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Research Article

CONTAMINATION STATUS OF CADMIUM IN DIFFERENT BIOTIC AND ABIOTIC COMPONENTS AROUND THE BIDHYADHARI RIVER OF INDIAN SUNDARBAN DELTA

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ABSTRACT: This study has been conducted to estimate the concentration of total Cadmium (Cd) in different biotic and abiotic substrates including human in and around the Bidyadhari river of Sundarban delta. Bidyadhari river presently serves as a sewage and excess rainwater outlet from Kolkata metropolitan and adjacent area, which ultimately empties at the Bay of Bengal. The study reveals that the Cd content in surface water of the river and ponds as well as ground water was generally high up to 0.294 µg/ml and 0.205 µg/ml respectively during most of the seasons, which was above the maximum permissible level for drinking water as per various national and international standards like Indian Standard Specification, European Union, WHO, USEPA etc. Though, range of Cd in sediment of the river and ponds was 0.025 to 0.281µg/g and 0.018 to 0.317µg/g respectively but that was considerably higher in grasses up to 0.324µg/g. Backyard hen demonstrated considerably high levels of Cd in their egg up to 0.247µg/g in albumen and 0.272 µg/g in yolk. Goat and cattle demonstrated Cd content in meat up to 0.295µg/g and milk up to 0.295µg/ml respectively which crosses the permissible levels recommended by different international standards. High Cd content in human hairs up to 1.11µg/g indicated considerably bioaccumulation of the metal in local inhabitants resides in the northern part of Sundarban mangrove eco-region. This whole observation may be considered as base line study to know the present status of Cd contamination and bioaccumulation in flora and fauna including humans in Sundarban mangrove eco-region to prepare mitigation planning against this carcinogen from the biota immediately.

Key words: Cadmium, Sundarban delta, Bidyadhari river, High tide, Ebb tide, Pond water, Tube well water, Sediment, Egg, Milk, Meat, Human hairs.

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INTRODUCTION

Indian Sundarban delta (21°40'N and 22°40'N, lat and 88°03'E and 89°07'E long) 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 more than 40 million people. Open access to biological 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). Multifarious industries like papers, textiles, chemicals, pharmaceuticals, plastics, shellac, leather, jute, pesticides etc situated in the bank of Hooghly-Matla-Bidyadhari estuarine complex are the predominant source of metal pollution in Sundarban region.

Bidyadhari river originates near 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). Presently the river is being used as the major drainage system and serves as sewage outlet for Kolkata metropolis and adjacent areas of North 24 Parganas district. Due to siltation, the Bidyadhari river does not receive any water supply from the Hooghly river in the western sector and is tide fed in nature receiving the tidal flux from Bay of Bengal. A small branch of Ichamati river is joined with the Bidyadhari river at Nazat near Dhamakhali which carries some freshwater as well as pollution load from the catchment areas of Ichamati river. Huge quantity of metropolitan waste, excess rainwater along with agricultural and urban runoff from Kolkata city and North 24 Parganas district is carried through a long dry weather-storm water flow combined canal and discharged into the out fall on Bidyadhari river at Kulti-Ghushighata at about 35 Km away from south east fringe of Kolkata city. The pollution discharged was pushed above during high tides and remains in the estuary for quite a long time during ebb tides (Bhattacharya *et al.,* 2014b).

Heavy metals like Cadmium (Cd) are released into the environment by different sources like mining, fertilizer industry, agriculture, tobacco uses etc. raising environmental and human health concerns (Alam *et al.,* 2011). Cd has been classified as Class 1 carcinogenic to humans by the International Agency for Research on Cancer (IARC 2012). In aquatic systems, Cd is most readily absorbed by organisms directly from the water in its free ionic form Cd (II) and chronic Cd exposure produces a wide variety of acute and chronic effects in birds and mammals including humans (EU 2002). Osteoporosis, skeletal damage, kidney dysfunction and lung emphysema are the primary effects of high Cd in human and it is also a risk factor associated with early atherosclerosis and hypertension which lead to cardiovascular disease (Järup 2003).

