Explor Anim Med Res,
Vol.6, Issue - 2, 2016, p. 150-158

ISSN 2277- 470X (Print), ISSN 2319-247X (Online)
Website: www.animalmedicalresearch.org

Research Article

LEAD CONTAMINATION STATUS IN ABIOTIC COMPONENTS AND HUMAN HAIR AROUND BIDHYADHARI ESTUARY OF INDIAN SUNDARBAN DELTA

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Received 02 May 2016, revised 08 October 2016

ABSTRACT: Lead (Pb) is found to be present in different abiotic components and human hair at all the stations from S1 to S5 around Bidyadhari river and its value ranged from 1.02 - 6.22 µg/gm. Concentration of Pb decreased in stations away from that river and seemed as less contaminated stations. The concentration of Pb is found to be about 25 times and 45 times more than the tolerance limit in surface water and tube well water respectively. Human hairs contained more concentration of Pb than that in water. Average concentration of Pb in human hairs was 2.78 and 3.73 µg/gm in less polluted station (S5) and more polluted stations (S1 to S4) respectively indicating bio-magnification of Pb in man. Tube well water appears to be more polluted than the river water and supposed to be a major threat of Pb pollution in the Bidyadhari estuary, West Bengal, India.

Keywords: Lead, Water, Sediment, Human hair, Bidyadhari estuary, Sundarban.

INTRODUCTION

Indian Sundarban delta (21°40'N - 22°40'N and 88°03'E - 89°07'E) is the largest mangrove based wetland in the world, lies on the southern fringes of the state of West Bengal, where the Gangetic plain meets the Bay of Bengal. This deltaic lobe is famous for its genetically diverse biotic resources and refuges of more than 4.4 million people. Open access to natural resources play an important role in supporting the livelihood of the burgeoning human population in the Sundarban delta. Rapid industrialization and urbanization have contaminated the riverine and estuarine ecosystem of Sundarban to a great extent (Mitra *et al*. 2010). Bidyadhari river originated near

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Haringhata in Nadia district of West Bengal, India and then flows through North 24 Parganas district before confluence with the larger Raimangal river in the Sundarban (Bhattacharya *et al.* 2014a). Mushrooming of industries like papers, textiles, chemicals, pharmaceuticals, plastics, shellac, leather, jute, pesticides etc along the banks of Hooghly-Matla-Bidyadhari estuarine complex served as the predominant source of metal pollution in the Sundarban region.

Huge quantity of metropolitan waste along with agricultural and urban runoff from Kolkata and North 24 Parganas district is carried through a discharge canal and emptied into the out fall on Bidyadhari river. The pollution discharged is pushed upwards during high tides and remained in the estuary for quite a long time (Bhattacharya *et al*. 2014b).

Hair analysis allows for an assessment of the contamination of natural environment, which is particularly important for the research on populations in habitation areas with different degrees of pollution (Baran and Wieczorek 2013). Toxic elements occur naturally in the environment and also get accumulated from anthropogenic sources. Heavy metals may enter human body through food, air, water or absorption through skin. Exposure can be from agricultural, manufacturing, industrial and other occupational exposures also (Chojnacka *et al*. 2012). For several years, human hair has been used to assess human exposure to heavy metals because toxic heavy metals can get accumulated in hair for a long time. The concentration of metals in hair sample is found to be high compared with those in body tissues or fluids (Pengping and Kungwankunakorn 2014). There are some significant changes in hair Cd, Cu, Zn and Pb concentrations, depending on the place of residence of the hair donors (Srogi 2004). Head hair accumulated metal concentration in the order Zn > Mn > Cu > Pb > Cd > Hg. Age and location strongly influenced metal concentration however no significant relationship was found between gender and metal concentration in Kenya (Otieno 2011). Pb is used in smelting and soldering works, painting, manufacture of batteries and in automobile fuel and is a neurotoxin. Its exposure may lead to inhibition of blood synthesis resulting into anaemia, kidney malfunctioning, cerebral oedema, gastro-intestinal and respiratory disorders (Mehra and Juneja 2004). Metals can enter the human body because of dispersion on the soil, directly through inhalation and contact, through drinking of contaminated water and, via assumption of vegetables themselves with high metal burden. The exposure to these metals is a continuous daily process, as they can be found at the place of work, in potable water, in food and in the air (Goyer 1996). Presence of large amount of heavy metals including Pb in human hair was observed in war torn Gaza strip where cast lead were freely used in the arsenals (Manduca *et.al*. 2010). Metals can enter an organism via different routes, from the air, water, food or pharmaceuticals applied through skin and the respiratory tract. Afterwards, they are transported and distributed through blood into organs (*i,e.* liver, kidney) and removed from the organism through the following excretory pathways: sweat, hair, urine and faeces (Lee *et al*. 2000; Apostoli 2002). Renal failure is related to contaminated drinking water with Pb and cadmium, liver cirrhosis to copper and molybdenum, hair loss to nickel and chromium, and chronic anemia to copper and cadmium. Studies of these diseases suggest that abnormal incidence in specific areas is related to industrial wastes and agriculture activities that have released hazardous and toxic materials in the groundwater and thereby led to the contamination of drinking water in these areas (Salem *et al*. 2000).

