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ECOLOGICAL IMPACT OF WATER AND SEDIMENT CONTAMINATION IN PASSUR RIVER ADJACENT TO SUNDARBANS

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ABSTRACT

Sundarbanss, the world's largest mangrove forest has a unique ecosystem of greate ecological and economical significance supporting marine biodiversity as well as providing livelihood for many people in this region. In this study the ecological risk of the Sundarbans is analysed through evaluating pollution assessment in Passur river water and the river bed sediment. The studied water quality parameters such as pH (6.7), hardness, BOD_5 (1.8 mg/l), alkalinity, Cl^- (135 mg/l) etc. showed no serious pollution in river water. The ecological risk in the concentration of six trace elements (Pb, Cd, Ni, Zn, Fe, Cu) in the Passur river sediment were inspected revealing that the sediment is moderate to severely contaminated with Cd (1.5 mg/kg), Fe (3.1%) and Ni (36.2 mg/kg). High concentration values of Cd and Ni suggest the risk of eco-toxicity for organisms living in the sediment. Pollutant load index for all of the three sampleas were founed to be 1.40, 1.23 and 1.35, respectively which are larger than the limiting value 1 which indicates deterioration of sediment. Risk index (RI) of these three sample of sediment analysis are 846, 223 and 446, respectively.Sediment sample 1 has high risk possibilty, sediment sample 2 poses moderate risk with the limiting range of RI ($150 \leq RI \leq 300$), sample 3 represents considerable risk with limiting range of ($300 \leq RI \leq 600$). Using simulation-based @Risk software, the values of Risk Index (RI) show certainity around 90%. Among the trace metals Cd has shown higher potential ecological risk factor (Er^i) indicating greater ecological imbalance causing serious harm on aquatic flora and fauna. Silt (75.8%) is the dominating grain size of the Sundarbans soil. Ecological impacts of the Sundarbans upon dredging was also briefly described. Conservaion of natural resources is of prime concern to maintain the biodiversity of the Sundarbans forest.

Keywords: *Water quality parameter, Trace element, Ecological risk, Passur river, Sundarbans forest.*

1. INTRODUCTION

The Sundarbans is one of the largest mangrove forests in the world covering about 10,200 km2 area (88000'-89055'E and 21030'-22030'N) of the south-west of Bangladesh (60%) and south-eastern region of India (40%). The forest is formed in the delta of Bay of Bengal formed by the confluence of three important rivers- the Ganges, Brahmaputra and Meghna (Ahmed et al., 2010). The Passur is an important river flowing close to the south-western boundary of Bangladesh is a distributary of Ganges which continues as the extension of the Rupsha river, meets the Shibsha river within the Sundarbans and near the sea it flows as the Kunga river. It is considered as the deepest river of the country and its entire length is affected by tides. In the confluence of the Passur river and the Mongla river lies the second largest port of the country called the Mongla sea port. This water resource is affected by anthropogenic activities threatening the river ecosystem along with the mangrove forest.

Ecosystem is a community of living organisms interacting together with the nonliving components of the environment. Sundarbans has a unique ecosystem providing habitation for 453 faunal wildlife, including 290 bird, 120 fish, 42 mammal, 35 reptile and eight amphibian species (Iftekhar and Islam, 2004). The formation and justification of mangrove food chain is unique, roled by both marine and terrestrial components but due to loss of biodiversity the marine status is at risk affecting the ecology of Sundarbans (Manna *et al*., 2010). The quality of Sundarbans ecosystem is degrading due to over exploration of natural resources and different anthropogenic activities including industrial discharges, port activities, ship breaking, use of fertilizer and pesticides in agriculture and shrimp aquaculture.

