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Impact Assessment of Lead on Water Quality of River Ganga in West Bengal, India

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The rapid increase in human population, industrialization and urbanization has resulted in tremendous increase in waste loads which are discharged into open rivers with or without treatment. Only about 10% of the municipal sewage generated is reported to be treated by wastewater treatment plants in India (DAE 2005) as well as in China (EPAC 2000). Anthropogenic activities like mining, industry and agriculture have led to accelerated release of metals present naturally in the Earth's crust at various levels (Angelone and Bini 1992) into the ecosystems causing serious environmental problems posing threat to human beings (Lantzy and Mackenzie 1979; Nriagu 1979; Ross 1994). Industrial waste effluents containing toxic metals as well as metal chelates (Amman *et al.* 2002) are creating water pollution problems. This has resulted in deterioration of water quality rendering it unfit for human consumption and sustaining aquatic biodiversity (Ghosh and Vass 1997; Das *et al.* 1997). The trace heavy metals that are sorbed to suspended matter or dissolved in the water may ultimately be hazardous to health, when they become available to man either directly via drinking water or indirectly through various food chains.

Some of the metals like Cu, Co, Fe, Mn, Ni, Zn are essential as micronutrients for life processes in plants and microorganisms while many other metals like Ag, Au, Cd, Hg, Pb have no known physiological activity, but all metals are toxic at higher concentrations (Marschner 1995; Bruins *et al.* 2000). Toxic metal contamination of soil, stream and ground water poses a major environmental and human health risk which is further aggravated by their long term persistence. During the last few decades the use of lead (Pb) in industrial activities for manufacturing of batteries, bearing metals, cable covering, gasoline additives, explosives and ammunition, antifouling paints and analytical reagents has caused widespread environmental contamination (Ewers and Schlipköter 1991; Watanabe 1997; Johnson 1998). The toxicity of Pb is a consequence of the ability of Pb^{2+} to interfere with several enzymes (Ewers and Schlipköter 1991) and may cause a large variety of toxic effects, e.g. gastrointestinal, muscular, reproductive, neurological and behavioral and genetic malfunctions (Johnson 1998; Tsuji and Karagatzides 2001). Therefore, monitoring of Pb is important for safety assessment of the environment and human health in particular. With this background, we monitored the water and bottom sediment quality of river Ganga

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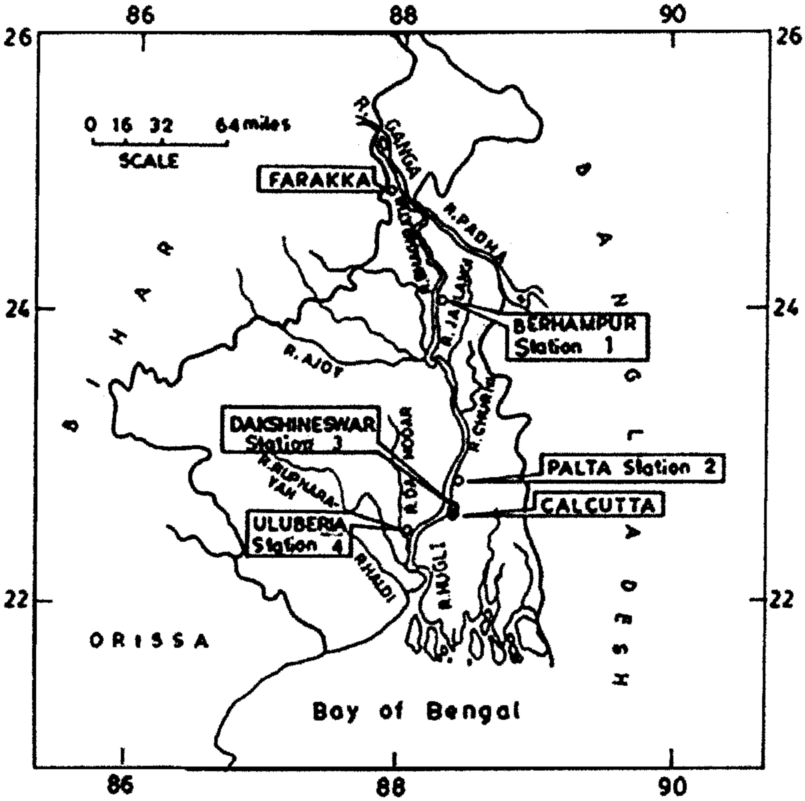

Figure 1. Locations of the monitoring stations on river Ganga (Bhagirathi -Hooghly stretch) in West Bengal.

in the Bhagirathi –Hooghly stretch of West Bengal with regard to the presence of heavy metals for impact assessment on the river water quality. The results obtained in respect of Pb are discussed here.