Studies have been reported in relation to heavy metal contamination including Pb in different biotic and abiotic components in different regions of Sundarban (Khan 1995; Guhathakurta and Kaviraj 2000; Kwokal *et al*. 2008, Chatterjee *et al*. 2009, Bhattacharyya *et al*. 2010). However, literature is scarcely available on Pb contamination in Sundarban region focusing Bidyadhari estuarine stretches. Presence of toxic Pb in environment can affect aquatic and terrestrial life. The present study was undertaken to highlight the level of total Pb in surface water and sediment of river and ponds; ground water and hairs from local inhabitants of the different stations in and around the Bidyadhari river.

MATERIALS AND METHODS

Seasons and stations: Study was conducted in and around Bidyadhari river in different seasons of pre-monsoon (March-June), monsoon (July-October) and post-monsoon (November- February) period from March, 2012 to February, 2013, in five different stations Kulti-Ghushighata (S1) where metropolitan sewages discharged and mixed up into water of Bidyadhari river which ultimately flowed via Malancha (S2), Kanmari (S3) to Dhamakhali (S4), just before the river confluences with the larger Raimangal river at Sundarban delta. Kulti-Ghushighata (22º 31.37'N, 88º 41.53'E) and Malancha (22º 30.69'N, 88º 46.16'E) located at the northwest side of the river and having a large number of brick kilns and aquaculture impoundments (*Bheries*) at either sides of the river. Being mostly populated area in comparison to other stations, Malancha having more anthropogenic activities and small scale industries, more agricultural activities, brackish water fish culture, automobile emissions, rechargeable battery production units etc. Kanmari (22º 26.46'N, 88º 48.24'E) lies at a considerable distance from the waste outfall point of the river and dominated by huge aquaculture activities. In Dhamakhali (22º 21.33'N, 88º 52.59'E), lot of pollution load containing industrial and municipal wastes along with agriculture runoff from catchment area of upstream Ichamati river through a small branch is discharged into the Bidyadhari river and create a cumulative effect of pollution load. The fifth station Dhuturdaha (S5), (22º 27.08'N, 88º 42.50'E) situated at about 5.5 Km aerial distance from the river where influence of river was considered quite lesser than other stations having more agricultural activities and freshwater aquaculture impoundments.

Water and sediments from river, pond and from human hair were considered to find the contamination status of Pb in the present study.

Sample collection and preservation

Collection of samples: All the samples (n=6) were collected randomly during each study season from all the stations, processed and preserved until analysis as follows:

(i) Water: Samples of surface water from river (high and ebb-tide) and ponds, and ground water from tube wells were collected in watertight pre acid treated neutral polyethylene containers separately from the sampling stations.

(ii) Sediment: Sediment samples were collected randomly from the 0-5 cm of sediment layer using soil core sampler from the river and ponds and placed into pre acid washed and cleaned polyethylene containers. Soil samples were oven dried at 40?C, ground and passed through 63 µm sieve and stored in polyethylene containers.

(iii) Human scalp hair: Samples of scalp hair of the local women only were collected and were rinsed with acetone and water (Trojanowski *et al*. 2010) and stored in zipped polythene pouches.