Water quality parameters determine levels of contaminants and pollution in river ecosystem. Different anthropogenic sources in/near the river stream cause water pollution by changes in the water quality parameters. Therefore, monitoring its water quality is important for aquatic biodiversity. Nevertheless, trace elements degrade the quality of aquatic ecosystem due to their toxicity and accumulation threatening biodiversity and risking human health thereby (Ahmed *et al*., 2010, Wu *et al*., 2017). Sediment can act as a sink for metals in the environment (Kumar *et al*., 2016) and is useful source of information on environment and geotechnical status of marine pollution (Uluturhan et al., 2011).

The study of water quality parameters and metal contamination in the bed sediment of Passur river near the Sundabans will help to develop strategies for better conservation and utilization of natural resources. This study aims at analysing the ecological impact of Passur river water and sediment quality on the Sundarbans ecosystem.

2. METHODOLOGY

2.1 Study Area

The water samples were collected in the month of September from three stations in the Passur river near Mongla port keeping GPS reference points with a distance of at least 1km between two successive stations. Samples were collected in acid-washed plastic bottles.

Table 1: Details of water sampling location

Sample No	Latitude	Longitude
WS1	22°29'18"	89°35'18"
WS2	22°29'20"	89°35'23"
WS3	22°29'16"	89°35'22"

A river bed sediment sample was also collected near Mongla port using an acid-washed plastic spatula, sealed in plastic bag and stored at 4°C until analysis.

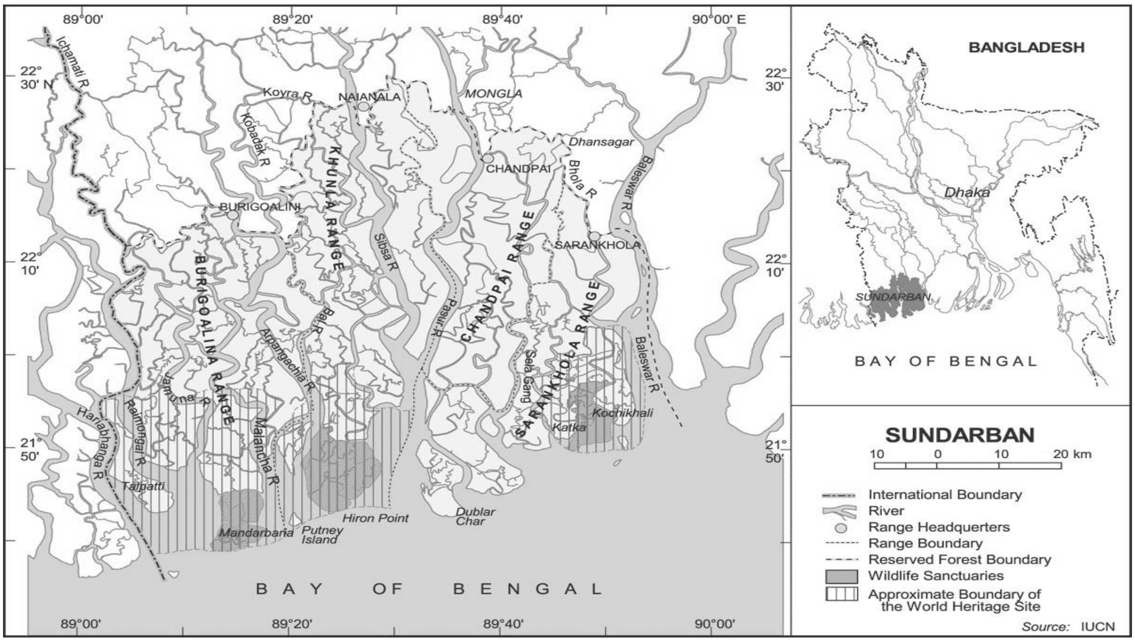


Fig 1: Map showing the Sundarbanss (Rahman *et al*., 2010)

2.2 Analysis of River Water & Bed Sediment

Laboratory water quality parameters were determined following the standard methods. PO_4^-, Fe, Mn, were analysed using UV Spectrophotometer (DR-2700, HACH, USA). Conductivity was analysed using conductivity meter (Sension-156) and pH was analysed using pH meter (pH -5011). The sediment sample was sieved and 50gm of the sample passing #200 sieve (0.075mm) was taken for hydrometer analysis to know the grain size distribution of the fine grained sediment sample. ASTM 152-H hydrometer was used for this analysis and the Sodium Hexametaphosphate was used as the dispersing agent. ASTM Standard sieves were used for grain size analysis.

