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SPATIAL ANALYSIS OF TRACE ELEMENT CONTAMINATION IN SEDIMENTS OF PASSUR RIVER

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ABSTRACT

The concentrations of sixteen different trace elements (Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Sb, Hg, Pb, Th and U) presented in a paper by Islam *et al*. (2017) can be further studied to assess the intensity and distribution of trace element contamination in Passur river bed sediments, which is here described and illustrated. The ecological impact of these trace elements is analyzed by calculating geo-accumulation indices (Igeo) which reveal that the sediments are uncontaminated to moderately contaminated by Sb, Th and U and moderately contaminated by Cd. Among the trace metals, Cd has shown a higher geo-accumulation index value indicating greater ecological disturbance that may cause serious harm to aquatic flora and fauna. In this study, GIS mapping is used to visualize the spatial distribution pattern of trace elements in river bed sediments which delineates the ecological imbalance in Passur river. These spatial variation maps based on geo accumulation index values establish that most trace elements show higher contamination near the Mongla Port, probably due to harbor activities in this region. The river ecosystem is affected by anthropogenic activities and requires environmental regulation in order to preserve its biodiversity.

Keywords: *Sediment quality, trace elements, geo-accumulation index, spatial variation, Passur river.*

1. INTRODUCTION

Passur river ecosystem supports a unique fish diversity and a large number of aquatic plants. Different anthropogenic activities such as industrial discharges, port activities, ship breaking, use of fertilizer and pesticides in agriculture and shrimp aquaculture have caused river pollution. In Passur river, a total of 95 fish species contributing to 14 orders, 45 families and 77 genera were found. Out of 95 species, 14 belonged to the threatened and 3 to the near threatened (Gain *et al*., 2015).

Sediment is a valuable source of information on the environment and geotechnical status of marine pollution. It can act as a sink for metals in the environment degrading the quality of an aquatic ecosystem (Kumar *et al*., 2016; Islam *et al.,* 2017). The degree of trace element contamination and its distribution pattern reveals the condition of an aquatic environment and help pollution sources (Förstner and Wittman, 1979, Chatterjee *et al.*, 2007). Trace elements can accumulate in aquatic flora and fauna, which may enter the human food chain and result in health problems. Moreover, rapid urbanization and industrialization, climatic change and conversion of the land-use pattern have put extra pressure on river water sources, degrading the river ecosystem. Hence, maintenance of this sediment-laden freshwater discharge has significant importance on preserving biodiversity.

Coastal marine environments are one of the most sensitive areas for the accumulation of trace elements. An enormous amount of sediments is carried every year by Passur river. Therefore, contamination of sediments is a sever problem as sediments are the ultimate sink for trace elements like Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Sb, Hg, Pb, Th and U etc. and is a potential source of marine pollution. This study aims to analyze the quality of Passur river bed sediment and to visualize the spatial variation of trace element contamination of river bed sediment using GIS.

2. METHODOLOGY

2.1 Study Area

The study area includes Passur river near the Sundarbans (Fig 1). It is an important river flowing close to the south-western boundary of Bangladesh. It is a distributary of Ganges that continues as the extension of the Rupsha river, meets the Shibsha river within the Sundarbans near the sea it flows as the Kunga river. In the assemblage of the Passur river and the Mongla river lies the second largest port of the country called the Mongla sea port.

2.1.1 Assessment of Pollution

The geo-accumulation index helps to assess the level of contamination in an aquatic ecosystem. The following equation was used:

$$I_{geo} = log_2(\frac{C_i}{1.5Bi}) \quad (1)$$

Here, C_i is the concentration of an individual element and B_i is the geochemical background value (UCC) of that element. Igeo >5 reveals the sediments to be extremely contaminated, Igeo = 4-5 indicates strongly to extremely contaminated, Igeo = 3-4 indicates strongly contaminated, Igeo = 2-3 indicates moderately to strongly contaminated, Igeo = 1-2 indicates moderately contaminated, Igeo = 0-1 indicates uncontaminated to moderately contaminated and Igeo <0 refers uncontaminated (Magesh *et al*., 2011).