High levels of heavy metal pollutants in general and Cd in particular are found in water, soil and fodder near various industrial and municipal sewage fed areas of India and many other countries which has potentiality to accumulate in the food chain where human is at the apex of the ecosystem. Higher level of heavy metals found in the organs and tissues of food animals and livestock is a serious concern in many developed and developing countries like India (Rajaganapathy *et al.,* 2011). Many works were done in relation to heavy metal contamination including Cd in different biotic and abiotic components at Sundarban region focusing western, central and eastern part (Bhattacharyya *et al.*, 2010; Chatterjee *et al.*, 2009, 2012; Guhathakurta and Kaviraj 2000; Khan 1995; Kwokal *et al.*, 2008, 2012). But, a little information is available pertaining Cd contamination status in Sundarban region focusing Bidyadhari estuarine stretches. Since, carcinogenic substance like Cd in excessive amount in environment can affect aquatic as well as terrestrial life, it is thus necessary to benchmark the baseline concentrations of Cd in the Bidhyadhari estuarine ecosystem and also to identify specific components that may be

Table 1: Inter seasonal concentration of Cd (ug/ml) in waters of river during high tides and ebb tides, ponds and tube wells at different stations around the course of Bidhyadhari river (Mean ± SE of six replicates).

Substrate	Station	Pre-Monsoon	Monsoon	Post-Monsoon	Sites based on maximum concentration
River Water-High tides	S1	0.098 ± 0.009	0.180 ± 0.017^{a}	0.144 ± 0.010 ^{a}	S1>S2>S3>S4
	S2	0.092 ± 0.006	0.162 ± 0.009^{a}	0.108 ± 0.006 ^{b}	
	S3	0.015 ± 0.007	0.128 ± 0.007 ^{b}	0.160 ± 0.006 ^{a}	
	S4	0.040 ± 0.006 ^{b}	0.091 ± 0.004 ^{c}	0.155 ± 0.006 ^{a}	
River Water-Ebb tides	S1	BDL ^{b}	0.155 ± 0.040	0.136 ± 0.008 ^{b}	S4>S2>S1>S3
	S2	0.047 ± 0.016 ^{a}	0.170 ± 0.008	0.144 ± 0.015 ^{b}	
	S3	0.014 ± 0.004 ^{b}	0.138 ± 0.008	0.131± 0.012 ^{b}	S4>S1>S2>S3 (Cumulative)
	S4	0.005 ± 0.003 ^{b}	0.127 ± 0.010	0.294 ± 0.021 ^{a}	
Pond Water	S1	0.112 ± 0.009 ^{a}	0.155 ± 0.019 ^{b}	0.184 ± 0.023 ^{ab}	S4>S2>S1>S3>S5
	S2	0.067 ± 0.021 ^{b}	0.181 ± 0.013 ^{b}	0.217 ± 0.024 ^{a}	
	S3	BDL ^{c}	0.148 ± 0.016 ^{b}	0.133 ± 0.013 ^{bc}	
	S4	BDL ^{c}	0.294 ± 0.009 ^{a}	0.156 ± 0.010 ^{b}	
	S5	BDL ^{b}	0.087 ± 0.003 ^{c}	0.083 ± 0.018 ^{c}	
Tube well Water	S1	0.069 ± 0.004 ^{a}	0.130 ± 0.007 ^{bc}	0.205 ± 0.016 ^{a}	S1>S4>S2>S3>S5
	S2	0.053± 0.003 ^{b}	0.149 ± 0.019 ^{ab}	0.132 ± 0.007 ^{b}	
	S3	BDL ^{c}	0.106 ± 0.004 ^{c}	0.102 ± 0.004 ^{cd}	
	S4	0.047 ± 0.004 ^{b}	0.164 ± 0.006 ^{a}	0.124 ± 0.011^{bc}	
	S5	BDL ^{c}	0.059 ± 0.003 ^{d}	0.088 ± 0.004 ^{d}	

Different superscripts (a, b, c, d) in same column against any substrate were significantly different ($P < 0.01$) in Tukey's HSD mean separation test.
S1: Kulti-Ghushighata; S2: Malancha; S3: Kanmari; S4: Dhamakhali; S5: Dhuturdaha
BDL: Below detectable limit

Table 2: Inter seasonal concentration of Cd (µg/g) in sediments of river and ponds along with grasses grown at the sides of river and ponds at different stations around the course of Bidhyadhari river (Mean ± SE of six replicates).