2.3 Assessment of Pollution

In order to assess the quality of sediment, different indices are used worldwide. In this study Pollution load index was used. It is calculated by multiplying the contamination factors (CF) of the elements and deriving the n-th root of the multiplication (Tomlinson *et al*., 1980). The equation for calculating PLI is as follows:

$$PLI = (CF_1 \, X \, CF_2 \, X \ldots \ldots X \, CF_n)^{1/n}$$

Where, CF is the ratio of concentration of each element to the background values of sediments. Here due to the absence of background values, UCC values can be used. PLI = 1 represents presence of baseline level of pollutants and PLI > 1 represents deterioration of the sampling site.

Potential ecological risk index (RI) was used to assess the degree of contamination by the following equation:

$$RI = \sum_{i=1}^{n} Er^i = \sum_{i=1}^{n} Tr^i \times CF^i$$

Where, Er^i is the potential ecological risk factor of an individual element, Tr^i is the biological toxic factor of an individual element and CF^i is the single element contamination factor (Hakanson, 1980).

To assess the toxicity level Mean ERM Quotient (M-ERM-Q) method was used which was obtained as follows:

$$M\text{-}ERM\text{-}Q = \frac{\sum_{i=1}^{n} \frac{C_i}{ERM_i}}{n}$$

where C_i is the concentration of element i, ERM_i is the ERM values for the element i and n is the number of elements. According to the classification of M-ERM-Q: M-ERM-Q < 0.1 indicates 9% probability of toxicity, 0.11 ≤ M-ERM-Q < 0.5 indicates 21% probability of toxicity, 0.51 ≤ M-ERM-Q < 1.5 indicates 49% probability of toxicity and M-ERM-Q > 1.5 indicates 76% probability of toxicity (Long *et al*., 2000).

3. RESULTS AND DISCUSSION

3.1 Water Quality Analysis

To assess the level of acceptance the findings of this study in table 1 were compared with the certified values in table 2. The values obtained from the study were very much close to the expected limiting values. Though BOD_5 values were within the acceptable limit but appeared quite high. The DO values were quite lower as the living organisms in the river used up large amount of oxygen. The Cl^- values were found to be lower as the study was conducted in rainy season. The Fe contents are higher may be due to different anthropogenic activities especially wastewater discharges, sewage sludge, mining and mineral processing.

Table 1: Water quality parameters in three different stations

Samples	pH	Hardness	DO	BOD_5	Alkalinity	Cl^-	$PO4^-$	EC	Fe	Mn
WS1	7.4	125	5.8	2.8	115	110	0.00	299	0.33	0.4
WS2	6.6	95	5.1	1.4	100	70	0.29	214	0.13	0.4
WS3	6.9	105	5.6	1.9	105	90	0.26	267	0.27	0.45

Table 2: Certified values in the reference materials

Parameters	Unit	EQS	CCC	WQS
pH	—	6.5-8.5	6.5-8.5	7-8.7
Hardness	mg/L	—	—	—
DO	mg/L	≥5	—	≥5
BOD_5	mg/L	≤3	—	—
Alkalinity	mg/L	—	—	—
Cl^-	mg/L	—	230	150
PO_4^-	mg/L	—	—	—
EC	μs/cm	—	—	—
Fe	mg/L	—	1	1
Mn	mg/L	—	—	1*

*Formula used: WQG ≤ 0.0044 hardness + 0.605

EQS = Environmental Quality Standards (JEQ)

CCC = Criterion Continuous Concentration (USEPA)

WQS = Water quality Standard (BCMOE, 2019)

3.2 Sediment Analysis

Another researcher undertook a s study where the concentration of heavy metals in the river bed sediments of Passur river were determined (table 3).

