Sediment Analysis of Some Physico-chemical Parameters of River Chambal near National Chambal Sanctuary Region

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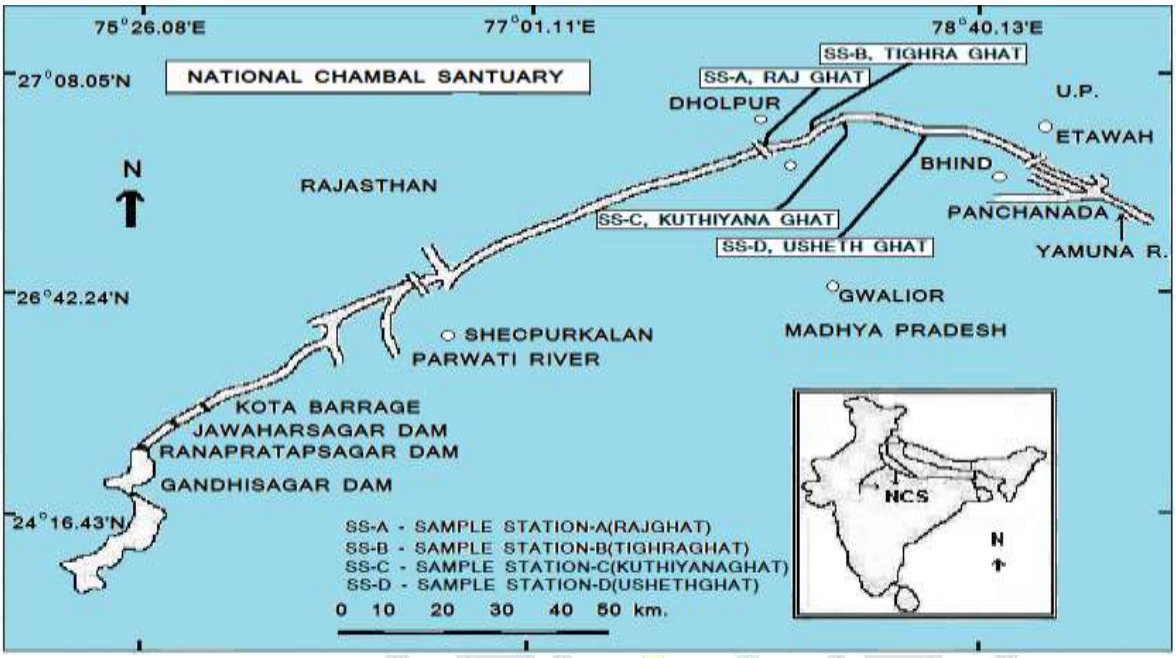
Abstract: *This study deals with the pollution load of river Chambal in context with physico-chemical parameters of river's sediment. The study was carried out for a span of one year from February 2017 to January 2018 at four sampling stations which is situated along with the drift area of river Chambal. Various physico-chemical parameters of river Chambal were observed viz., pH, soil texture, bulk density, water holding capacity (WHC), alkalinity, chloride, phosphate, sodium, potassium along with some trace metals like copper, iron, zinc, manganese, lead, cadmium, etc. The mean concentrations of trace metal elements were found in order of Fe>Mn>Pb>Cr>Cu>Zn>Cd respectively. High quantity of Fe and Mn were found at certain locations showing the interference of some local contaminants. The results give vital information regarding the pollution load of the river Chambal. There is an urgent need for more representative samples to be used to go beyond initial assessment as reported in the present study for making adequate recommendations.*

***Keywords**: Chambal River, Sediment, Physico-chemical parameters, Metal Elements, National Chambal Sanctuary etc.*

Introduction: In India, the number of available source of potable water for drinking, domestic and industrial purposes are de-escalating day to day because of population, urbanization and industrial activities are increasing rapidly (Mane *et al.*, 2013). Impurities are mainly found adsorbed on to the particles in polluted water and are bound to organic substances (Chapman D., 1992). Changes in weathering conditions, regional distances alter the different phases of impurities found on particulates, sometimes causing impurities to be released in to the water and sometimes precipitated (Konhauser *et al.*, 1997; Jain *et al.*, 2005). Water, soil and sediment have their own importance in regulating the biological mechanism of any river system.