Substrate	Station	Pre-Monsoon	Monsoon	Post-Monsoon	Hierarchy of sites based on maximum concentration
River Sediment	S1	0.076 ± 0.005^{a}	0.252 ± 0.013^{a}	0.204 ± 0.017 ^{bc}	S4>S1>S2>S3
	S2	0.071 ± 0.006 ^{a}	0.248 ± 0.015^{a}	0.250 ± 0.017 ^{ab}	
	S3	0.034 ± 0.007 ^{b}	0.189 ± 0.012 ^{ab}	0.195 ± 0.019 ^{c}	
	S4	0.025 ± 0.012 ^{b}	0.169 ± 0.034 ^{b}	0.281 ± 0.012 ^{a}	
Pond Sediment	S1	0.180 ± 0.007 ^{a}	0.243b ± 0.019 ^{c}	0.208 ± 0.009 ^{a}	S4>S2>S1>S3>S5
	S2	0.172 ± 0.007 ^{a}	0.259 ± 0.008 ^{b}	0.208 ± 0.003 ^{a}	
	S3	0.026 ± 0.008 ^{b}	0.220 ± 0.016 ^{c}	0.192 ± 0.003 ^{a}	
	S4	0.034 ± 0.007 ^{b}	0.317 ± 0.006 ^{a}	0.198 ± 0.006 ^{a}	
	S5	0.018 ± 0.004 ^{b}	0.149 ± 0.007 ^{d}	0.174 ± 0.004 ^{b}	
Grasses-River side	S1	0.297 ± 0.012 ^{a}	0.175 ± 0.005 ^{a}	0.181 ± 0.006 ^{a}	S1>S2>S3>S4
	S2	0.214 ± 0.009 ^{b}	0.191 ± 0.008^{a}	0.161 ± 0.010 ^{a}	
	S3	BDL ^{c}	0.111 ± 0.004 ^{b}	0.088 ± 0.012 ^{b}	
	S4	BDL ^{c}	0.077 ± 0.007 ^{c}	0.101 ± 0.011 ^{b}	
Grasses-Pond side	S1	0.167 ± 0.019 ^{a}	0.182 ± 0.008 ^{b}	0.163 ± 0.014 ^{a}	S4>S2>S1>S3>S5
	S2	0.131 ± 0.010 ^{b}	0.184 ± 0.003 ^{b}	0.145 ± 0.005 ^{ab}	
	S3	BDL ^{c}	0.163 ± 0.007 ^{c}	0.089 ± 0.004 ^{c}	
	S4	BDL ^{c}	0.324 ± 0.007 ^{a}	0.123b ± 0.011^{c}	
	S5	BDL ^{c}	0.098 ± 0.005 ^{d}	0.033 ± 0.018 ^{d}	

Different superscripts (a, b, c, d) in same column against any substrate were significantly different (P< 0.01) in Tukey's HSD mean separation test
S1: Kulti-Ghushighata; S2: Malancha; S3: Kanmari; S4: Dhamakhali; S5: Dhuturdaha
BDL: Below detectable limit