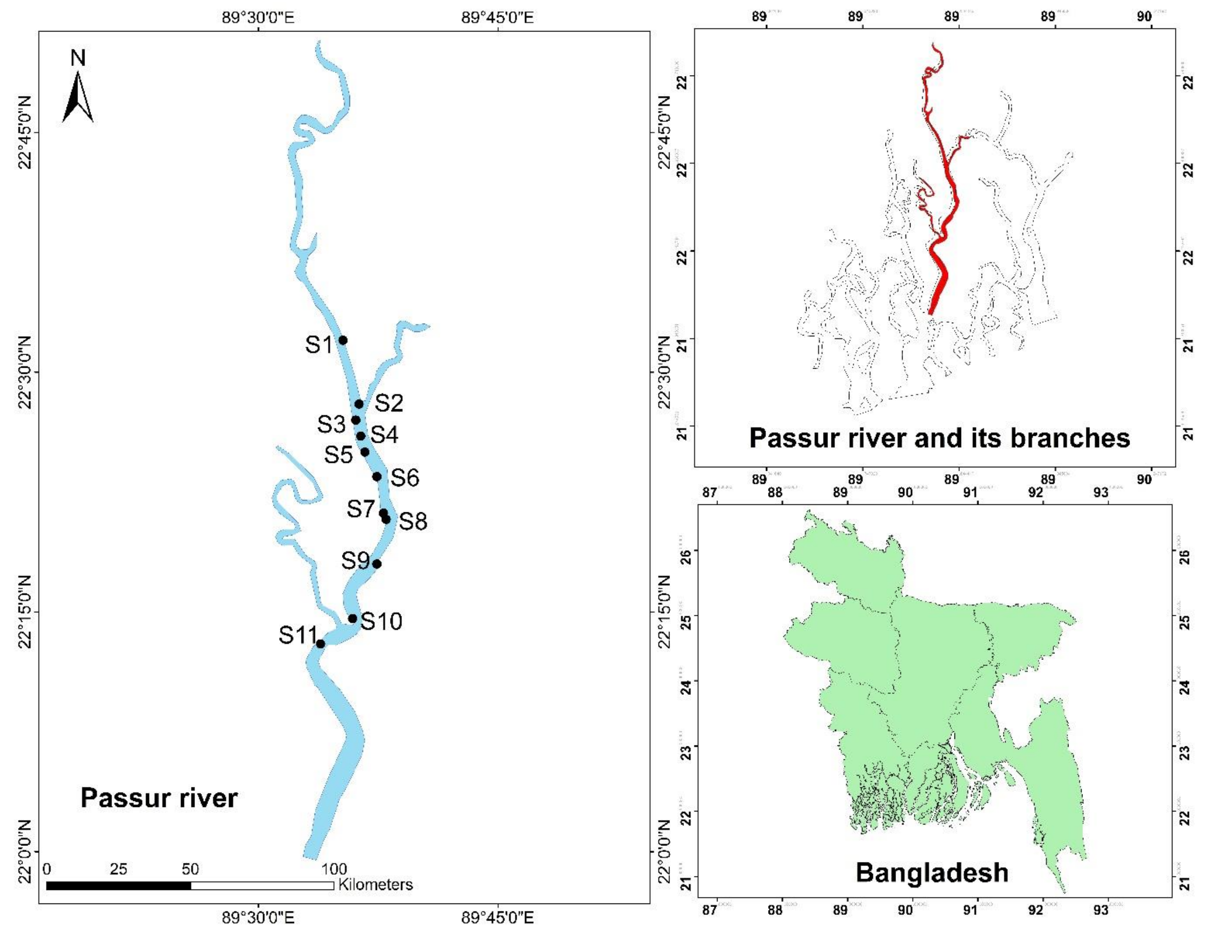

Figure 1: Map showing the study area and sediment sampling stations

2.1.2 Spatial Variation of Trace Elements

Geographic Information System (GIS) was used to do statistical analysis of Passur River. This statistical analysis was done by the spatial distribution of Geo accumulation index of different heavy metals. Statistical analysis is often used to explore data. For example, to examine the distribution of values for a particular attribute or to spot outliers (extremely high or low values). Having this information is useful when defining classes and ranges on a map, when reclassifying data, or when looking for data errors. Inverse Distance Weighted (IDW) interpolation was used for identifying the spatial distribution of geo accumulation index of sixteen trace elements like Pb, Cu, Ni, Zn, Cd, Fe. This distribution or interpolation can easily predict the ranges of distribution of geo accumulation index at a certain distance.

The following procedures were obtained for mapping using ArcGIS.

a) An Excel file was developed with 97-2003 version worksheet.
b) Shape file of Passur river was added. The excel file was also added and the data were exported.
c) The XY data were added considering spatial reference WGS 1984.
d) Considering spatial analysis tool, the data were interpolated with IDW.
e) Finally, raster analysis was done.