Estimation of Pb: Total Pb in all samples was quantified by wet ashing procedure in hot plate. Water was digested with 70% nitric acid as per the method of Carbrey *et al*. (2009) while other samples were digested using tri-acid mixture of nitric acid, perchloric acid and sulphuric acid at 10:4:1 ratio by volume following modified methods of Welsch *et al*. (1990) and Datta *et al*. (2010). Estimation of Pb content of the samples was done by Atomic Absorption Spectrophotometer (AAS) (Model: VARIAN AA 240) using air-acetylene flame, through standard procedure.

RESULTS

Observations and results obtained from this study regarding occurrence of Pb at different stations and in different substrates are summarized in the tables and graphical presentations.

DISCUSSION

The results has conclusively proved that the water of all three different sources like river, pond and tube well contained Pb, concentration of which varied from 0.32 to 4.76 µg ml^{-1}, and maximum being recorded in pond water at station S1 in the post monsoon period, while the minimum is recorded in the tube well water in pre monsoon season at station S5.

Usually higher concentration of Pb has been observed in surface water of river and ponds as well as ground water of tube wells at all the sites during monsoon or post monsoon in comparison to pre monsoon season (Table 1). According to De Smedt *et al*. (1998), anoxic condition of estuary in summer (due to excess environmental temperature) enabling the formation of lead sulphide which precipitates the metal become immobile when sediments are settling to the bottom and ultimately lessen the Pb concentration in water and upper sediment of the estuary. During monsoon, further downstream in the seaward direction, the lead sulphide is mobilized again, when dissolved oxygen concentration increase and oxidize lead sulphide and form soluble salt of Pb. Thus, Pb concentration in water and upper sediment is enhanced again in the estuary. During post monsoon, estuaries possess higher dissolved oxygen in water bodies due to lower ambient temperature as well as more soluble Pb salts in waters.

Similar trend of higher accumulation of Pb during monsoon and post-monsoon season in the water of river, pond and tube well at all the stations suggested the alarming state of Pb reaching the ground water table through down ward percolation and finally entering human body system. While the yearly arithmetic mean concentration of Pb in the river water (2.37 µg ml^{-1}) and in the pond water (2.56 µg ml^{-1}) in the stations from S1 –S4 (Table 2) is more than 23 and 25 times respectively than the permissible level of Pb 0.10 µg ml^{-1} (BIS 1992), the same is about 45 times more than the permissible limit in the tube well waters (2.29 µg ml^{-1}). This therefore confirms the findings of Goyer 1996, Lee *et al*. 2000 and Apostoli 2002 that heavy metals like Pb get entry in human system through drinking water. As presented in Fig 1, both pond water and tube well water contains dissolved Pb much above the safe permissible level. Both of these two sources of water serve as drinking water to the common people of the region under study, who are therefore more susceptible to Pb pollution and its deleterious effects.

According to Odem *et al*. (2000), anaerobic condition (low oxygen) prevail in continuously flooded soil (like river) because microbes use up the small amount of dissolved oxygen in soil water. In anoxic condition, sulphate reducing bacteria reduce sulphate to sulphide which then reacts with lead and other heavy metals to precipitate as microscopic water insoluble solid particles of metal sulphides. Thus, in general, the lotic Bidyadhari river having constant flow of water exhibited less Pb concentration in its water and sediment in comparison to the lentic pond water and sediment (Table 1).

Concentration of Pb in the sediment of river and pond is found to be more than that in the water in all the stations proved the presence of insoluble Pb salts in the sediments, however, such remaining much below the permissible limit (Table 2 and Fig. 1). According to De Smedt *et al*. (1998), heavy metals are strongly adsorbed by estuarine sediments, which act as

Table 1: Seasonal concentration (Mean ± SE) of total Pb (μg ml^{-1} or μg g^{-1}) present in different substrate at different stations of Bidyadhari estuary.