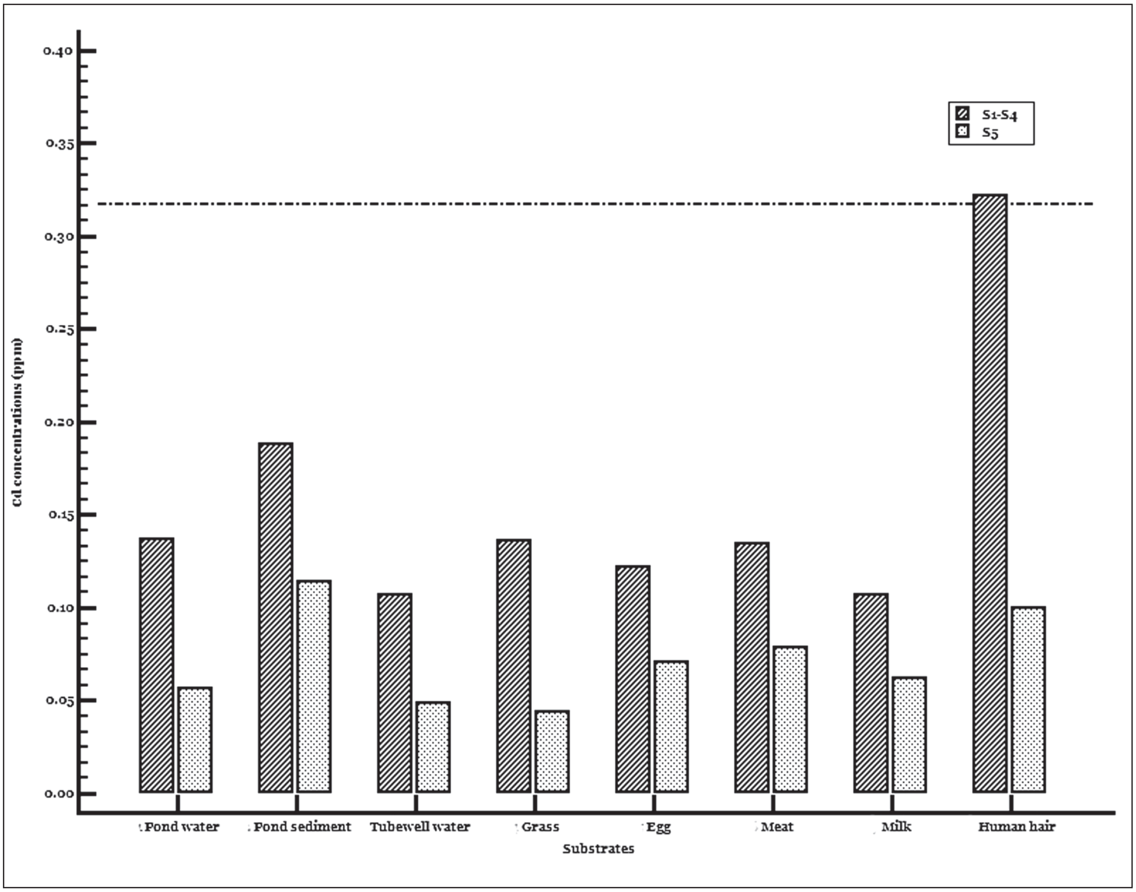
particularly selective and sensitive to accumulation of Cd. In continuation to the fact, the present paper aims to highlight the level of total Cd concentration in different abiotic and biotic substrates of the estuarine ecosystem of Bidyadhari river *viz*., surface water and sediment of river and ponds, ground water, grasses grown at river and pond sides, eggs of backyard hen, meat and milk from the free ranged goat and cow respectively, and hairs

Table 3: Inter seasonal concentration of Cd (μg/g or μg/ml) in eggs (albumins and yolks), cow milks, goat meats (chevon) and human scalp hairs at different stations around the course of Bidhyadhari river (Mean ± SE of six replicates).