3. RESULTS AND DISCUSSION

3.1 Sediment Quality Analysis

Another group of researchers conducted a study where concentrations of sixteen different trace elements in Passur river bed sediment were recorded. Table 1 shows concentrations of sixteen different trace elements (Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Sb, Hg, Pb, Th and U) in eleven samples of Passur river bed sediments along with their UCC values. These concentration values are analysed by establishing geo-accumulation indices.

Table 1: Concentration of sixteen trace elements in Passur river bed sediment (Islam *et al*., 2017)

Metals	Samples											
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	UCC
Al	7.46	8.50	8.05	7.05	8.28	8.02	7.05	6.53	7.36	6.97	7.61	8.15
V	84.1	120	104	87.1	96.4	89.4	84.8	74.6	90.7	80.8	90.6	97
Cr	68.0	82.1	82.4	78.0	64.0	68.1	64.9	57.8	64.4	58.1	75.1	92
Mn	723	510	505	708	737	668	689	500	830	723	818	775
Fe	4.11	4.90	4.62	4.00	3.97	3.59	3.91	3.56	3.95	3.19	3.80	3.92
Co	15.2	15.0	14.6	15.1	14.7	14.7	14.8	13.2	13.8	11.9	15.3	17.3
Ni	28.4	38.1	33.7	28.6	28.1	25.5	30.5	24.1	29.2	27.4	28.6	47
Cu	21.28	30.25	27.76	21.38	22.58	19.55	24.03	20.55	21.20	20.85	22.50	28
Zn	58.1	88.8	77.8	68.7	46.8	64.8	83.6	46.2	68.0	65.8	76.9	67
As	6.8	9.04	7.48	7.15	7.42	5.80	3.40	6.30	7.40	6.30	8.20	4.8
Cd	0.45	0.40	0.82	0.47	0.45	0.42	0.50	0.47	0.40	0.47	0.42	0.09
Sb	0.62	1.24	0.952	0.718	0.702	0.576	0.624	0.964	0.955	0.728	0.781	0.4
Hg	34.25	42.50	46.40	29.75	28.75	21.50	26.25	25.50	23.25	24.25	33.00	50
Pb	15.0	19.8	23.6	16.5	15.3	14.0	17.5	13.3	15.5	14.3	15.8	17
Th	21.7	22.2	21.9	26.7	20.8	21.6	23.3	19.7	21.7	19.0	17.5	10.5
U	4.22	7.88	6.02	5.21	4.28	4.17	4.08	4.77	6.84	6.64	5.16	2.7

All the concentrations are in mg/kg except Al (%), Fe (%) and Hg (μg/kg).
UCC = Upper Continental Crust (Rudnick and Gao, 2014).

Geo-accumulation index is a measure of the degree of pollution in an aquatic environment. Igeo values show that river bed sediment is uncontaminated for most of the trace elements. However, the samples are uncontaminated to moderately contaminated by As, Sb, Th, U and moderately contaminated by Cd (Table 2). The higher concentration of Cd, As and Sb indicates usage of chemical fertilizer and pesticides in agriculture and shrimp aquaculture.

High geo-accumulation index values for Cd indicate that high Cd concentration present in river bed sediment may degrade the quality of the aquatic ecosystem. Cd in river bed sediment is known to be originated from different anthropogenic sources, such as industrial discharge, agricultural wastes and oil spillage (Yasar *et al*., 2001). Cd is a 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. Entering the food chain can affect the liver, kidneys, placenta, lungs, bones and brain (Jaiswal *et al*., 2018).

Table 2: Geo-accumulation index values of sixteen trace elements in Passur river bed sediment