MATERIALS AND METHODS

Water samples were collected once in every month during October, 1993 to September, 1998 from three sites (1/3rd from east and west banks and middle of the river stretch) of four permanent monitoring stations (viz. Berhampore, Palta, Dakshineswar and Uluberia) on the river Ganga, a 300 km stretch known as Bhagirathi-Hooghly in West Bengal (Figure 1). Water samples were collected from a depth of 1ft from the surface of water using Nansen type water sampler and kept in polythene containers (500 mL) with the addition of concentrated HNO_3 @ 2 mL as a preservative. Sediment samples from the four locations were also collected quarterly (once in every three months) from the bottom of the river with the help of grab sampler. Sediment samples were air dried and crushed thoroughly to pass through 80 mm sieve for analysis of the heavy metal.

Water (200 mL) and sediment (5 g) samples were digested with 5 mL of di-acid mixture (HNO_3 : $HClO_4$ :: 9 : 4) on a hot plate and filtered by Whatman No. 42 filter paper and made up the volume to 50 mL by double distilled water for analysis of Pb using Atomic Absorption Spectrophotometer (GBC - 902, Australia). Pb was detected in samples by direct aspiration into an air-acetylene flame with the operating conditions of the Spectrophotometer maintained as follows: Lamp current: 5.0 mA, Wave Length: 217 nm, Silt Width: 1 nm, Working range: 2.5 - 20 µg /mL, Sensitivity: 0.06 µg /mL.

The data thus obtained on the occurrence of Pb in water and sediment samples of river Ganga in West Bengal were subjected to statistical analysis to test the analysis of variance (ANOVA) using SPSS statistical package.

RESULTS AND DISCUSSION

A total number of 641 water samples and 189 sediment samples were analysed for Pb during the period 1993-1998. Pb was detected in 74% of water samples and 63% of sediment samples in the wide range of concentration as shown in Table 1. The seasonal mean values obtained at different locations over the yrs regarding the occurrence of Pb in water are presented in Table 2. The significant variation in the values was observed due to the change in sampling location, season as well as over the yrs of sampling. The overall spatial and temporal changes on the occurrence of lead in river water are presented in Figure 2 and 3. The maximum mean concentration of Pb in water (0.148 mg/L) was obtained at Uluberia (the last location) in the downstream (Figure 2). The phenomenal increase in urbanization, industrialization and higher density of human population along the Hooghly estuary towards Kolkata resulted in increased discharge volume of domestic sewage effluents and industrial wastes into the river water. This might be the reason of higher Pb content in water in the downstream of the river water as compared to that of the upstream. Among the seasons, monsoon exhibited the highest concentration (0.164 mg/L) followed by summer and winter (Figure 3). The frequency distribution of the concentration of Pb obtained in water is presented in Figure 4 which revealed that majority of the detected water samples (more than 70%) in the concentration range of 0.015-0.20 mg/L.

Table 1. Concentration range of Pb in water and sediment of river Ganga in West Bengal.

Substrate	No. of samples		Range of concentration
	Analysed	Detected	
Water	641	477	0.003 – 3.350 mg/L
Sediment	189	119	8.10 – 143.20 mg/kg

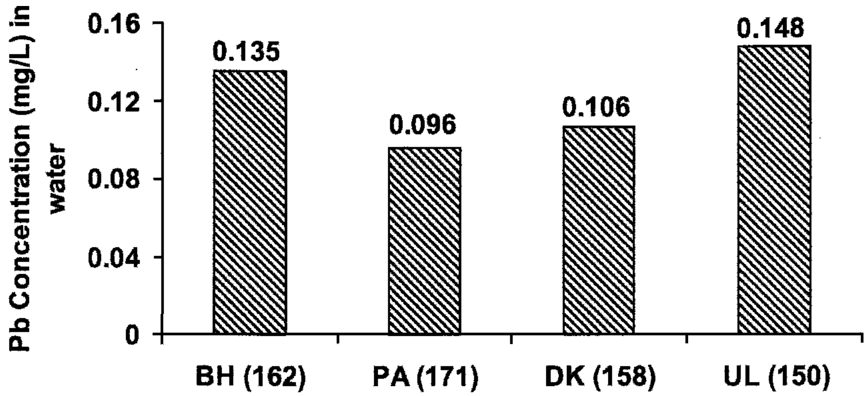

Figure 2. Spatial changes in Pb content in Ganga water during 1993-98 (Values in parentheses indicate number of samples analyzed at each center).

Table 2. Occurrence of Pb in water of river Ganga in West Bengal.