Substrates	Season	Pb (μg ml^{-1} or μg g^{-1}) Stations				
		S-1	S-2	S-3	S-4	S-5
River water	Pre-Monsoon Mean	1.49±0.12	1.26±0.08	1.32±0.08	1.79±0.10	NA
	Monsoon Mean	1.22±0.07	2.74±0.13	2.86±0.12	4.04±0.46	NA
	Post-Monsoon Mean	3.45±0.27	2.38±0.10	2.76±0.11	3.13±0.25	NA
River sediment	Pre-Monsoon Mean	3.96±0.28	2.97±0.30	2.99±0.16	4.16±0.15	NA
	Monsoon Mean	1.60±0.04	3.87±0.20	4.03±0.20	6.04±0.21	NA
	Post-Monsoon Mean	4.96±0.15	3.81±0.19	3.89±0.20	4.35±0.18	NA
Pond water	Pre-Monsoon Mean	1.73±0.14	1.08±0.09	1.16±0.06	2.05±0.29	1.02±0.09
	Monsoon Mean	2.24±0.17	2.59±0.08	2.75±0.07	2.80±0.09	1.89±0.10
	Post-Monsoon Mean	4.76±0.63	3.02±0.18	3.15±0.22	3.36±0.24	2.72±0.12
Pond sediment	Pre-Monsoon Mean	5.16±0.24	4.23±0.28	4.37±0.29	6.22±0.29	3.46±0.18
	Monsoon Mean	2.87±0.09	3.41±0.09	4.16±0.25	5.28±0.27	2.59±0.24
	Post-Monsoon Mean	4.55±0.12	4.00±0.27	4.08±0.11	4.44±0.23	3.92±0.23
Tube well water	Pre-Monsoon Mean	1.91±0.08	0.83±0.08	1.17±0.07	2.14±0.14	0.32±0.03
	Monsoon Mean	0.58±0.12	1.77±0.13	3.14±0.13	3.21±0.11	0.50±0.10
	Post-Monsoon Mean	3.54±0.11	2.68±0.13	3.03±0.10	3.44±0.13	2.24±0.08
Human hair	Pre-Monsoon Mean	4.55±0.30	3.11±0.16	3.90±0.26	5.17±0.48	2.94±0.29
	Monsoon Mean	2.32±0.06	3.18±0.32	3.28±0.20	4.96±0.27	2.25±0.06
	Post-Monsoon Mean	3.73±0.59	3.26±0.12	3.54±0.29	3.69±0.10	3.17±0.12