Metals	Samples										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Al	-0.71	-0.52	-0.60	-0.80	-0.56	-0.61	-0.80	-0.90	-0.73	-0.81	-0.68
V	-0.79	-0.28	-0.48	-0.74	-0.59	-0.70	-0.78	-0.96	-0.68	-0.84	-0.68
Cr	-1.02	-0.75	-0.74	-0.82	-1.11	-1.01	-1.09	-1.25	-1.10	-1.25	-0.88
Mn	-0.68	-1.19	-1.20	-0.72	-0.66	-0.80	-0.75	-1.21	-0.50	-0.68	-0.51
Fe	-0.51	-0.26	-0.35	-0.56	-0.57	-0.71	-0.59	-0.72	-0.57	-0.88	-0.62
Co	-0.78	-0.79	-0.83	-0.78	-0.82	-0.82	-0.81	-0.97	-0.91	-1.12	-0.76
Ni	-1.31	-0.89	-1.06	-1.31	-1.33	-1.47	-1.21	-1.55	-1.27	-1.36	-1.31
Cu	-0.98	-0.47	-0.60	-0.97	-0.90	-1.10	-0.81	-1.03	-0.99	-1.01	-0.90
Zn	-0.79	-0.18	-0.37	-0.55	-1.10	-0.63	-0.27	-1.12	-0.56	-0.61	-0.39
As	-0.08	0.37	0.05	-0.01	0.04	-0.31	-1.04	-0.19	0.04	-0.19	0.18
Cd	1.74	1.57	2.60	1.80	1.74	1.64	1.89	1.80	1.57	1.80	1.64
Sb	0.05	1.05	0.67	0.26	0.24	-0.06	0.06	0.68	0.67	0.27	0.38
Hg	-1.13	-0.82	-0.70	-1.33	-1.38	-1.80	-1.51	-1.55	-1.69	-1.63	-1.18
Pb	-0.77	-0.37	-0.11	-0.62	-0.74	-0.87	-0.54	-0.94	-0.72	-0.83	-0.69
Th	0.46	0.50	0.48	0.76	0.40	0.46	0.56	0.32	0.46	0.27	0.15
U	0.06	0.96	0.57	0.36	0.08	0.04	0.01	0.25	0.76	0.71	0.35

3.2 Spatial Distribution of Trace Elements

GIS mapping from geo-accumulation index values of trace elements helps visualize the pollution status of the coastal ecosystem. Cd is widely distributed in the sediments of Passur river and all of the samples have Igeo values greater than 1.5. The river bed sediments are less susceptible for Cr, Mn, Co, Ni and Cu in comparison with other trace elements.

GIS maps (Fig: 2 a-h) illustrate that most of the trace elements show higher contamination near the Mongla Port. This suggests the presence of a point source of contamination for S1 and S2 near the Mongla port. Harbour activities and untreated discharge from several cement and oil processing industries situated in this area are accountable for this. Other samples show comparatively less contamination of trace elements, indicating non-point sources of pollution for those samples. Distribution maps for Co, Ni and Cr show relatively homogenous spatial variation, which indicates their origin from non-point sources. The distribution pattern of Mn presents a different scenario than other trace elements. Mn concentration is comparatively low in sediments near the port, implying its origin is different from other usual activities near the port. Nevertheless, spatial variation can result from variation in anthropogenic activities, the influence of tides and the geo-chemical condition of the soil (Jonathan et al., 2010). Spatial variation along the river can also be observed due to oil spillage accidents which are very common in this region.