Table 3: trace element concentration in bed sediment of Pussur river (Rahman *et al*., 2010)

Samples	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Zn (mg/kg)	Fe (%)	Cu (mg/kg)
S1	12.2	2.5	32	50.43	2.78	29.25
S2	16.15	0.8	37.40	64.81	3.16	18.30
S3	13.12	1.30	39.32	62.78	3.34	23.25

3.2.1 Metal Contamination Analysis

The Pollution load index for all of the three samples are more than 1 (S1=1.40, S2=1.23, S3=1.35) indicating deterioration of sediment over the period. The CF values are low for Pb, Ni, Zn, low to moderate for Cu and considerably higher for Cd indicating sever contamination. In comparison with other literature data of mangrove forest over the world, concentration of Fe is remarkably higher representing higher contamination (Islam *et al*., 2017). Port activities and ship breaking are the possible sources for Fe contamination in this region.

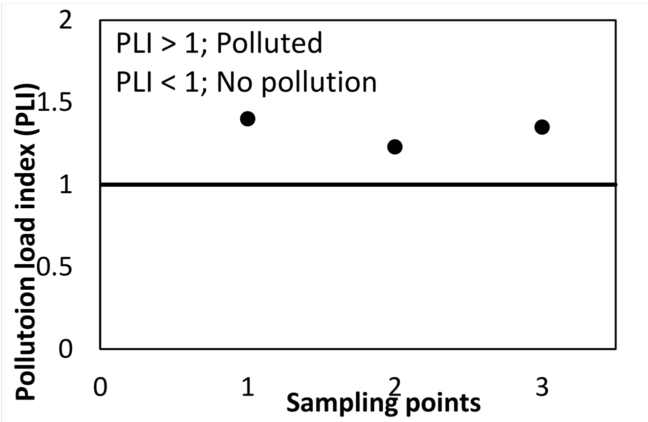


Figure 1: PLI values for bed sediment samples

Table 4: Certified values in reference materials

Standards (mg/kg)	Pb	Cd	Ni	Zn	Fe*	Cu
TEL	30.24	0.68	15.9	124	—	18.7
PEL	112	4.21	42.8	271	—	108
ERL	46.7	1.2	20.9	150	—	34
ERM	218	9.6	51.6	410	—	270
UCC	17	0.09	47	67	3.92	28

* The concentration of Fe is given in percentage
TEL = Threshold effect level (CCME, 1999)
PEL =Probable effect level (CCME, 1999)
ERL= Effect range low (NOAA, 2012)
ERM = Effect range medium (NOAA, 2010)
UCC = Upper Continental Crust (Rudnick and Gao, 2014)

According to sediment quality guidelines, no element shows concentration above PEL. Cd, Ni and Cu fall above TEL values where Cd and Ni exceeds both the TEL and ERL values and can possess threat to the organisms. Pb, and Zn are not considered as threats to the ecology. Cd concentration is reported to be very high compared with the UCC value. Comparing with these values the Sundarbans sediment is low to moderately contaminated with these elements whereas Cd concentration is remarkably higher and moderate to severely contaminated in the sediment of Sundarbans. Cd is non-essential element and in excess amount hampers photosynthesis and plant growth, alters mineral uptake, produce oxidative stress in plants (Benavides et al., 2005). In fauna Cd can decrease growth and reproduction capability. If enter in foodchain can affect liver, kidneys, placenta, lungs, bones and brain (Jaiswal et al., 2018). Cd exposure can cause anosmia, cancers, cardiac failure, cerebrovascular infarction, osteoporosis, emphysema, proteinuria, and cataracts (Lalor, 2008). Fe is an important mela as micronutrients for life process in plants and microorganisms but excess amount may have negative toxic biological effect on the biota of the Sundarbans. Excessive Fe uptake in plants can cause alteration of enzymatic activities, plant necrosis or death and colonies disintegration as well as roots abscission at (Jucoski et al., 2015). Overexpose to Fe can affect liver, gills, testis and intestines of fishes.