Substrate	Station	Pre-Monsoon	Monsoon	Post-Monsoon	Hierarchy of sites based on maximum concentration
Egg-Albumen	S1	BDL	0.183 ± 0.010^{b}	0.156 ± 0.014^{a}	S4>S2>S1>S3>S5
	S2	BDL	0.202 ± 0.010^{b}	0.144 ± 0.004^{a}	
	S3	BDL	0.157 ± 0.006^{c}	0.123 ± 0.005^{ab}	
	S4	BDL	0.247 ± 0.008^{a}	0.129 ± 0.012^{ab}	
	S5	BDL	0.087 ± 0.006^{d}	0.099 ± 0.022^{b}	
Egg- Y olk	S1	BDL	0.188 ± 0.011^{c}	0.219 ± 0.011^{a}	S4>S2>S1>S3>S5
	S2	BDL	0.226 ± 0.011^{b}	0.173 ± 0.006^{b}	
	S3	BDL	0.185 ± 0.013^{c}	0.154 ± 0.008^{b}	
	S4	BDL	0.272 ± 0.017^{a}	0.157 ± 0.007^{b}	
	S5	BDL	0.107 ± 0.006^{d}	0.128 ± 0.009^{c}	
Cow Milk	S1	BDL	0.165 ± 0.002^{b}	0.152 ± 0.005^{a}	S4>S2>S1>S3>S5
	S2	BDL	0.165 ± 0.010^{b}	0.145 ± 0.014^{a}	
	S3	BDL	0.118 ± 0.007^{c}	0.112 ± 0.012^{ab}	
	S4	BDL	0.295 ± 0.011^{a}	0.131 ± 0.012^{a}	
	S5	BDL	0.105 ± 0.003^{c}	0.081 ± 0.026^{b}	
Goat Meat (Chevon)	S1	0.116 ± 0.007^{a}	0.177 ± 0.012^{bc}	0.161 ± 0.005^{a}	S4>S2>S1>S3>S5
	S2	0.107 ± 0.008^{a}	0.203 ± 0.026^{b}	0.145 ± 0.007^{ab}	
	S3	BDL^{b}	0.153 ± 0.006^{cd}	0.130 ± 0.005^{bc}	
	S4	BDL^{b}	0.295 ± 0.008^{a}	0.139 ± 0.009^{b}	
	S5	BDL^{b}	0.125 ± 0.005^{d}	0.113 ± 0.005^{c}	
Human Scalp Hairs	S1	0.318 ± 0.023^{a}	0.511 ± 0.099^{ab}	0.205 ± 0.023^{a}	S4>S2>S1>S3>S5
	S2	0.306 ± 0.029^{a}	0.690 ± 0.148^{ab}	0.175 ± 0.027^{ab}	
	S3	BDL^{b}	0.293 ± 0.022^{b}	0.118 ± 0.034^{b}	
	S4	BDL^{b}	1.109 ± 0.455^{a}	0.134 ± 0.023^{ab}	
	S5	BDL^{b}	0.185 ± 0.014^{b}	0.114 ± 0.020^{b}	

Different superscripts (a, b, c, d) in same column against any substrate were significantly different ($P< 0.01$) in Tukey's HSD mean separation test
S1: Kulti-Ghushighata; S2: Malancha; S3: Kanmari; S4: Dhamakhali; S5: Dhuturdaha
BDL: Below detectable limit

Fig 1: Yearly Mean Cd concentration (μg/g or μg/ml) in different substrates at S1-S4 in comparison to S5.



from local inhabitants of the different areas around the Bidyadhari river.

MATERIAL AND METHODS

Study seasons and sites: To quantify the recent xenobiotic quantum of Cd in different biotic and abiotic components in and around the Bidyadhari river in different seasons of a year *viz.* pre-monsoon (March-June), monsoon (July-October) and post-monsoon (November-February) period from March, 2012 to February, 2013, five different stations situated around the course of the river at considerable distances have been selected. Four stations situated around the course of the river from the outfall of sewage canals at 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 31.368'N, 88º 41.537'E) and Malancha (22º 30.688'N, 88º 46.157'E) were 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 26.464'N, 88º 48.246'E) lies a considerable distance from the waste outfall point of the river and dominated by huge aquaculture activities. In Dhamakhali (22º 21.332'N, 88º 52.595'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 was discharged in to the Bidyadhari river and create a cumulative effect of pollution load. The fifth station Dhuturdaha (S5; 22º 27.080'N, 88º 42.496'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.

Sample collection and storage: All the samples (n=6) were collected randomly during each study season from all the stations, processed and preserved as follows:

Water: Water was collected from river as well as river adjacent ponds and tube wells. Surface water from river was collected during high-tide and ebb-tide separately. Samples were stored in watertight neutral polyethylene containers previously soaked and washed with 10% nitric acid and double distilled water. The water samples were acidified in the field with concentrated HNO_3 at the rate of 5ml/liter of water sample, to reduce the pH of the sample below 2.0 and stored at 4^0C prior to analysis (Singh *et al.*, 2005).