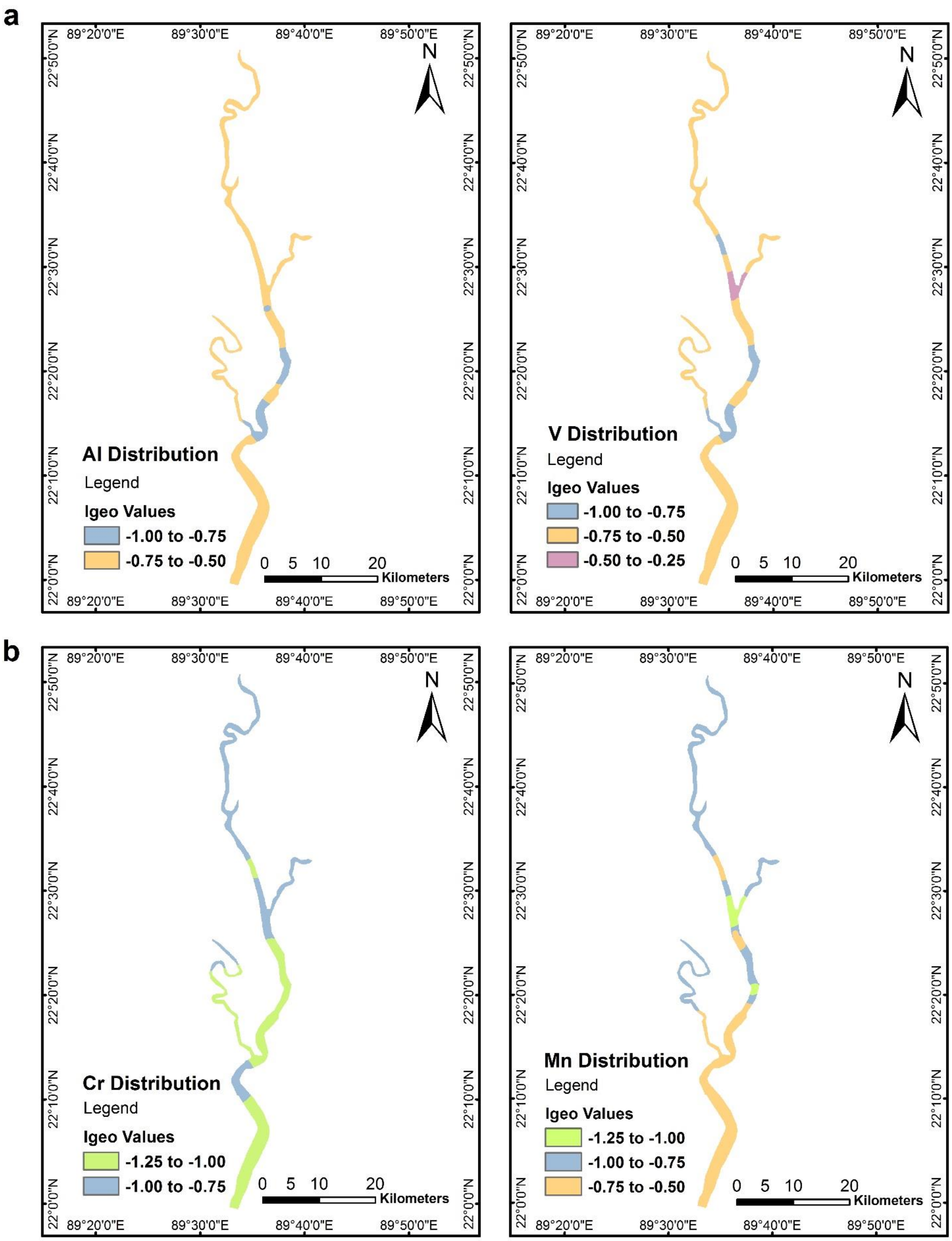

Figure 2. a) Spatial variation of Al and V in Passur river. b) Spatial variation of Cr and Mn in Passur river.