Yr	Season	Mean concentration of Pb (mg/L) in water at different monitoring stations			
		Berhampore	**Palta**	**Dakshineswar**	**Uluberia**
1st yr	Winter	0.071	0.058	0.063	0.069
	Summer	0.016	0.013	0.015	0.011
	Monsoon	0.156	0.117	0.133	0.133
2nd yr	Winter	0.088	0.082	0.065	0.072
	Summer	0.133	0.139	0.114	0.138
	Monsoon	0.180	0.129	0.112	0.096
3rd yr	Winter	0.036	0.054	0.075	0.053
	Summer	0.405	0.012	0.027	0.030
	Monsoon	0.348	0.348	0.341	0.343
4th yr	Winter	0.138	0.143	0.155	0.146
	Summer	0.042	0.046	0.052	2.217
	Monsoon	0.032	0.029	0.078	0.104
5th yr	Winter	0.120	0.111	0.113	0.121
	Summer	0.149	0.082	0.163	0.084
	Monsoon	ND	ND	ND	0.005

ND = Not Detected

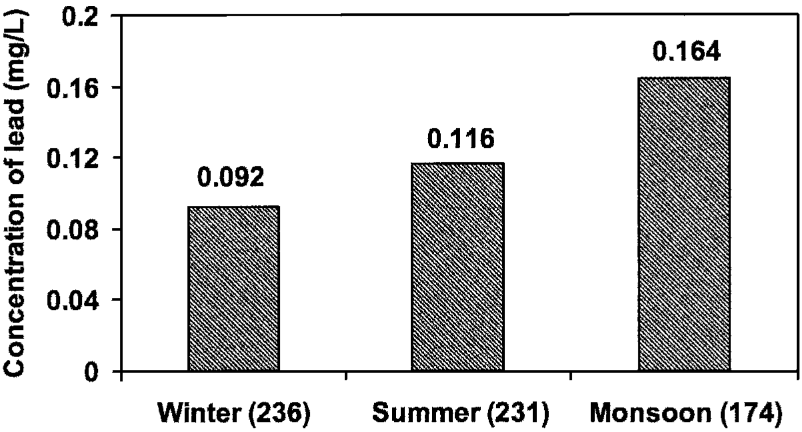

Figure 3. Temporal changes in Pb content in Ganga water (Values in parentheses indicate number of samples analyzed in each season).

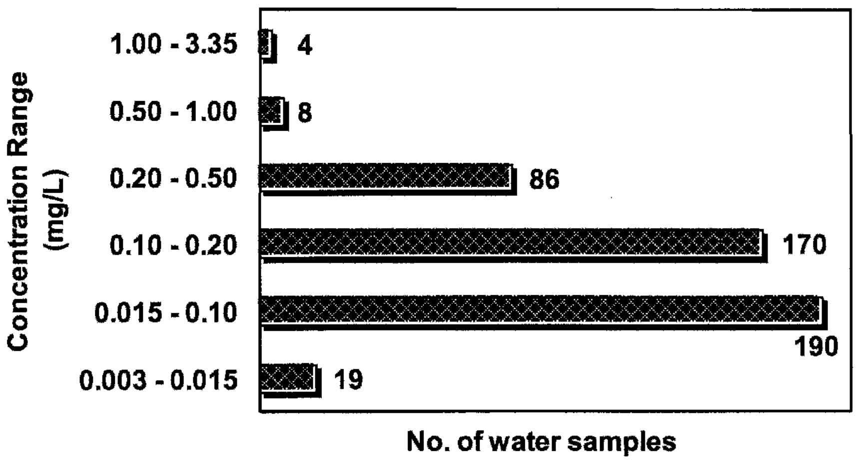

Figure 4. Frequency distribution of lead content in water.

A considerably higher level of Pb concentration was detected in sediment as compared to water samples (Table 1). The slightly alkaline nature of the river water facilitated precipitation of the metal from water to sediment. The mean values of Pb obtained at different locations over the yrs are presented in Table 3. The majority of the detected sediment samples (about 75%) were found in the concentration range of 8.10 – 60 mg/kg (Figure 5). Interestingly, Pb content at the two intermediate stations (viz. PA & DK) was significantly higher (Figure 6) in

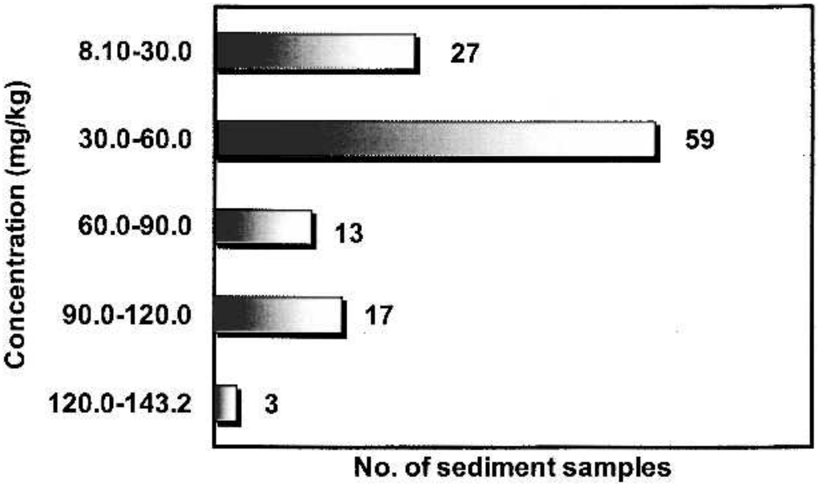

Figure 5. Frequency distribution of lead content in sediment.