Sedimentation is a natural process of any stream which provides sound ecological places for diverse organisms with quality food resources containing all necessary elements. Sediment is also an important ideal consanguineous habitat for underwater life (Marathe *et al.*, 2011). The adsorption-desorption of pollutants and minerals on sediment have an important role that affects the distribution and destiny of pollutants between water and sediment (Jain and Ram, 1997). Sediment degrades water quality and often carries soil absorbed polluting chemicals. Sometimes in aquatic food chain system, toxic substances comes through the sediment contamination due to the increased level of contaminants in stream sediments and thus the life cycle of all aquatic flora and fauna continues to be affected by the toxicant concentrations involved in sediment (Lee and Lee, 1993). Some animal and plant species are especially sensitive to the effects of contaminated sediments and quickly accumulated by their tissues. High levels of suspended sediment can interfere with their ability to find food, risking the health of the ecosystem by disrupting the delicate food web and the quality of water. Besides providing habitats for submerged organisms, sediments play a key role in determining the overall environmental quality of riverine ecosystem (Etim and Adie, 2012). This Paper is purposive to provide guidance in making the future policies for the river and gives illustrations of the associated results to support assessment of sediment quality conditions of the study area.

Study Area: The river Chambal plays vitally important role in north central region of India. This river is the most prominent water resource in many cities and towns which is situated in all the three states on its shores (Tiwari and Singh, 2008). The river Chambal originates from Janapav hill, South of Mhow town, south escarpments of vindhyan range in Madhya Pradesh. The river Chambal is located in west central India, passing through tri-state protected area of the Indian states; Madhya Pradesh, Rajasthan and Uttar Pradesh between latitude $25^0$23'-$26^0$52' N and longitude $76^0$28'-$79^0$15'E. The study area lies in the famous 'National Chambal Sanctuary-NCS' region of the river flowing between Dhaulpur (Rajasthan) and Morena (Madhya Pradesh) districts. Within the sanctuary region, the river Chambal flows through the areas of deeply eroded alluvium. Stony rapid, sand banks and gravel bars are abundant, and there are many steeps banks and sheers where the depth of water exceeds (Saksena *et al.*, 2008). The river is ecologically very important, as it harbours a wide variety of many rare aquatic animals. It is a perennial river which is declared as National Reserve Sanctuary for the 'Crocodile Project' on behalf of the Government of India. Location of river Chambal and all the sampling stations are shown below in the figure.



Material and Methods:

The sediment samples were collected for the present investigation from four different experimental sites within a specific stretch of 70±10 kms. of river Chambal. The river bed samples from various depths were collected by dredge and scoop method (Robert and Christopher, 2001), quarterly from each sampling station and analyzed for a span of one year from February 2017 to January 2018. Samples were collected in fine quality polyethylene bags which were properly cleaned, labeled to indicate collection point, date and place, sealed and then taken to the laboratory for further analysis (USEPA, 1977). In laboratory, the collected samples were air dried and finely powdered by using mortar and then sieved. Before determination of metal elements the sediment samples were digested with HNO_3 and $HClO_4$ digestion method. The air dried samples were analyzed for metal elements with the help of an atomic absorption spectrophotometer. The protocol and analysis strategies were followed according to Method Manual for Soil Testing in India, 2011.

Result and Discussion:

The physico-chemical analysis provides a proper idea of any river's ecosystem. The results of determination of various physico-chemical parameters of river Chambal sediment at four locations; are summarized in Table-1 and station wise variations are shown in Fig.1 and Fig.2.

The color of sediment gives prefatory information of any soil or sediment that how much minerals included in it. All the four sampling stations sediment's color is found brown except station 'A'. Sediment or soil texture indicates about particle contents of different sizes which it includes. The Chambal river sediment is found almost sandy. The pH is simple but extremely important factor since most of the chemical reactions in aqueous environment are controlled by any change in pH value (Korfali S.I., 2003). Excessive acidic or alkaline environment of any habitat can kill marine life. Thus, pH value describes the quality of waste water effluent (Singare *et al*.; 2011).

Table-1 Showing the results of physico-chemical characters of river sediment.