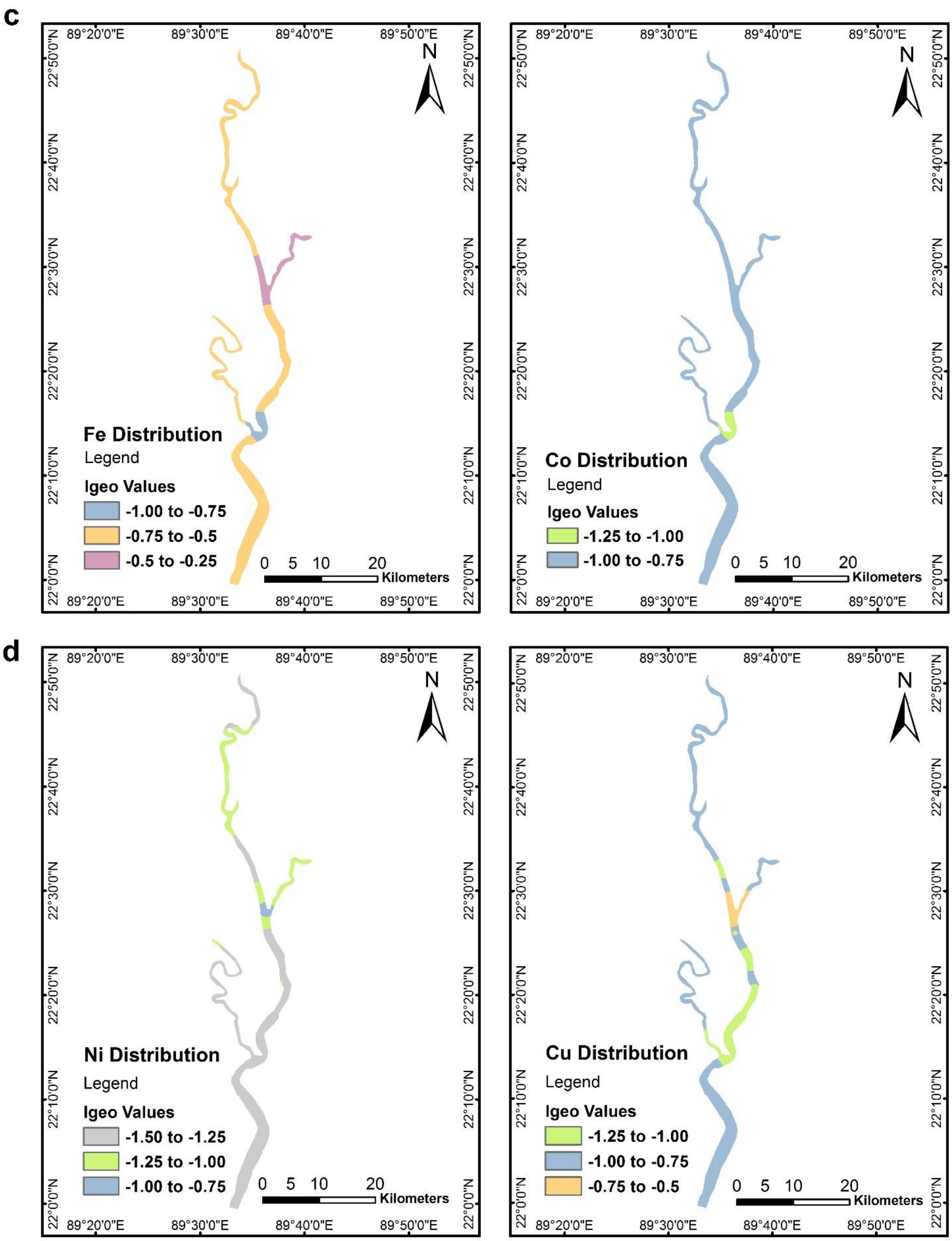

Figure 2. c) Spatial variation of Fe and Co in Passur river. d) Spatial variation of Ni and Cu in Passur river.

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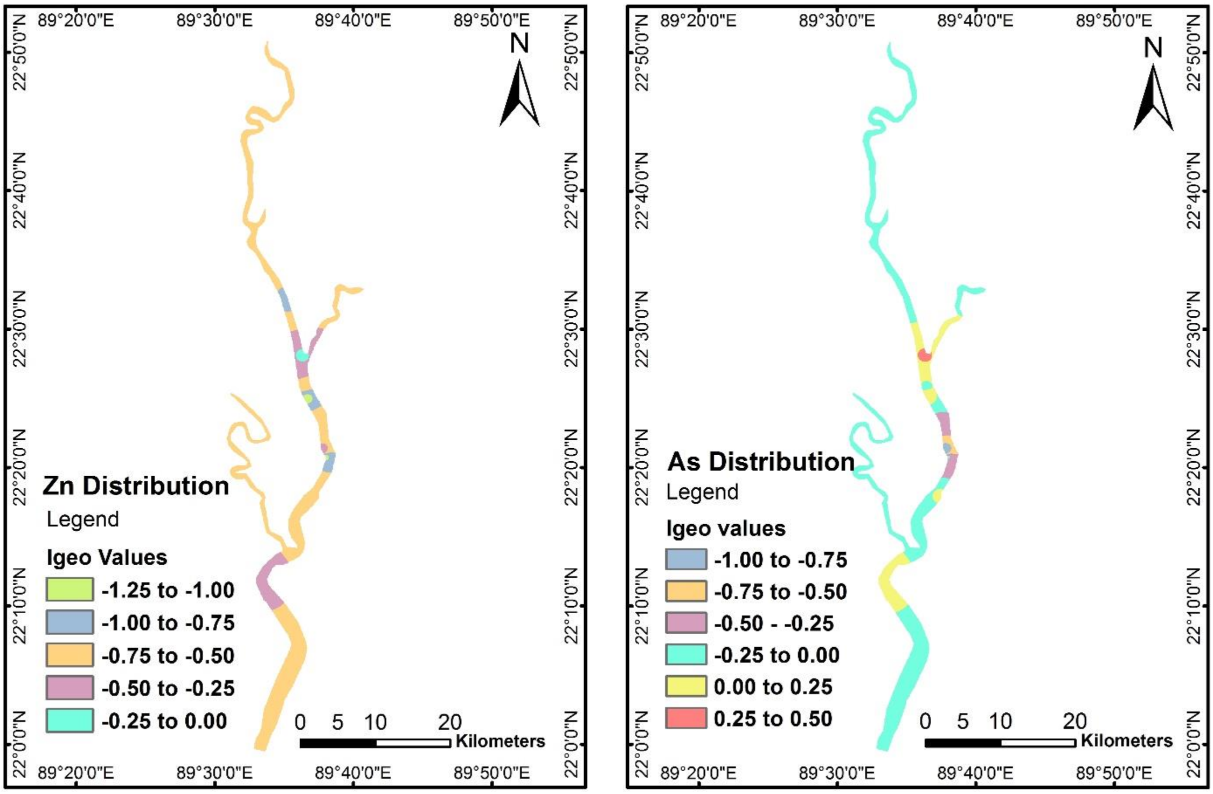