Sediment: Sediment samples were collected randomly from the 0-5 cm layer using soil core sampler from the river and ponds and placed into pre cleaned polyethylene containers. After that, samples were processed through oven dried at 40^oC; lightly ground, the visible marine organisms and coarse shell fragments along with grass leaves and roots when present were removed manually. Then samples were sieved through 63 µm metallic sieve and stored in acid washed polyethylene containers until analysis.

Grasses: Green blades and stems of the grasses of *Cynodon* species were collected from river as well as pond sides and washed thoroughly with normal water followed by washing with distilled water thrice. Adhered water in grasses was air-dried before placing into pre cleaned polyethylene containers followed by refrigeration at -20^OC until analysis.

Eggs: Fresh eggs from local non-descript hens were collected and washed with normal water followed by distilled water. Adhered water on egg shells was soaked by tissue paper and kept in separate polypropylene container each before its refrigeration at -20^OC until analysis.

Milk: Milk from local free ranged non-descript and/or crossbred cows were collected directly into pre cleaned polypropylene containers and refrigerated at -20^OC until analysis.

Meat (Chevon): Samples of fresh meat (Chevon) of local goat (Breed: Black Bengal, *Capra hircus*) were collected directly from local meat shops in to sterile polypropylene containers and refrigerated at -20^{0}C until analysis.

Human scalp hairs: Naturally fallen hairs during combing preserved by the women of the study area were collected and kept in zipped polythene packets at room temperature.

Estimation of Cd: Total Cd in all samples was quantified by wet ashing procedure in hot plate. Water samples were 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 following some modifications of the method of Welsch *et al.* (1990) and Datta *et al.* (2010). Successive steps of sample preparation as per standard procedure were followed according to method for estimation of Cd in Atomic Absorption Spectrometer (AAS) (Model: VARIAN AA 240) and 10 ml of each sample was estimated in flame mode (Air-acetylene mode). 0, 0.5, 1.0, and 2.0 µg/ml standards were prepared from 10 µg/ml standard Cd solution. Calibration of instrument and standard curve was assured with freshly prepared standards before taking the reading. Absorbance was recorded at wavelength 228.8 nm. Operating parameters and procedures *viz.* instrumental condition operation, preparation of working standard solution, instrument calibration and validation of total metal analysis methods were monitored accordingly. Millipore water was used and all chemicals of analytical grade were purchased from Rankem Pvt. Ltd., E-Merk (India) and Sigma Aldrich (USA).

Statistical analysis: One Way Analysis of variance (ANOVA) was performed to assess whether Cd concentrations varied significantly between and within the sites with a Tukey's HSD means separation test to determine the differences among the means. Probability less than 0.01($P<0.01$) was considered as statistically significant. All statistical analyses were performed with SPSS 10.0 for Windows (SPSS Inc. Chicago, IL USA). All numerical data are represented as the mean ± SE.

RESULTS AND DISCUSSION

Irrespective of tides, hierarchy of sites based on maximum mean Cd concentration in river water as well as in river sediment was S4>S1>S2>S3 and in case of tube well water that hierarchy was S1>S4>S2>S3>S5 during monsoon or post monsoon (Table 1and Table2). The study reveals that the Cd content in surface water of the river and ponds as well as ground water at all the stations was generally high (up to 0.294 µg/ml) during most of the seasons and exceeded the maximum permissible level for drinking water as per Indian Standard Specification, IS: 10500 (0.01 mg/l), European Union Standards, 1998 (0.005 mg/l), WHO, 1993 (0.003 mg/l) (Lenntech BV, 2013) and USEPA (0.002 mg/l). This observation was very much alarming too in consideration to the earlier observation of Haque *et al.*, (2005) who estimated Cd concentration seasonally varied from 0.0045 to 0.013µg/ml in surface water of the rivers and estuaries of Sundarban mangrove forest in Bangladesh.