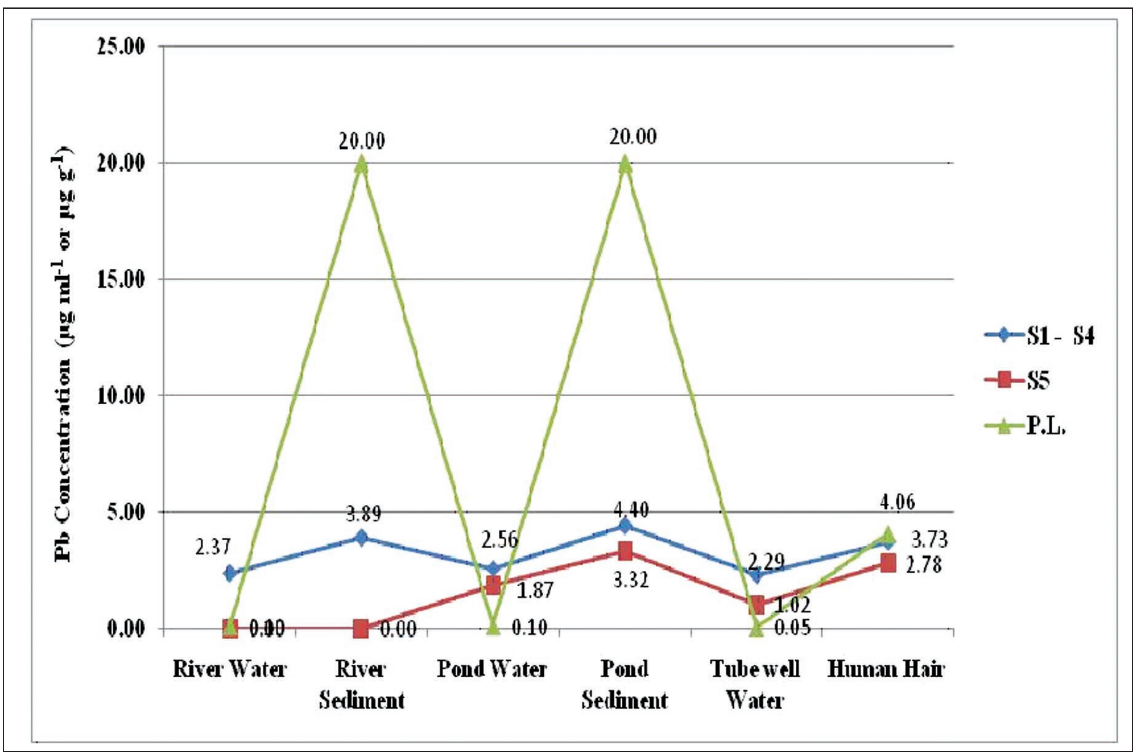
NA: Not applicable

Table 2. Yearly arithmetic mean concentration of Pb (µg ml^{-1} or µg g^{-1}) in different substrates at S1-S4 in comparison to S5 of Bidyadhari estuary with permissible levels.

Substrates	Pb (µg/ml or µg/gm) Stations		Permissible levels (P.L.)	Sources
	S1 - S4	S5		
River Water	2.37	NA	0.10	BIS (1992)
River Sediment	3.89	NA	20.00	Turkian & Wedepohl (1961)
Pond Water	2.56	1.87	0.10	BIS (1992)
Pond Sediment	4.40	3.32	20.00	Turkian & Wedepohl (1961)
Tube well Water	2.29	1.02	0.05	BIS (1992)
Human Hair	3.73	2.78	4.06	Kaniewski *et al.* (1997)

reservoir for these metals and make that considerable ecotoxicological risks in the estuary. In general, the metals are present at a lower concentration in sediment than in solution phase might be due to the neutral to alkaline pH of the estuarine water which effected metals

Fig. 1. Yearly arithmetic mean concentration of Pb (µg ml^{-1} or µg g^{-1}) in different substrates at stations S1-S4 in comparison to S5 of Bidyadhari estuary with permissible levels (P.L.).



released into the river system to remain associated with solid (suspended or dissolved) and sediment, mostly (Aktar *et al*. 2011). Most of the heavy metals have precipitated and settled as carbonates, oxides, and hydroxides bearing sediments and elevated levels indicate higher exposure risks to the benthic biota of the river and ponds (Singh *et al*. 2005).

Thus the vegetation might absorb lower amount of Pb from the sediment than that of water soluble forms. Above finding indicated less flow of Pb from the sediment to the biotic pathway to enter the human system finally. However this aspect remained out of scope of the present study.

Among all the stations, the station Dhuturdaha (S5) is only situated far away from the river has always the least Pb content in all the substrates through over the year (Table 1, 2; Fig. 1). This observation indicated that sewage and industrial effluents bearing river Bidyadhari definitely has a role in disseminating this heavy metal more in its estuarine ecosystem through over its stretches from S1 to S4 in comparison to distant station S5. This observation has re-established the theory of anthropogenic inputs of pollutants in nature.

Pb is found to have got deportation in the human hair with a minimum deposition of 2.25 $\mu g\ g^{-1}$ at station S5 (during monsoon) and a maximum deposition of 5.17 $\mu g\ g^{-1}$ (during pre-monsoon) at station S4. A positive correlation therefore exists between the lower depositions of Pb in other substrates and in human hair in S4 (Table 1 and Fig. 1). However, a higher deposition of Pb in human hair has been confirmed in all the study stations in comparison to different water substrates. Present study therefore corroborates the findings of Manduca *et al*. (2010) that hair has the potential of being an excellent bio-monitor due to its historical representation of intake over prior weeks to years and can be utilized for investigating the exposure of individuals or populations to heavy metal pollutants like Pb.

Further studies on the transmission of Pb from different anthropogenic sources through different biotic and abiotic substrates finally reaching human body through different diffused routes may enrich our knowledge bank on this aspect.