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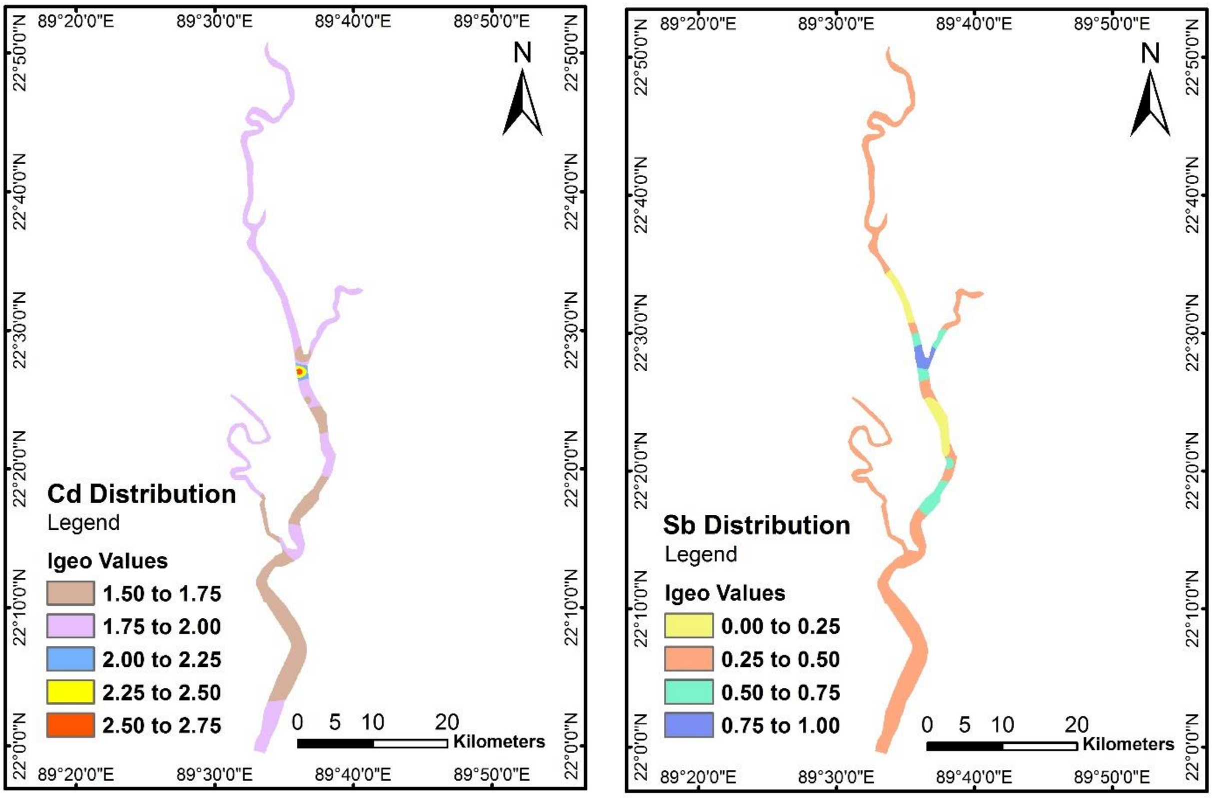

Figure 2. e) Spatial variation of Zn and As in Passur river. f) Spatial variation of Cd and Sb in Passur river.