Table 5: Pearson correlation matrix for elements in the sediment

Metals	Pb	Cd	Ni	Zn	Fe	Mn
Pb	1.00					
Cd	-0.86	1.00				
Ni	0.47	-0.85	1.00			
Zn	**0.77**	-0.99	**0.93**	1.00		
Fe	0.42	-0.82	**0.99**	**0.90**	1.00	
Mn	-0.94	-0.98	-0.75	-0.94	-0.71	1.00

Bold correlations are significant at $p < 0.01$

To analyse the transport behaviour of the elements a correlation has been established shown in table 5. Strong positive correlation between Fe, Zn, Ni and Pb represents that they are of similar origin and controlled by pretty much the same factors. All of the elements are strongly negatively correlated with Cd and Mn representing that these two metals have less influence on accumulation of other trace elements (Islam et al., 2017).

3.2.2 Ecological Risk Assessment

Table 6 indicates that the ER^i values for all the samples are within the expected values ($ER^i < 40$) and posse low potential ecological risks except Cd which is high ($160 < ER^i < 320$) to very high ($ER^i > 320$) and may pose high ecological risk. The RI values found out be moderate ($150 \leq RI \leq 300$) for S2 and considerable ($300 \leq RI \leq 600$) for S3 and is of high risk for S1 (Zhao *et al*., 2012). The values of M-ERM-Q for all three samples falls in the range of 0.11-0.5 which indicates 21% probability of toxicity (long *et al*., 2000).

Table 6: Sediment contamination based on ecological risk assessment

Samples	Er^i					RI	M-ERM-Q
	Pb	Cd	Ni	Zn	Cu		
S1	3.58	833	3.40	0.75	5.22	846	0.23
S2	4.85	267	3.98	0.97	3.27	280	0.22
S3	3.86	433	4.18	0.93	4.15	446	0.24
Tri	5.0	30.0	5.0	1.0	5.0		

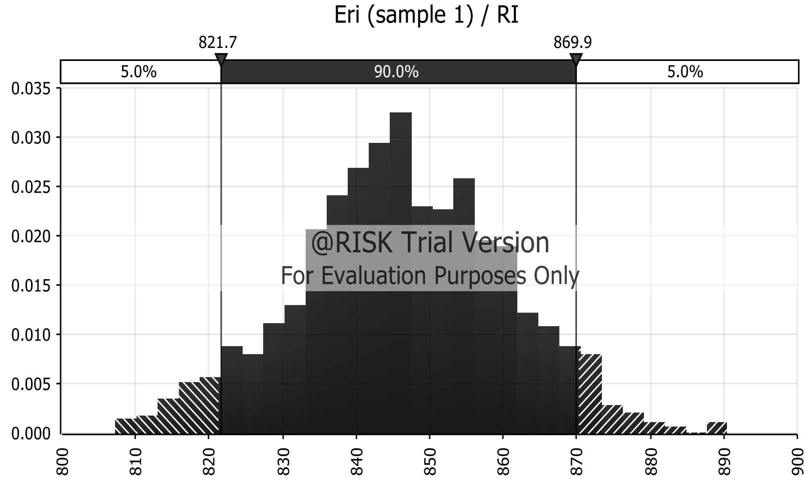
A simulation-based approach was also adopted to assess the probability of risk occurrence. Fig 2 illustrates 90% possibility of the outcome to occur in all of the three samples revealing that the RI values have significant influence on possible risk occurrence of trace element accumulation on sediments in this region.