Table 3. Occurrence of Pb in bottom sediment of river Ganga.

YR	CONCENTRATION OF PB (MG/KG) IN SEDIMENT AT DIFFERENT MONITORING STATIONS			
	BH	PA	DK	UL
1st	17.61	14.57	18.02	16.68
2nd	35.23	44.65	39.57	42.32
3rd	39.21	42.06	43.11	38.59
4th	28.81	27.62	31.84	36.48
5th	48.04	66.77	68.52	38.95

comparison to the two ultimate stations (BH & UL) in contrast to that observed in water (Figure 2). This phenomenon might be explained in terms of relatively higher velocity of water current in upper and lower stretches of the river leading to high content of suspended solids resulting in more metal content in water as compared to that observed in the intermediate stretch of the river with lower velocity of water current leading to low content of suspended solids.

Source water quality criteria in respect of Pb content of different countries vary considerably (Chang *et al.* 1999). From the present investigation, it was revealed that Pb content in 83 % of water samples far exceeded the permissible limit (0.05 mg/L) prescribed by USEPA. Primary drinking water quality standards for Pb concentration have been proposed by various countries. It was revealed that in the world context, Pb was found to exceed the permissible limit in about 96% of the samples, in the European context 78% and in the Indian context, it was exceeded in 49% of the samples (Figure 7).

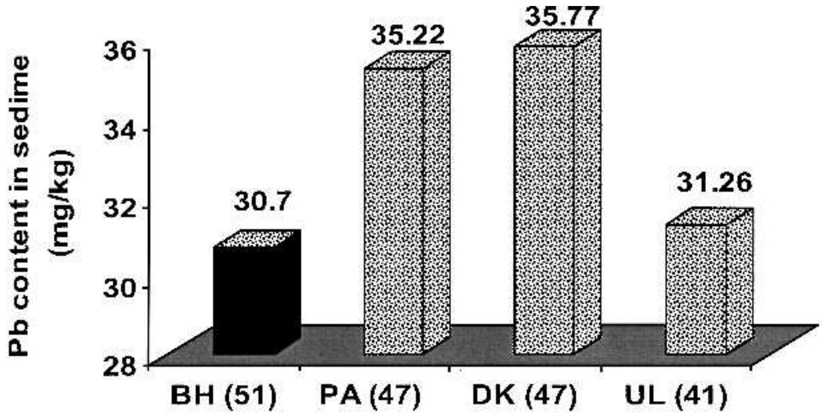

Figure 6. Spatial changes in Pb content in sediment during 1993-1998 (values in parentheses indicate number of samples analyzed at each location).

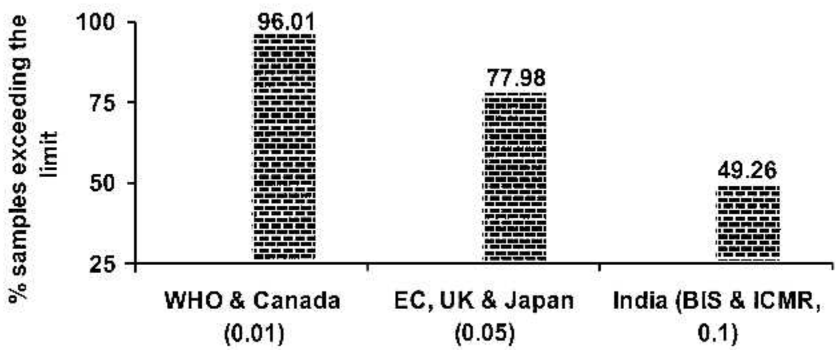

Figure 7. Evaluation of the river water in comparison to Primary Drinking water standards of Pb (Values in parentheses indicate the standard values prescribed by different countries / organizations in mg/L).

Considering the status of Pb concentration in water, it may be concluded that the river water as such is not suitable for drinking purposes. The river water needs proper treatment for use as source water for drinking. So, the improvement of the sanitary quality of the river will depend on the proper pre-treatment of all kinds of discharges that are released into the river at various sites. The study emphasizes strict surveillance on raw discharges in the river.

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