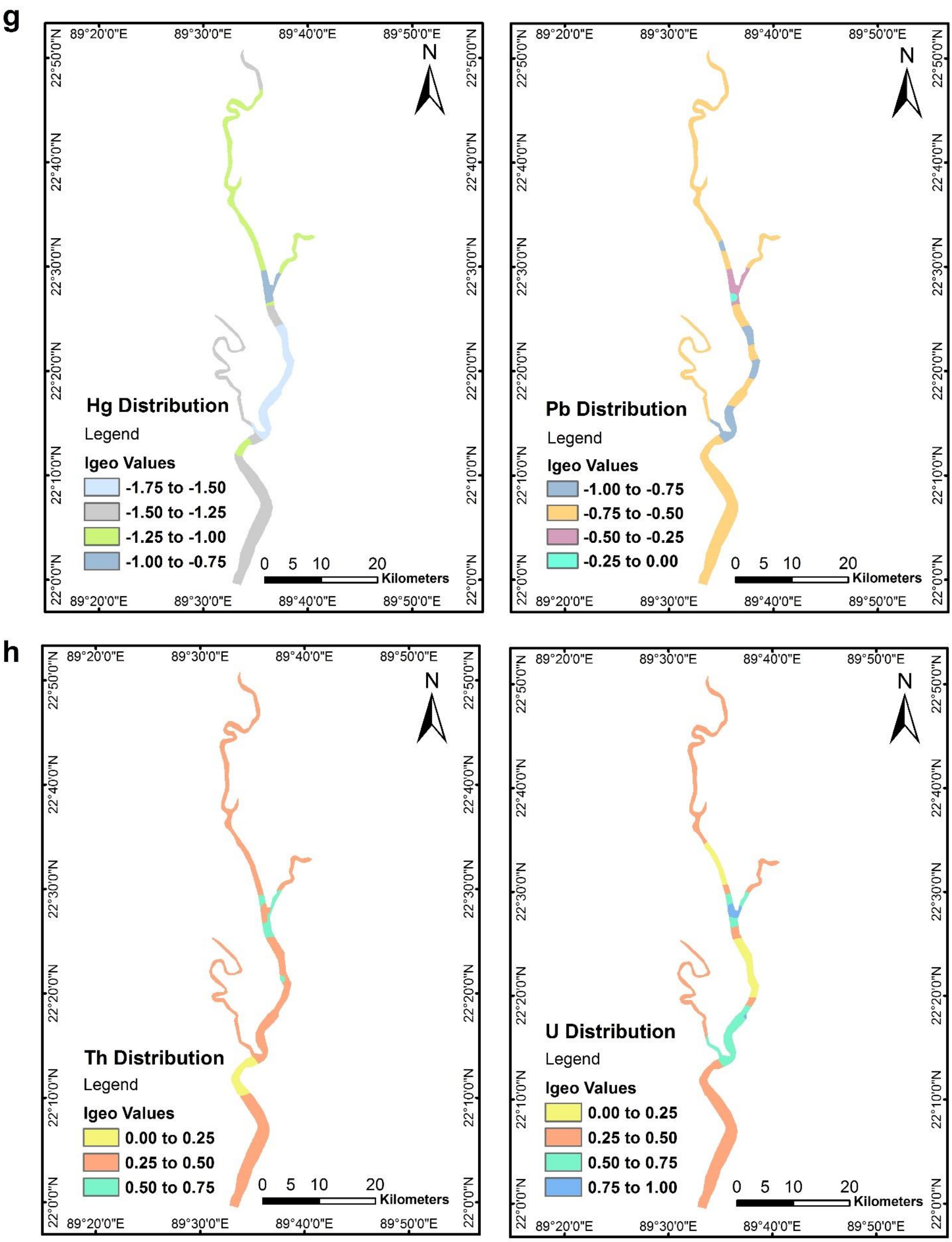

Figure 2. g) Spatial variation of Hg and Pb in Passur river. h) Spatial variation of Th and U in Passur river.

4. CONCLUSION

This study analysed the intensity and distribution of trace element contamination in Passur river bed sediment. The degree of contamination of river bed sediments was evaluated by determining geo-accumulation indices of sixteen different trace elements (Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Sb, Hg, Pb, Th and U). The geo-accumulation values suggest that Passur river bed sediment is uncontaminated to moderately contaminated by Sb, Th and U while moderately contaminated by Cd. GIS mapping was employed in the form of geo-accumulation values to assess the extent of river pollution. The spatial variation maps illustrate that most trace elements show higher contamination near the Mongla Port, possibly due to different anthropogenic activities in this region, such as the discharge of industrial effluents and harbour activities. This study suggests the need for pollution control measures and decontamination programs for this region.

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