Frequent accidents of cargo vessels carrying oil, coal, cement, chemical elements and other harmful materials near the Sundarbans have huge negative impact on the Sundarbans aquatic flora and fauna. The tide-influenced depositional system helps the oil to reach the forest and affect the trees and enter into the Sundarbans food-cycle. To facilitate the navigation of water vehicle, dredging has been occurred now a days. It greately impacts on aquatic flora and fauna. Dredging can cause bank erosion leading to vegetation disturb and fish population alteration. Fishes experience higher mortality rates due to injuries, physiological stressors, disorientation, abrasions and infections and even death (The Daily Star, 2016). Dredging increase turbidity, reduce light availability putting the organisms living under water, fishes, especially dolphins and the aquatic ecology as a whole in a threat. Sediment dredging increases the amount of salinity on the roots of the plants. There was a significant reduction in seed germination with increasing salt stress. Increasing soil salinity significantly retarded stem and root elongation. (Bhatt et al., 2008). Disposal of dredged sediment in the Sundarbans forest can also affect the vegetation and the wildlife.

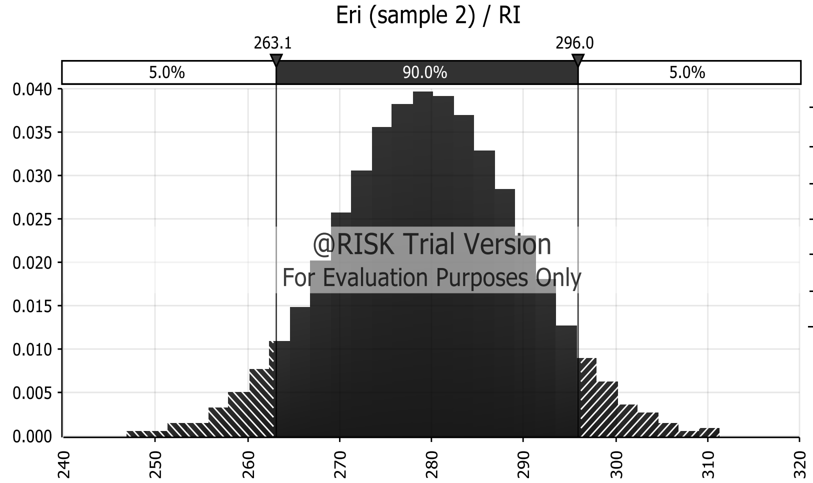
3.2.3 Grain Size Analysis

Fig 3 shows that the sediment sample collected in this study contain silt mostly. The percentages of silt and clay are higher than sand. Sediment grain size decreases with increase in metal content

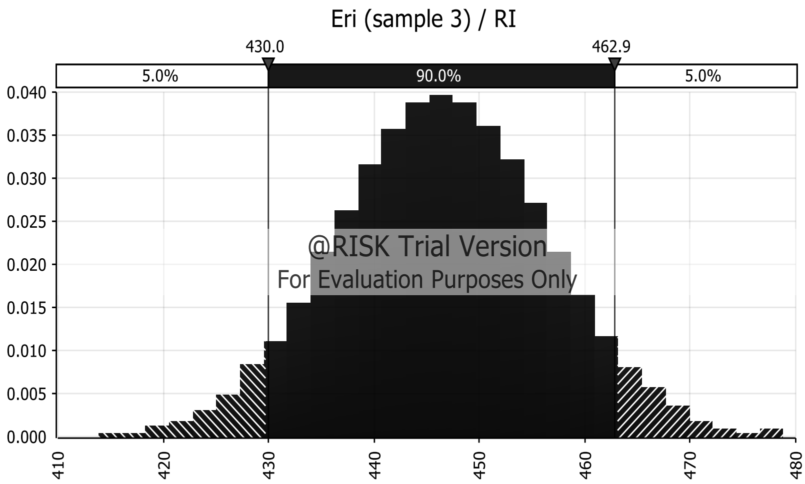
(Maslennikova e*t al*., 2012). The mean size indicates that the sediments are deposited at moderately low energy condition (Ramanath *et al*., 2009). Fig 3 represents the textural characteristics of the Passur river bed sediment which is primarily silty loam or silty clay loam revealing that silt is the dominating grain size in the Sundarbans soil.