In case of other substrates *viz.* pond water and sediment, grasses grown around pond sides, eggs (albumen and yolk), cow milk, goat meat and human hairs, the hierarchy of sites based on maximum mean Cd concentration in a year was astonishingly the same as

S4>S2>S1>S3>S5 (Table 1, 2 and 3). That hierarchy in case of grasses grown in river side and high tide of river water were same *i.e.* S1>S2>S3>S4 (Table 1 and 2). During pre monsoon, mean Cd concentrations of river water and sediment, pond sediment, goat muscles and human hairs at S1 and S2 were not significantly differed ($P > 0.05$) which were significantly higher than ($P < 0.05$) that of remaining sites. Cd contents of pond water, tube well water, grasses grown at river side and pond sides at S1 were significantly higher than ($P < 0.05$) that of remaining sites (Table 1, 2 and 3). During monsoon, mean Cd concentration of river water (high tide), grasses grown at river side at S1 and S2 were not differed and significantly higher than ($P < 0.05$) that of remaining sites where as mean Cd contents of pond water, pond sediment, grasses grown at pond sides, egg albumen, egg yolk and cow milk at S4 were significantly higher than ($P < 0.05$) that of remaining sites (Table 1, 2 and 3). Mean Cd concentrations of human hairs at S1, S2 and S4 were homogeneous ($P > 0.05$) and the mean Cd content at S4 was significantly higher than ($P < 0.05$) that of S3 and S5 (Table 3). During post monsoon, mean Cd concentrations of pond water, goat meat and grasses grown at river side and pond sides at S1 and S2 were not differed significantly ($P > 0.05$) where as mean Cd content of river water-ebb tide at S4 was significantly higher than ($P < 0.05$) that of remaining sites (Table 1, 2 and 3). Mean Cd concentrations in pond sediment, egg-albumen, and cow milk were also homogeneous in S1, S2, S3, and S4. Mean Cd contents of human hairs at S1, S2 and S4 were homogeneous and the mean Cd content at S1 is significantly higher than ($P < 0.05$) that of S3 and S5. Again, mean Cd contents at S2, S3, S4 and S5 were also homogeneous (Table 2 and 3).

The concentration of Cd in all sediment samples of both the river and/or ponds at all stations through over the year was ranged between 0.018 ± 0.004 to 0.317 ± 0.006 μg/g (Table 2) which were much below the Ontario Ministry of the Environment (OME) standard for permissible level *i.e.* 1.0 ug/g (Nichols *et al.*, 1991). During the year, mean Cd content in grasses of area of study was varied from BDL to 0.324 μg/g (Table 2) which was also above the permissible maximum level for Cd (0.2 mg/kg) for paddy and leafy vegetables as per National Food Safety Standard of China (2012) and Codex Standard (193-1995).

In different sites, egg samples from back yard hen revealed mean Cd concentration in their albumen and yolk were considerably high levels of ranges from 0.087± 0.006 to 0.247± 0.008 μg/g and 0.107± 0.006 to 0.272± 0.017 μg/g respectively during monsoon or post monsoon (Table 3) which also exceeded the permissible maximum level for Cd (0.05 mg/kg) in eggs as per National Food Safety Standard of China (2012)**.** On the other hand, mean Cd contents in milk samples from cattle were highest during monsoon within the ranges 0.105± 0.003 to 0.295± 0.011μg/ml which also exceeded the Cd concentration in milk (0.05μg/ml) samples in industrial area of Bangaluru, India as reported by Gowda *et al.* (2003). Mean Cd content in goat meat (Chevon) was highest during monsoon within the ranges from 0.125± 0.005 to 0.295± 0.008 μg/g which also exceeded the permissible maximum level for Cd (0.1 mg/kg) in meat and meat products as per National Food Safety Standard of China (2012). Similarly, mean Cd contents in human scalp hair samples were also highest during monsoon within the ranges 0.125± 0.005 to 0.295± 0.008µg/g and 0.185±0.014 to 1.109 ± 0.455µg/g respectively (Table 3).According to Wilson (2012), an acceptable amount of cadmium on a hair tissue mineral analysis is about 0.1µg/gm. A lower reading is even better, as less as 0.05µg/gm. This is very low, but anything higher than this usually indicates excessive cadmium in the body.

In comparison to other substrates, the highest mean Cd content in scalp hairs of the local people was indicating considerable bioaccumulation of the metal in the human body of the locality under study.