S. No.	Parameters	SS-A (Rajghat)	SS-B (Kuthiyana ghat)	SS-C (Tighra ghat)	SS-D (Usheth ghat)	Average Values
1.	Color	Dark Brown	Brown	Brown	Brown	-
2.	pH	8.87	8.54	7.78	8.06	8.31
3.	Soil Texture	Sandy Silt	Sandy	Sandy	Sandy	-
4.	Bulk Density (g/cc)	1.34	1.88	1.70	1.62	1.63
5.	Specific Gravity	2.81	2.54	2.70	2.61	2.66
6.	Moisture content (%)	6.82	7.97	6.90	7.46	7.29
7.	WHC (%)	19.67	26.84	18.93	21.56	21.75
8.	Alkalinity (%)	0.005	0.012	0.023	0.019	0.014
9.	Chloride (%)	0.048	0.071	0.042	0.037	0.049
10.	Sodium (%)	0.074	0.095	0.088	0.091	0.087
11.	Potassium (%)	0.55	0.38	0.42	0.76	0.52
12.	Calcium Oxide (%)	16.71	13.42	14.12	12.68	14.23
13.	Magnesium Oxide (%)	1.68	0.95	0.87	0.90	1.1
14.	Phosphate (%)	0.02	0.05	0.07	0.06	0.05
15.	Iron* (%)*w/w*	2.67	2.92	3.36	2.79	2.93
16.	Zinc($mgKg^{-1}$)	1.53	1.12	1.54	1.27	1.36
17.	Copper ($mgKg^{-1}$)	39.84	32.96	28.13	35.54	34.11
18.	Chromium($mgKg^{-1}$)	33.77	37.19	36.75	41.08	37.2
19.	Lead ($mgKg^{-1}$)	77.59	65.38	82.01	71.66	74.16
20.	Manganese($mgKg^{-1}$)	673.92	187.52	134.71	206.75	300.72
21.	Cadmium($mgKg^{-1}$)	BDL	BDL	BDL	BDL	-

*Value of Fe metal is given here in % (*w/w*), convertible in $mgKg^{-1}$; BDL = Below Detection Level.

In present investigation the maximum value of pH is observed 8.87 at SS-A and the minimum 7.78 at SS-C while the average pH is found 8.31(as shown in table-1). Higher value of bulk density is an indicator of low porosity and sediment compaction. Bulk density is used to express sediment's physical, chemical and biological measurement on volumetric basis for sediment quality assessment (Ramachandran *et al.*, 2012). From station 'A' to 'D', the bulk density varies 1.34 g/cc to 1.88 g/cc and the mean value is observed 1.63 g/cc, whereas for sandy type of soil texture, below 1.60 g/cc is considered ideal bulk density for plant growth.

Table-2 Sediment Quality Guidelines (SQG) for metal elements in ppm.

Metal Elements	USEPA Sediment Quality Guidelines (SQG) limits	WHO Sediment Quality Guidelines (SQG) limits	Threshold Effect Concentration (TEC)	Probable Effect Concentration (PEC)
Copper (Cu)	16	25	31.6	149

Chromium (Cr)	25	25	43.4	111
Lead (Pb)	40	-	35.8	128
Iron (Fe)	30	-	20000	40000
Zinc (Zn)	110	123	121	459
Manganese (Mn)	30	-	460	1100
Cadmium (Cd)	0.6	6	0.99	4.98

*Acc. to Helen D. *et al*., (2016); MacDonald *et al*., (2000); U.S.EPA (2004), WHO (2004).

Specific gravity is a specific ratio which gives information about sediment or soil containing organic matter and porous particles. Normally sediment or soil having heavy substances may have specific gravity around 3.0. In the analysis of specific gravity of river Chambal sediment, it is found in order to sample stations A>C>D>B; but during the whole study the average value 2.66 observed, which is almost close to 3.0.

There is little critical difference between moisture content and water holding capacity (WHC) of soil. Moisture content of samples varies from 6.82% (SS-A) to 7.90% (SS-B) whereas the average moisture content of river sediment is found 7.29% (as shown in table-1). Water holding capacity is the maximum capacity of soil or sediment for holding water content itself. The maximum WHC is found 26.84% at SS-B while the minimum 18.93% is found at station-C. Overall the average WHC of river Chambal sediment is observed 21.75% of which variation is shown in Fig.1. Alkalinity provides a buffering capacity to aqueous system and support to resists pH changes. The alkalinity of river Chambal sediment is found maximum 0.023% at SS-C and minimum 0.005% at SS-A; whereas the mean of alkalinity of river sediment is 0.014% observed. Chloride is one of the major anion in stream water which acts as a disinfectant if present in a limited amount. In sediment it comes through atmosphere, earth crusts, igneous rocks, accumulation in sedimentary particles and by many anthropogenic activities. During this study the average value of chloride is seen 0.049% and the maximum is obtained 0.071% at SS-B (Table-1 and Fig.1 respectively).