CONCLUSION

Sewage and effluents from various industries along with agricultural runoff from Kolkata metropolis and North 24 Parganas, West Bengal carried through different sewage canals and discharged in Bidyadhari river are not only caused Pb contamination of that river but also contaminated the other surface and ground water sources like pond water and tube well water around the river. All water substrates having Pb concentration is above the permissible levels during most time of the year at riverine stations from Kulti-Ghushighata (S1) to Dhamakhali (S4) whereas, Pb contamination is the lowest at Dhuturdaha (S5) situated 5.5 km away from the river. In relation to permissible level, tube well water appears to be more polluted in comparison to river and pond water and supposed to be a major threat of Pb pollution in the Bidyadhari estuary. The highest concentration of Pb in human hair compared to water available at those stations indicated probable bioaccumulation of the Pb in human body. Enhancement of Pb level in the river water and its dissemination in other substrates of the Sundarban may be dangerous for the estuarine ecosystem as well as grave concern for the public health of Sundarban delta. Further studies are needed to understand the ecotoxicological cycling of Pb in mangrove ecology. Excessive using of Pb based commodities in West Bengal and its wastes disposal in Bidyadhari river might cause the serious Pb pollution in Sundarban mangrove land mass in near future. To mitigate the upcoming pollution due to this possible carcinogenic heavy metal, the sources of Pb and its transport process in the ecosystems need to be identified, quantified and evaluated properly.

ACKNOWLEDGEMENT

Authors are thankful to Vice-Chancellor, West Bengal University of Animal and Fishery Sciences; Dean, Faculty of Veterinary and Animal Sciences, WBUAFS and Head, Department of Pharmacology and Toxicology, WBUAFS, Kolkata, India for providing necessary permission and laboratory facilities to do the research work.

REFERANCES

Aktar MW, Sengupta D, Chowdhury A (2011) Occurrence of heavy metals in fish: a study for impact assessment in industry prone aquatic environment around Kolkata in India. Environ Monit Assess 181: 51–61.

Apostoli P (2002) Elements in environmental and occupational medicine. J Chromatogr B 778: 63-72.

Baran A, Wieczorek J (2013) Concentrations of heavy metals in hair as indicators of environmental pollution. E3S Web of Conferences 1,21005. EDP Sciences, 2013.

Bhattacharya S, Dash JR, Patra PH, Dubey SK, Das AK, Mandal TK, Bandyopadhyay SK (2014a) Spatio-temporal variation of mercury in Bidyadhari river of Sundarban delta, India. Explor Anim Med Res 4(1): 19-32.

Bhattacharya S, Dubey SK, Dash JR, Patra PH, Das AK, Mandal TK, Bandyopadhyay SK (2014b) Assemblages of total mercury in the tropical macrotidal Bidyadhari estuarine stretches of Indian Sundarban mangrove eco-region. J Environ Anal Toxicol 4: 241.

Bhattacharyya S, Chaudhuri P, Dutta S, Santra SC (2010) Assessment of Total Mercury Level in Fish Collected from East Calcutta Wetlands and Titagarh Sewage Fed Aquaculture in West Bengal, India. Bull Environ Contamin Toxicol 84: 618–622.

BIS (1992) Drinking Water Specifications IS: 10500; 1992 (Reaffirmed 1993). Bureau of Indian Standard, New Delhi, India.

Carbrey JM, Song I, Zhou Y, Yoshinaga M, Rojek A, Wang Y, Liu Y, Lujan HI, Dicarlo SE, Nielson S, Rosen BP, Agre P, Mukhopadhyay R (2009) Reduced arsenic clereance and increased toxicity in aquaglyceroporin-9-null mice. Proc Nat Acad Sci, USA. 106 (37): 15956-15960.

Chatterjee M, Canario J, Sarkar SK, Branco V, Bhattacharya A, Satpathy KK (2009) Mercury enrichments in core sediments in Hugli–Matla–Bidyadhari estuarine complex, north-eastern part of the Bay of Bengal and their ecotoxicological significance. Environ Geol 57: 1125-1134.

Chojnacka K, Saeuid A, Michalak I, Mikulewicz M (2012) Effects of local industry on heavy metals content in human hair. Pol J Environ Stud 21(6): 1563-1570.

Datta BK, Mishra A, Singh A, Sar TK, Sarkar S, Bhattacharya A, Chakraborty AK, Mandal TK (2010) Chronic arsenicosis in cattle with special reference to its metabolism in arsenic endemic village of Nadia district West Bengal India. Sci Total Environ 409(2): 284-288.

De Smedt F, Vuksanovic V, Van Meerbeeck S, Reyns D (1998) A time-dependent flow model for heavy metals in the Scheldt estuary. Hydrobiologia 366: 143-155.