Eri (sample 1) / RI	
Minimum	807.389
Maximum	890.317
Mean	848.304
Std Dev	14.240
Values	1000



Eri (sample 2) / RI	
Minimum	246.374
Maximum	311.266
Mean	279.627
Std Dev	9.993
Values	1000



Eri (sample 3) / RI	
Minimum	413.853
Maximum	478.846
Mean	446.466
Std Dev	9.996
Values	1000

Fig 2: Percentage (90%) of certainty of ecological risk in sediment samples S1, S2, S3 respectively.

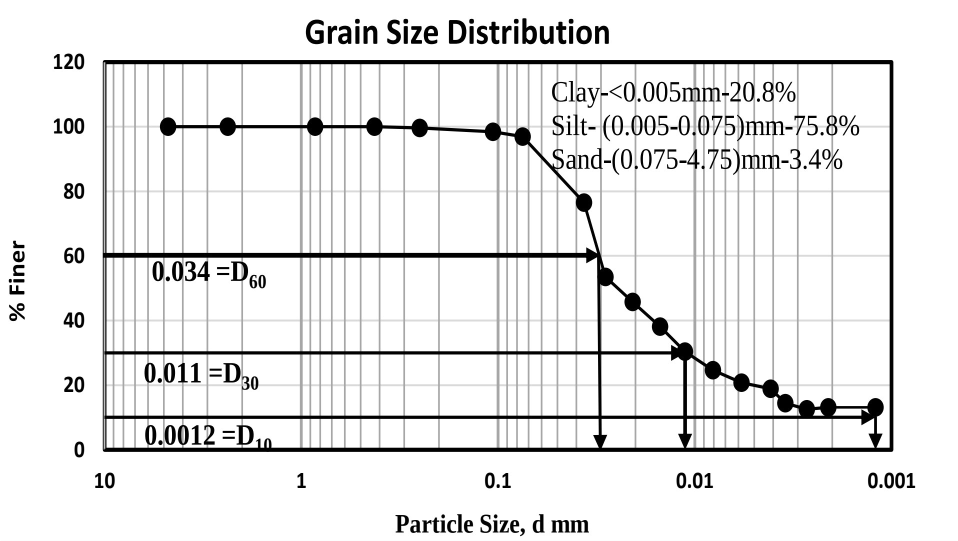


Fig 3: Grain size distribution curve of the Passur river bed sediment sample

Gradation curve indicates that the amount of silty sand is large enough than clay and fine sand. The size of clay particle is <0.005mm and the gradation curve indicates the percent finer of clay is 20.8%. The amount of silt is large (75.8%) and contains huge amount of trace metals. Coefficient of uniformity is 3.09 which is less than the limiting value 4 to 6. So it is classified as poorly graded soil. Also the Co-efficient of curvature is 2.97 which is in betweem 1 to 3.

4. CONCLUSIONS

In this study, water quality parameters for Passur river were determined. The study findings indicated no serious pollution of the river water. The Passur river bed sediment near Sundarbans is rich in silt content. The ecological risk in the concentration of six trace elements (Pb, Cd, Ni, Zn, Fe, Cu) in the collected river bed sediment had been analysed. The concentration values for Cd (1.5 mg/kg), Fe (3.1%) and Ni (36.2 mg/kg) were high which suggests that the sediment is moderate to severely contaminated with these trace metals which may originated from different anthropogenic sources. The concentration of Cd and Ni are higher than the TEL and ERL reference values indicating the possible risk of eco-toxicity. Cd has higher value of potential ecological risk factor (Er^i) indicating high ecological risk and posing negative effect on aquatic flora and fauna. Dredging is also degrading the aquatic ecosystem causing harm to aquatic flora and fauna and the disposal of dredged materials in the Sundarbans could hamper vegetation growth in the forest area.

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