Fig.1
Graphical Representation of Sediment Parameters

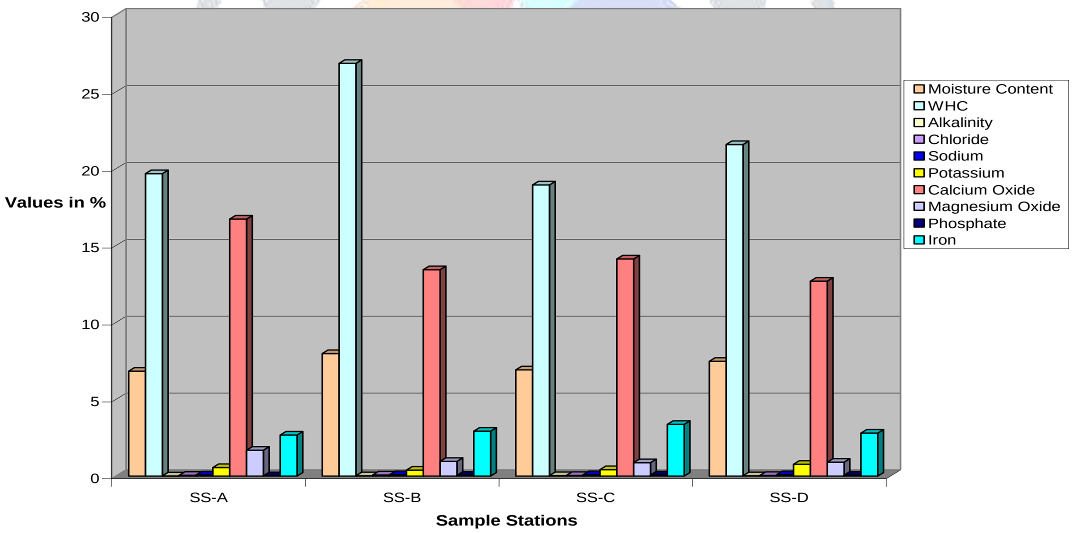
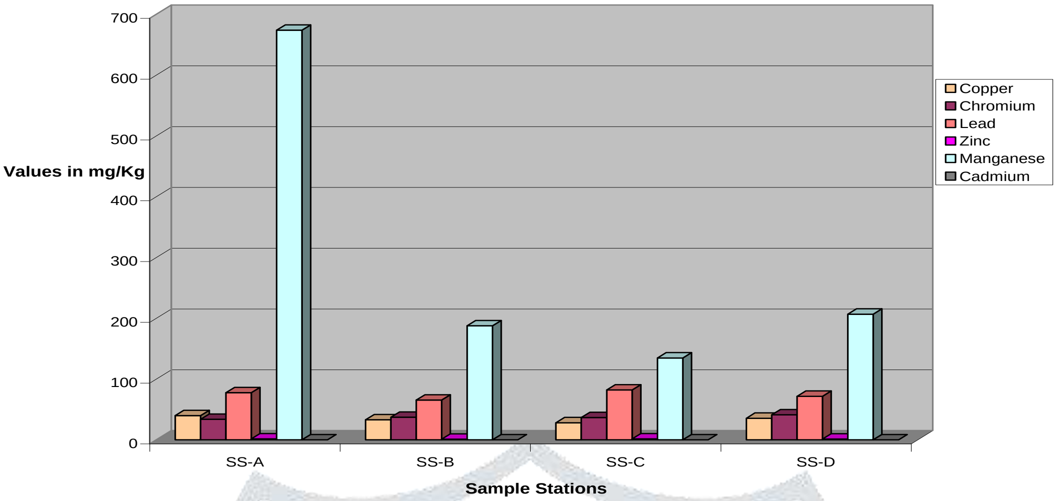


