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Studies on Geochemistry of Sediments in river Kuakhai, Odisha, India

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Abstract

The present study was carried out in the vicinity of Bhubaneswar city, Odisha, India in the year 2012 with six sampling location to assess the geochemistry of sediments of River Kuakhai carrying heavy metals. It was found to contain 89.76% to 98.26% sands with the highest being in T- 5 i.e., at Haridaspur and the lowest in T- 4 in Naharkanta . The lowest silt content of 01.16% was also recorded in Haridaspur whereas maximum silt and clay content of 07.96% and 02.96% were obtained in T- 4 in Naharkanta and T- 3 in Hanspal Bridge 2, respectively. The organic carbon and organic matter content varies from 0.40% to 0.81% and 0.70% to 01.39%, respectively. The pH level of sediments in all locations were also found to be neutral ranging between 06.66 to 07.04. However, the highest electrical conductivity of 0.48 ds/m was recorded in T-2 of Hanspal Bridge 1. It was revealed that greater grain size of sediments, neutral pH and higher organic carbon and organic matter content of sediments play an important role in governing the level of metal concentrations. It was recorded an excess level of Mn (ranging between 33.7 ppm and 10.3 ppm in various locations) in which suggests possibility of pollution and adverse effects on environment.

Key Words: Geochemistry, Sediments, Heavy metals, Pollution.

Introduction

Natural resources i.e., soil, water, grasslands, forests, livestock's and mineral resources are the basic components which essentially mean what the Almighty God has created for the survival of human beings, mankind, animal and plant kingdom. For the same, we depend absolutely on various natural resources like soil (Land), water, livestock's, grasslands, forests and mineral resources. However, the industrial effluents, residues of randomly used agro-chemicals, dumping of hazardous wastes and sewage sludge, weathering of rocks, leaching of ore deposits, forest fires, terrestrial and marine volcanism, mining, dredging and shipping are some of the important sources by which heavy metals or toxic elements are introduced into the air, soil and aquatic systems. River sediments are essential and integral part of any river ecosystem providing substrate for living organisms and through interaction with overlying waters such as nutrient cycling plays an important role in aquatic ecosystems (Tiedmann *et. al.*, 1988)**;** Burden *et. al.,* 2002). Heavy metal contamination has become a worldwide problem disturbing the normal functions of polluting rivers and lakes and toxic to all living organisms (Storelli *et. al*., 2005). Sediments form a natural buffer and filter system and often play an important role in the storage and release of nutrients in the aquatic ecosystems. Pollution of the environment is reflected by levels of contamination of rivers, lakes and other reservoirs. There are sites of accumulation of impurities coming from human activity, due to dissolution, precipitation and adsorption (Abdel-Satar, 2010). Sediments can also be defined as the material deposited at the bottom of rivers, which are silt and deposits (Davies *et. al.*, 2009). During the last two centuries, heavy metals released by human activities have superimposed new pattern of metal distribution on those which are naturally occurring. Heavy metals are widely used in automobiles, mining industries, pesticides, house-holds appliances, dental amalgams, paints, photographic papers, photo chemicals etc. (Lohani *et. al.*, 2008). A number of processes influence the sedimentary content and quality of river water. Sediments in water originate from surface erosion and contain mineral, bedrock erosion and organic components during the process of soil formation (Kamarudin *et. al.*, 2009). Sediment has important role in the nutrient cycle of aquatic environments. In some cases, sediment composition is responsible for the It helps in transportation of essential nutrients as well as pollutants. Thus, sediment analysis is increasingly important in evaluating qualities of the total ecosystem of a water body (Adeyemo *et. al.*, 2008).

Keeping in view of the importance of sediments an attempt has been made to evaluate the status of some elements in the sediments of the River Kuakhai

Materials and Methods

The investigation was carried out during the year 2012 with the sediments samples collected along the river Kuakhai,Bhubaneswar Odisha, India analysed in laboratory and field condition.

