrigation for agriculture or flooding. It has been also reported that rivers may transport cadmium from its source to a distance up to 50 km (WHO, 1970; 1988). Cadmium content in fresh water system shows seasonal variations due to discharge of industrial wastes. Occhiogrosso et al (1979) showed high content of cadmium in aquatic ecosystem of marshes along the eastern side of Hudson River, New York. There are evidences that high value of cadmium is associated with the sediments, increasing from the mouth of river towards the estuary and open sea. Seasonal variations in the metals like cadmium in estuarine water were reported by Anderson et al (1999); Huang et al (1999); Chakrabarthy et al (2009). Metal content within aquatic organisms is typically several orders of magnitude greater than that in the water, this is because they are progressively concentrated at higher trophic levels (Patil et al, 2005). In the present study, the cadmium content in sediment ranged between 1.42 -4.39 µg/g. While it was lower in summer and higher in monsoon. The application of fertilizers containing cadmium in bed (agricultural fields) of Godavari river might wash in rainy season and reach the Dam to result in high cadmium content within water or sediments. Further the different tributaries also convey sewage sludge to Godavari which also might increase the cadmium content of soils (Pondhe et al, 2005). Even atmospheric cadmium deposition on the surface of soil has been attributed for the increased concentration of cadmium (Bak and Jensen, 1998).

The natural lead content of lakes, rivers, and dam’s water world wide has been estimated to be 1-10 ppm. Although higher values have been recorded where contamination has occurred particularly from industrial sources, such situation are relatively rare, since there are number of natural mechanism that control the levels. However, particularly high lead levels can result when the water is soft or has low pH (Chai and Webb, 1988). Wetlzel (1983) concluded that lead wastes were the most important factor in resulting in eutrophication and algal growth. In the present study, the lead content in water ranged between 14.31 - 18.38 µg/L. While it was lower in summer and higher in monsoon. The discharge of lead in Labu River System, Yamuna river and Godavari river has mainly been attributed to lead containing domestic wastewater, corrosion of household plumbing systems, open burning, surface runoff of pesticide in agricultural estates and wet deposition (Pondhe and Jadhav, 2002). Extensive open burning of diffused battery and newspaper has primarily been identified in causing pollution of the local atmosphere with lead (Ho et al, 2003). In the present study the lead content in sediment ranged between 16.86 - 24.38 µg/g being lower in summer and higher in monsoon. Gaghate and Hasan (1999) reported that increase in Pb in soil may be from municipal solid wastes material because that contains various compounds like glass, electrical wires, batteries etc.

In the present study the mercury content in water ranged between 15.24 - 18.21 µg/L. It was lower in monsoon and higher in summer. The discharge of domestic sewage water and that of industrial waste might have contributed mercury in the water and sediments. In summer the level of water considerably decreases which might result in an enhanced mercury concentration and the water body receives much water in monsoon due to heavy rainfall and gets flooded which might cause the dilution of metal during monsoons. Similar observations were reported by Patil and Mane (1998) as well as Patil and Patwari (2005). Effluents from industries involved in the manufacture of batteries, switches, fluorescent tubes and lamps, thermometers, paper and pulp contain mercury (ATSTR, 2000). It is from the industrial effluents the mercury compounds are able to enter the water body and reach their bottom, where by action of anaerobic microbes, these get converted into methyl mercury compounds. Methyl mercury has affinity towards lipids and therefore after its intake it accumulates within the fatty tissues. Fishes directly accumulate methyl mercury ions and the concentration might reach 3000 times greater in fish as compared to in water. In Minamata bay, all the mercury in seafood was organic methyl mercury compounds. It has been observed that in the present study, the mercury content in sediment ranged between 10.26 - 13.31 µg/g. Similar observations were reported by Patwari (2006) and Kamman et al (2005). High sediment contents of mercury near swear outfalls was recorded in Canada (Ontario Research Water Resources Commission, 1970) as well as in bottom sediments below the discharge from a chemical plant and several pulp and paper mills in Wisconsin, U.S.A. Considerable research has been directed to understand the toxicological effects and pathological disorders due to metals. Grimstone (1972) stated that the large portion of mercury lost in effluent is retained by sediment and subsequently released over a period of a year. Feick et al (1972) found that mercury could be released in considerable quantities from bottom sediments in fresh water by the addition of road salt calcium chloride which increased the soluble mercury content of the water by 2 to 5 orders of magnitude.

Conclusion

Heavy metal contamination of aquatic environments is a cause of major concern since it may lead to deterioration of natural habitats by depleting ecologically sensitive species or by eliminating commercial species and also pose a serious health hazard to humans. Assessment of metals in water and sediments becomes necessary for drawing certain baseline information for monitoring metals which are toxic to aquatic life and subsequently get concentrated in food chain posing threat to human life. Hence the present study was aimed at investigating the concentration of certain key heavy metals such as Zinc, Chromium, Cadmium, Mercury and Lead, in water along with sediments in the Jaikwadi dam. This dam on the river Godavari is the lifeline of Marathwada region and therefore, such a study assumes considerable significance for the area. It has been found that the content of mercury was the highest in both water (15.24 - 18.21 µg/L) and sediments, it is followed by lead (14.31 - 18.38 µg/L), cadmium (1.95 - 2.29 µg/L), chromium (0.68 - 4.00 µg/L) and finally zinc (0.88 - 1.77 µg/L). High concentrations particularly of mercury and lead warrant studies for their remediation so that the concentration remains safe for the populace dependent on the water.

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