Fig.2
Graphical Representation of Sediment Parameters



The major sources of metals and nutrients are almost all type of detritus sedimentary rocks, industries effluents in which they used, anthropogenic activities, agricultural runoff nearby areas coming in to river drift area, finally settle down, stabilized and accumulated in sediment (Cheung *et al.*, 2003). Surface water generally contains sodium and potassium as naturally abundant elements. As the sediments have low concentration of these nutrients, consequently the concentration of these ions is found in small quantities. In this sediment analysis, sodium varies from 0.074% to 0.095% and found maximum at SS-B, and minimum at SS-A. The average value of sodium 0.087% is observed; whereas potassium ranges from 0.38% at SS-B to 0.76% at SS-D during the study. An average value of potassium is obtained 0.52% at all locations of the river (Table-1). Although potassium is comparatively less hazardous in water, but spreads rapidly in water due to its relatively high mobility and transformation capability. In this analysis, the concentration of potassium is found little higher at all the stations in comparison to sodium (as shown in Fig.1).

Calcium and magnesium are also essential nutrients for all aquatic organisms and humans, occurs naturally in water bodies. Excess of cations such as Ca, Mg, Fe, Mn etc. influences the hardness and alkalinity of water (Shrivastava and Patil, 2002). Their presence in water is often closely correlated with the type of land use in the catchment area. Limestone is one of the naturally occurring sedimentary rock consisting of calcium and magnesium. Metal elements which bound to carbonates, oxides are released in water as a result of pH decrease (Zerbe *et al.*, 1999). It is found during the study that the amount of calcium in sediment is relatively high compared to magnesium. The values of both Ca and Mg are observed maximum at SS-A, 16.71% and 1.68% respectively; and minimum value of calcium 12.68% at SS-D while the lowest value of magnesium is observed 0.87% at station-C (Table-1 & Fig-1). Similarly the mean concentration of Ca and Mg are found 14.23% and 1.1% respectively.

Phosphorus is one of the key elements necessary for the growth of planktons, plants and animals. The presence of phosphorus is often very rare in properly oxygenated freshwater system. The recycling of sediment bound phosphorus is particularly important because it may increase the rate of eutrophication and whenever eutrophication rises, it indicates phosphate augmentation in a water body resulting in depletion of dissolved oxygen (Chattopadhyay *et al.*, 1995). Generally it is assumed that a major carrier for phosphate in sediments; is organic matter which acts as the source of nutrients to microbial communities (Ruttenberg *et al.*, 2009). In this study period, the amount of phosphate in sediment is not observed so high. The average value of phosphate is recorded 0.05% in river sediment (Table-1) and doesn't show any wide fluctuation in its concentration.

The study of risk analysis of trace metals in any urban aquatic system is extremely important due to their persistence, bio-accumulation, toxicity and non bio-degradability (Helen D. *et al.*, 2016). Large amount of metals are accumulated by all the creatures that are involved in aquatic food chain, in their bodies from water and sediment and finally reaching in a human body by this food cycle; can cause severe health and environmental problems to those, whose life depends on them (Adeyemo *et al.*, 2008). Trace metals can be bound to or congested in amorphous materials, adsorbed on clay surfaces or iron/manganese oxyhydrides, complexes with organic matter, co-precipitated in secondary minerals such as carbonates, sulphates or oxides etc. (Lakshmanasenthil *et al*., 2013). There are many ways through which trace metals can be leaked into water viz. the erosion of geological matrixes, atmospheric depositions or anthropogenic sources such as sewage outfalls, industrial and agricultural runoff etc. (Edward *et al.*, 2001; Kumar Rahul *et al.*, 2014). In this study, total seven trace metals Cu, Cr, Pb, Fe, Zn, Mn and Cd have been investigated. Distribution and comparison of trace metals according to sampling sites are shown in Fig.2. The concentration of these metals significantly varies in the bed sediment samples collected from four locations of river Chambal. If the level of metals in sediment is below the threshold effect concentration (TEC), there is less possibility of harmful effects likely to be observed, but If the level is above the probable effect concentration (PEC), harmful effects can be seen broadly (Hoda *et al.*, 2009).