Study area

The River Kuakhai, originated as a branch of Kathajodi river of Mahanadi River tributaries, is one of the main rivers in the state of Odisha. It is located between N $20^0$30'27.7" latitude and E $85^0$34'23.4" longitude surrounded by urban area within the jurisdiction of Bhubaneswar. The mean temperature is 27.4°C and the annual mean rainfall is 1,542 mm. A large townships, industries and municipality were developed and new residential area is also sprung up to accommodate the increasing population. Many cattle sheds are also proliferated around the river in Bhubaneswar .The municipality, industries came up and residential area are generating variable quantity and quality of domestic waste. Compost, solid effluent and liquid effluent comprising various inorganic and organic chemicals, acids, and biological waste etc. along with animal and human excreta. These untreated or under treated effluents from various sources either discharged in to the river flowing out skirt of the city. These besides having high amounts of various organic and inorganic components, also contain variable quantity of trace elements and heavy metals and pose potential threat to the sediments and nearby soils are contaminated through absorption and accumulation of trace and heavy metals of Cu, Zn, Fe, Mn, Cd, Co, Ni, Pb, Cr, etc. Heavy metals in soils pose a serious damage to the soil health.

Sampling

The representative composite sediments samples from surface as well as profile layer were collected from 6 different strategic site of the river bank. The Kuakhai river bank that are likely to be affected in different degree by organic and inorganic pollutants discharge from the adjoining areas. The sampling location of river bed were designated as T_1 - K. C. Pur (Location 1), T_2 - Hanspal Bridge 1 (Location 2), T_3 = Hanspal Bridge 2 (Location 3),T_4-Naharkanta (Location4),T_5-Haridaspur (Location5) and T_6 - Banguari (Location 6).Sampling stations were chosen to provide good area coverage of the background and anthropogenic input values.

Analysis of sediments

Representative composite sediments samples of 0-20 cm depth were collected from different location of Kuakhai River bank in Bhubaneswar and its adjoining areas. Sediments were collected from six selected contaminated sites of the localities. The samples were drawn with the help of post hole auger. The composite soil samples from river bank were collected and were cleaned remaining primary sand particles and gravels and root debris air dried in shades, grounded in wooden mortar and pestle and passed through a 2 mm sieve. The processed samples were then store in clean polythene container separately for analysis.

Methods of analysis of sediments

Soil pH

Soil pH was determined from soil water suspension in 1:2:5 ratio with the help of systronic electrode pH meter (Model No 362) as described by Jackson (1973).

Electrical Conductivity

Electrical conductivity (EC) of the soils was determined from soil water suspension in 1:2:5 ratio with the help of Systronic conductivity meter (Jackson,1973).

Organic Carbon and Organic matter

Organic Carbon (OC) of the soils was estimated by oxidizing the soil with a mixture of N $k_2Cr_2O_7$ and Conc.H_2SO_4 and back titrating the excess $K_2Cr_2O_7$ with standard ferrous ammonium sulfate sulphate solution following the wet digestion method of Walkelly and Black (1934) as outlined by Jackson (1973). Organic matter was calculated by multiplying 01.47 to Organic Carbon value.

Mechanical Analysis

Mechanical analysis of the soils was carried out to assess the sand, slit and clay fraction in the soils following the Hydrometer method (Boayoucos, 1962). The USDA system of soil classification was used for the determination of textural classes.

Available Nitrogen

Available N content of the soil was determined by using alkaline permanganate for oxidative hydrolysis of the soil organic matter and the absorbed, liberated and condensed ammonia in boric acid was titrated against standard 0.02 N H_2SO_4 following the method as proposed by Subbiah and Asija (1956).

Available Phosphorus

2 gram of soil was taken in a 100 ml. conical flask with 20 ml of extracting solution and was shake for 5 min by hand and 10 minutes in orbital shaker fallowed by filtrating to another 100 ml. conical flask. 5 ml of extracted filtrate solution and 5

ml of Chloromolybdic acid was added to it followed by addition of 1 ml of Stannous Chloride from Stannous Chloride working solution. The volume makeup was done and it was shaken well. Then the prepared solution was taken for reading in spectrophotometer.

Available Potassium

Available Potassium content of the soils was determined by extracting the soils with neutral normal Ammonium acetate and Potassium from the clear supernantant La chealate was estimated using Systronics flame photometer (Model No 2950) as outlined by Jackson.

Heavy metals in sediment

Available heavy metals (Cr, Hg, Ni, Cu, Zn, Pb, Mn and Fe) were determined by Atomic Absorption Spectrophotometer technique after acid digestion. Before analysis the unknown sample of each elements in the soil extracts, the AAS has calibrated with standard solution having known concentration of the elements.