Goyer R A (1996) Toxic effects of metals. In: Casarett and Doull’s toxicology: The basic science of poisons. (C D Klaassen, M O Amdur and J Doull, Eds,), 5th edn., Mc.GrawHill, New York : 691-736.

Guhathakurta H, Kaviraj A (2000) Heavy metal concentration in water, sediment, shrimp (*Penaeus monodon*) and mullet (*Liza parsia*) in some brackish water ponds of Sunderban, India. Mar Pollut Bull 40(11): 914-920.

Kaniewski A, Takagi Y, Marcinkowski JT (1997) Concentrations of 21 elements in hair of people living in Poznan. Probl Med Spol 32: 391- 396.

Khan RA (1995) Ecology of Kulti estuary with reference to discharge of Calcutta metropolitan sewage. Hugli Matla Estuary, Estuarine Ecosystem Series Part-2, Zool Surv India. 465-495.

Kwokal Z, Sarkar SK, Chatterjee M, Franciskovic-Bilinski S, Bilinski H, Bhattacharya A, Bhattacharya BD, Md Alam A (2008) An assessment of mercury loading in core sediments of Sundarban mangrove wetland, India (A preliminary report). Bull Environ Contam Toxicol 81: 105–112.

Lee W C, Lee S M, Kim J S, Bae C S and Parka T K (2000) An observation on the mercury contents of scalp hair in the urban residents of South Korea. Envron Toxicol Pharmacol 8: 275-286.

Manduca P, Barbieri M, Barbieri M (2010) Analysis of pilot survey of Metal content in samples of hair collected in December 2009 in Gaza. www.newsweapons.org

Mehra R, Juneja M (2004) Biological monitoring of Pb and cadmium in human hair and nail and their correlations with biopsy materials, age and exposure. Indian J Biochem Biophy 41: 53-56.

Mitra A, Banerjee K, Ghosh R, Ray SK (2010) Bioaccumulation pattern of heavy metals in the shrimps of the lower stretch of the river Ganga. Mesopot J Mar Sci 25: 1-14.

Odem HT, Wôjcik W, Pritchard L (Jr.), Ton S, Delfino JJ, Wôjcik M, Leszczynski S, Patel JD, Doherty SJ, Stasik J (2000) Heavy Metals in the Environment: Using Wetlands for their Removal. Lewis Publishers. 42.

Otieno P Abuor (2011) Determination of Heavy Metals in Scalp Hair of Selected Kenyan Urban and Rural Population. M.Sc dissertation. 1-63

Pengping S, Kungwankunakorn S (2014) Determination of Some Heavy Metals in Human Hair by Ultrasonic Acid Digestion and Atomic Absorption. Chiang Mai J Sci 41(1): 148-155.

Salem H M, Eweida A E, Farag A (2000) Heavy metals in drinking water and their environmental impact on human health. *ICEHM*, Cairo University, Egypt. 542- 556.

Singh KP, Mohan D, Singh VK, Malik A (2005) Studies on distribution and fraction of heavy metals in Gomti river sediments- a tributary of the Ganges, Indian J Hydrol 312: 14-27.

Srogi K (2004) Heavy metals in human hair samples from Silesia province: the influence of sex, age and smoking habit. Problems Forensic Sci LX: 7–27.

Trojanowski P, Trojanowski J, Antonowicz J, Bokiniec M (2010) Pb and cadmium content in human hair in Central Pomerania (Northern Poland). J Elementol 15(2): 363-384.

Turkian KK, Wedephol KH (1961). Distribution of the elements in some major units of the earth's crust. Bullet Geol Soc Americ. 72: 175-192.

Welsch EP, Crock JG, Sanzolone R (1990) Trace-level determination of arsenic and selenium using continuous- flow hydride generation atomic absorption spectrophotometry (HG-AAS). Quality assurance manual for the branch of geochemistry. U.S. Geol Surv, Reston. 38-45.

***Cite this article as:** Bhattacharya S, Chattopadhyay A, Das AK, Mandal TK, Bandyopadhyay SK (2016) Lead contamination status in abiotic components and human hair around Bidhyadhari estuary of Indian Sundarban delta. Explor Anim Med Res 6(2): 150-158.