Iron and zinc, are the two most essential trace elements for growth of plants and animals but in excess they may have adverse effects too. The main source of fluvial iron mainly includes agricultural runoff, erosion, natural decomposition of rocks and minerals, municipal wastes and untreated effluents of various industries etc. which keeps flowing in the stream and slowly depositing in river bottom sediment. During the study period, the level of iron has also been examined in the river sediment; which was found maximum among all the analyzed metals at all the sites and clearly crossing the limit of 30 ppm given by USEPA. The concentration of iron varies between 2.67% (26700 mg/Kg) at SS-A to 3.36% (33600 mg/Kg) at SS-C with an average value of 2.93% (29300 mg/Kg), station wise fluctuation are shown above (in Fig.1 and Table-1); However the mean concentration of Fe is found far above the TEC limit and less than the PEC limit but at station 'C' its value seems nearer to PEC limit (Table-2), which is the matter of serious concern. The concentration of Zn is recorded 1.54 mg/Kg maximum at SS-C and 1.12 mg/Kg minimum at SS-B with an average value of 1.36 mg/Kg for the river's sediment. The level of zinc is observed far below the limits given by USEPA and WHO sediment quality guidelines which are shown in Table-2 respectively.

The maximum concentration of 39.84 mg/Kg for copper is observed at SS-A, while the minimum value of 28.13 mg/Kg is detected at SS-C with the mean value of 34.11 mg/Kg during the study period. The USEPA (United State Environment Protection Agency) guideline value 16 ppm (equivalent to mg/Kg) of Cu in sediment is acceptable. The concentration of Cu is not found within the tolerable limit at any sampling station. The amount of chromium ranges between 33.77 mg/Kg (SS-A) to 41.08 mg/Kg (SS-D) with an average concentration of 37.2 mg/Kg while according to USEPA and WHO sediment quality guidelines (SQG) Cr should be under the range of 25 ppm; and no station shows the volume of Cr below the acceptable limit (Table-2). During this study, observed lead content in river sediment ranges between 65.38 mg/Kg (SS-B) to 82.01 mg/Kg (SS-C) with an average value of 74.16 mg/Kg (Table-1). The quantity of Pb in samples is also crossing the USEPA limit of 40 ppm. The exceeding value of Pb is very hazardous and noxious for riverine ecosystem (Singh *et al.*, 2012). The results show the anthropogenic activities as well as nature's interference in the river.

The concentration of manganese has also been determined which is the second most observed metal in all the bed sediment samples. The dissolvability of Mn in water from sediment depends on pH level with many other factors (Ha N.T. *et al.*, 2011). The maximum amount of Mn is found 673.92 mg/Kg at SS-A and the minimum 134.71 mg/Kg at SS-C, which seems much higher than the normal range. The average value of Mn in river sediment is recorded 300.72 mg/Kg; which is also exceeding the acceptable limit of 30 ppm given by USEPA for Mn (as shown in Table-2). Cadmium is another toxic metallic element which may be very dangerous for aquatic animals as well as ecological system of river; found below detection level at all the sampling stations. High concentrations of iron, manganese, copper, lead and chromium have been found in this river sediment; if they leached tardily in water from sediment in different weathering conditions and intaked regularly for a long period, then prove to be very fatal and carcinogenic.

Conclusion:

The sediment assessment gives significant information about relavantness of factors playing role in contamination of sediment and toxicity in bio-accumulative substances. The release of elements from sediments and their reaction with water are influenced by various environmental factors of an ecosystem. Many important physico-chemical parameters like bulk density, specific gravity, water holding capacity, sodium, potassium, calcium, magnesium etc. are determined which shows their extensive variations in all collected samples. High quantity of some metal elements confirms about anthropogenic activities as well as directly putting of sewage effluents by the municipalities and the industries of near by cities, agricultural runoffs, Nallah's falling, illegal sand mining, cremation of dead bodies near river banks and directly flown of these ashes into the river etc. According to the mean concentration of trace metals in river Chambal sediment; the sequence is as follows Fe>Mn>Pb>Cr>Cu>Zn>Cd. The concentration of almost all the trace metals in the collected samples is exceeding the guideline limits except Zn and Cd. But Fe and Mn contents are found superabundant in comparison to other metals; and on the basis of risk assessment code (RAC), environmental risk of Mn is found very high (Davutluoglu *et al.*, 2011); that is indicating towards the contamination of sediment and continuously increasing pollution level of river Chambal. Through this study we have made an attempt to define the level of chemical exposure to biota. However, due to river fluxes, floods, tidal fluctuations and other weathering processes sediment contents changes accordingly, therefore more efforts needed to be made in this direction so that the river's fragile ecosystem can be retained.

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