Result and Discussion

It is evident from the Table 1, that the sediments of River Kuakhai contain mostly the sand particles in all the locations with a minimum of 89.76 % in the treatment, T_4 *i.e.*, at Naharkanta of Location 4 whereas the highest sand content of 98.26 % was obtained in the treatment, T_5 *i.e.,* in Location 5 of Haridaspur. However, all the treatments were found to be non-significant. In the evaluation of metal contamination in freshly deposited sediment of Hugli Estuary, India, Mukherjee and Kumar (2012) obtained sand content in sediments ranges between 11.8 % to 99.8 % with an average of 48.7 % during dry season and between 6.6 % to 98 % with an average of 44.3 % during wet season. It is assumed that high percentage of sand content in sediment may have favourable effects on flora and fauna and on the environment as a whole. The heavy metals and trace elements like Fe, Zn, Mn, Cu, Ni, Pb, Hg, may not be bonded by the sand particles and may be washed away to sea escaping toxicity or environmental pollution. Several workers have performed a large number of research studies on this aspect, particularly to identify the sources and sinks of heavy metals in rivers, estuaries and near shore environment (Vale, 1986; Mance, 1987; Klomp, 1990; Windom,1990). Heavy metals or contaminants are not necessarily fixed permanently by sediments but they also may be recycled through biological and chemical agents within both sedimentary compartment and the water column. However, recycling from bottom deposits can be significant factor in the nutrient budget of an aquatic system (Forstner, 2002). So, sediment data are important factors that should be taken into account when we conduct environmental monitoring programmes in river ecosystems (Bormann and Likens, 1979). The sediment distribution pattern depends on several factors such as sediment sources, the texture of the sedimentary materials supplied, the bottom topography of the basin and general hygrographic features (Murty and Veerayya, 1972; Seralathan, 1986; Nair, 1992).

It was revealed in the present investigation, that the silt and clay content in the sediments were also non-significant and were very low. It contained a silt content of as low as 01.16 % in T_5 whereas the maximum silt content of 07.96 % was found in T_4 (Table 1). However, Mukherjee and Kumar (2012) in the evaluation of metal contamination in freshly deposited sediment of Hugli Estuary, India noted a silt content in the ranges between 0.5 % and 70 % with an average of 38.4 % in dry season and between 1.8 % and 78.9 % with an average of 43.7 % during wet season. It has been reported that surface run off bring huge amount of silt during monsoon season in addition to other pollutants from upland (Khan, 2002).

Maximum clay content of 02.96 % was noted in T_3 with a lowest in T_1 (0.06 %) as is evident and the result for the same as shown in Table 1. The OC (Organic Carbon) in sediments ranges between 0.40 % to 0.81 % with an average of 0.61% whereas the OM (Organic Matter) content varies from 0.70 % to 1.39 % Table 1, respectively which almost corroborates the normal value of OC of 0.5-0.75 % and OM of 0.86-1.29 %. In an experiment, Mukherjee and Kumar (2012) obtained carbonate in sediments ranging between 0.0 % to 4.7 %, with an average of 2.0 % during dry season and between 0.4 % and 5.5 %, with an average of 3.2 % during wet season whereas OM in sediment ranges between 0.0 % and 0.9 % with an average of 0.3 % during dry season and between 0.0 % and 3.1 % with an average of 0.8 % during wet season. The OC in sediments is mainly related to the decomposition of aquatic organisms and surface run off from the basin. They also opined that the distribution pattern of texture, carbonate and organic carbon is more or less identical with metal distribution pattern over the sampling sites. The metal concentrations were found to be less where OC content were low which indicates that metal content in sediments originates partly with the organic materials. Sediments containing high levels of OM are likely to contain higher concentration of heavy metals as compared to sediments lacking organic matter. It was also inferred that grain size of sediment play crucial role in governing the level of metal concentrations in the sediments

The result for the same is shown in Table 1. The pH of sediments of River Kuakhai in the present investigation were found to be non-significant. It was recorded that the pH is almost ranging between 6.66 and 7.04. A pH level above 6.0 tends to show more metals adsorbed into sediment than a lower pH. Investigators concluded that fine-grained particles with more surface area contained more metals than coarse-grained sand (Horowitz *et. al.*, 1987). However, the pH and OM can directly change metals distributions in sediments.

EC of sediments presented in Table 1. Unlike OC and OM, the EC was also non-significant. It was noted that the highest EC (0.48 ds/m) obtained in T3 (Location 3 of Hanspal Bridge 2) whereas the lowest one of 0.25 ds/m was found in the T_1 (Location 1 of K. C. Pur).