The levels of Cd studied in the present investigation are potential hazards that can harmful both animal and human health (Mance 1987). Barber (1998) argued that in environment, Cd is a highly toxic metal and accumulates in liver and kidney of mammals through the aquatic food chain. According to Gupta *et al.* (2003), Cd may enter into the aquatic bodies through sewage sludge and with the runoff from agricultural lands as it is one of the major components of phosphate fertilizers and also, the major sources of contamination include electroplating, paper, PVC plastic, pigments and ceramic industries, battery, mining and smoldering units and many other modern industries.

Cd content in all substrates of all sites was usually highest during monsoon or post monsoon except grasses grown in river side in which Cd concentration was highest during pre monsoon at S1(0.297±0.012 µg/g) followed by at S2 (0.214±0.009 µg/g). According to De Smedt *et al.* (1998), heavy metals are strongly adsorbed by estuarine sediments, which act as reservoir for these metals and make that considerable ecotoxicological risks in the estuary. In summer, anoxic condition of estuary (due to excess environmental temperature) enabling the formation of heavy metal sulphides which precipitate those metals become immobile when sediments are settling to the bottom and ultimately lessen the metal concentration in water and sediment of the estuary as well as other substrates of the ecosystem. During monsoon, further downstream in the seaward direction, the sulphides are mobilized again, when oxygen concentration increase and thus metal concentration in water and sediment enhanced again in the estuary and its surrounding ecosystem. The existence of precipitated sulphides of Cd, Cu and Zn has been demonstrated by Zwolsman and Van Eck (1990). Consumption of metal rich organisms could transfer biomagnified metals to humans and therefore pose a threat to human health (Kumar *et al.*, 2008).

Among all the stations, the station Dhuturdaha (S5) was only situated far away from the river had always the least Cd content in all the substrates through over the year (Table 1, 2 and 3; Fig. 1). This observation indicated that sewage 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. It has been observed that among all the stations, either two extreme stations S1 and S4 or Station S2 was most contaminated regarding Cd content present in all substrates. This was happened due to maximum accumulation of the pollutant, its geographical position and local anthropological activities. Higher level of heavy metals in the area was observed which situated in the close proximity of the effluent discharge point (Garg and Totawat 2005) like S1, S2 and S4 in this study. Toxic heavy metal like Cd can cause dermatological diseases, cancer (skin, liver, kidney, lung and bladder), cardiovascular disease, diabetes, anaemia, as well as reproductive, developmental, immunological and neurological effects in the human body (Rose *et al.,* 1992; Lukawski *et al.,* 2005). In this context, the observation of this present study is very much alarming to public health and required a speedy environmental impact analysis on discharge of uncontrolled sewage of Kolkata metropolis and industrial wastes in the Bidyadhari estuary and necessary action to be taken to mitigate the hazardous contamination of heavy metals immediately.

CONCLUSION

Sewage and effluents from various industries along with agricultural runoff from Kolkata metropolis and North 24 Parganas carried through different sewage canals and discharged in Bidyadhari river were not only caused Cd contamination of that river but also contaminated the ecosystem around the river. Estimation of Cd concentration in different abiotic and biotic substrates of the estuarine ecosystem of Bidyadhari river revealed that, except the sediment of river and ponds, all other substrates having Cd concentration was more or less above the permissible levels during most time of the year at riverine stations from Kulti-Ghushighata (S1) to Dhamakhali (S4) whereas, Cd contamination was the lowest at Dhuturdaha (S5) situated 5.5 km away from the river. The highest concentration of Cd in human hairs in comparison to water and other food items like egg, milk and meat available in that area indicated probable bioaccumulation of the Cd in human body. Enhancement of Cd 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 Cd in mangrove ecology. Excessive using of Cd based commodities in West Bengal and its wastes disposal in Bidyadhari river might cause the serious Cd pollution in Sundarban mangrove land mass in near future. To mitigate the upcoming pollution due to this carcinogenic heavy metal, the sources of Cd and its transport process in the ecosystems need to be identified, quantified and evaluated properly.

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