The Fe content of the soil adjacent to River Kuakhai was found to be significant, the highest being in the T_1 *i.e.*, at K. C. Pur of Location 1 with Fe content of 39.9 ppm followed by T_4 (24.2 ppm). However, the Fe content of flora was found to be non-significant with an optimum and minimum Fe content in T_1 of Location 1 at K. C. Pur (73.8 ppm) respectively (Table 2). Zn content of soil was also recorded to be significant with 29.4 ppm in T_1 which near same range with T_3 (22.5 ppm) and T_6 (20.9 ppm). Mn content of soil in T_1 containing 33.7 ppm was significantly highest than all other treatments followed very closely by T_5 (33.4 ppm) and T_7 (32 ppm). Mn content is much higher in the soil near River Kuakhai against the normal save limit of 5 ppm concluding that suggests that there is every possibility of soil and water contamination and environmental pollution. However, the concentrations of Mn may vary from place to place and year to year. In an experiment with heavy metals in Mithi River of Mumbai, Singare *et. al*., 2013 recorded Mn concentrations in the range of 03-239 ppm whereas it was found to be higher in the assessment year of 2010-11. Accumulation of Mn in soil usually occurs in the sub-soil and not on the soil surface (WHO, 1981). The significantly highest content of Cu *i.e.,* 75.8 ppm was recorded in T_1 followed by T_2, T_3, T_4, T_5 and T_6. Cu is an essential element for biological activities and forms an essential component of most of the oxidative enzymes like catalase, peroxidase, tyrosinage superoxide dismutase, amine oxidase and cytochrome oxidase. At the same time, it is considered as the most toxic element after Hg and may be fatal for human beings, animal and plant kingdom. It was revealed from Table 2 that the Location 1, T_1 recorded the highest Ni content of 39.9 ppm followed by T_4 (28.4 ppm) and was found to be significantly superior to other location. It was also revealed that Pb, Hg and Cr contents in the soil near Kuakhai River were very negligible and even below detection level (Table 2). N, P, K are major plant nutrients essential for growth, development and yield of field crops and tree species. For proper growth and development and good harvest of crops, the requirement of N, P and K should be in the range of 01-04 %, 0.1-0.37 and 01-3.5 %, respectively and found to be contained in the flora near River Kuakhai. It suggests that the soil of river banks and adjoining areas were fertile enough to raise various types of tree species.

Conclusion

It was concluded from the study that greater grain size of sediments, neutral pH and higher organic carbon and organic matter content of sediments play an important role in governing the level of metal concentrations. It was also concluded that an excess level of Mn in soil and excess limit of Cu and Ni in flora can pose a serious threat for soil and water pollution which can severely affect human, animal and plant kingdom.

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Table 1. Geochemistry of sediments of River Kuakhai.

Sl. No.	Location	Sand %	Silt %	Clay %	OC %	OM %	pH	EC (ds/m)
1	T1	97.40	1.93	0.06	0.51	0.88	6.78	0.25
2	T2	97.50	1.63	0.93	0.40	0.70	6.78	0.25
3	T3	91.63	5.40	2.96	0.59	1.02	7.04	0.48
4	T4	89.76	7.96	2.30	0.78	1.35	6.93	0.23
5	T5	98.26	1.16	0.56	0.55	0.94	6.74	0.26
6	T6	96.57	2.03	1.40	0.81	1.39	6.66	0.33

Table 2. Presence of heavy metals and major nutrients in the sediments of River Kuakhai.

Sl No.	Location	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Hg (ppm)	Cr (ppm)	N (%)	P (%)	K (%)
1	T1	39.9	29.4	33.7	75.8	53.5	BDL	BDL	BDL	0.00229	0.00032	0.00048
2	T2	16.4	17.0	11.8	70.3	48.4	BDL	BDL	BDL	0.00206	0.00026	0.00018
3	T3	17.4	22.5	17.9	65.3	31	BDL	BDL	BDL	0.00238	0.00026	0.00070
4	T4	24.2	16.3	17.3	57.3	28.4	BDL	BDL	BDL	0.00324	0.00038	0.00067
5	T5	19.9	12.5	33.4	51.4	32.7	BDL	BDL	BDL	0.00329	0.00039	0.00054
6	T6	11.6	20.9	10.3	25.7	14.4	BDL	BDL	BDL	0.00603	0.00028	0.00037

BDL – Below Detection Limit (Lead < 10 mg/kg, Mercury < 1 mg/kg, Chromium < 10 mg/kg)