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Temporal and Spatial Distribution of Carbon, Nitrogen and Phosphorous in Ganges River Basin

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ABSTRACT

The Ganges basin is the largest river basin of India. It is one of the geologically youngest and tectonically active drainage regimes of the world. The sediment load of the basin consist of fine sand, silt and clay and mineral assemblage is dominated by quartz, feldspars, illite and kaolinite. For the present study of Ganges river basin middle Gngetic plain was chosen because of its immense cultural and economic significance. It covers the Bihar plain and entire Eastern Uttar Pradesh on either side of Ganges and Ghaghara rivers within Himalaya and peninsular ramparts on the north and south respectively. The sediment samples were collected from three locations, viz., upstream at Varanasi, midstream at Ghzipur and downstream at Patna, twice once in pre-monsoon period (April, 1999) and other in post-monsoon period (October, 1999). The sediments were analyzed to understand the distribution and biogeochemistry of C, N and P. The Organic Carbon (C_{org}) was found to be decreasing with depth due to the age of the sediment and extent of anaerobic decomposition. The post-monsoon concentrations were lower than pre-monsoon due to conducive environment for decomposition of organic matter. Total Carbon (C_{total}) was found to be comparable at all these three locations. The substantial part of C_{total} is found to be inorganic in origin. Nitrogen contents were very low decreasing with the depth due to mineralization of organic matter, as more than 90 % of nitrogen is organic in nature. Phosphorous content in all these three locations were comparable. The phosphorus content was decreasing with the depth due desorption of Fe-bound phosphorous under anaerobic condition formed by burial and compaction of the sediments. A distinct spatial pattern was obtained in the distribution of phosphorous. C_{org}/N ratio was found to be increasing with depth by mobilization and leaching out of nitrogen, due to its mineralization.

Introduction

The major part of river organic matter is allochthonous in genesis, comes from the soil. Soil is potential source of both, dissolved and particulate organic matter (Hedges *et al.*, 1986; Cuffney, 1988 and Grushbaugh and Anderson, 1989). The other important source of river organic matter is the product of agricultural activities, and comparatively small autochthonous fraction formed *in situ* by river phytoplanktons (*Ittekkot et al.*, 1986). The concentration of DOC and POC increases with increasing stream flow (Meyer *et al.*, 1988). The POC in total suspended solid ranges between 1.3 and 2.8 percent for Himalayan Rivers (Subramanian *et al.*, 1985). The main reservoir of nitrogen on the earth is rock deposits, atmospheric air and living organisms. The excessive use of nitrogenous fertilizers in the intensively cultivated middle Gangetic plain is an important source of nitrogen in the river thorough soil run off.

The main reservoir of the phosphorous on the earth surface is living organism and relatively insoluble calcium phosphate deposits in rock and sediments. Phosphorous is solubilized from its deposits under conditions of low pH and low oxidation potential. Plants and animals after their death and decay return phosphorous to the sediments and water. Bulk of the phosphorous in the sediments is fixed or adsorbed on the sediment surface and part of it is lost through the run off. Vaithyanathan *et al.*, (1989) and Subramanian (1984) worked out the content and transport of phosphorous by Indian Rivers. In their studies phosphorous content was found to vary between 700 and 1400 µg/g with an average about 1100 µg/g. This paper deals with the occurrence and behaviour of C, N and P in the Basin of Middle Gangetic Plain, as no considerable work has yet been made.

Study Area

Ganges basin is the largest river basin of India, with a geographical area of about 0.9 million km^2. It is home for about 37% of population of the country. The basin is one of the geologically youngest and tectonically active drainage regimes of the world (Morgan and McIntire, 1959; Coleman, 1969; Valdiya, 1984).The sediment load of the basin consist of fine sand, silt and clay and mineral assemblage is dominated by quartz, feldspars, illite and kaolinite (Datta and Subramanian, 1997). For the present study of Ganges river basin middle Gngetic plain was chosen because of its immense cultural and economic significance. The middle Gangetic plain (24° 30' N to 27° 50' N and 81° 47' E to 87° 50' E) is a large physical area of 144,409 km^2. It covers the Bihar plain and entire Eastern Uttar Pradesh on either side of Ganges and Ghaghara rivers within Himalaya and peninsular ramparts on the north and south respectively. The west and east side of the region is wide open and there is no physical boundary as the plain imperceptibly opens up in the west from upper Gangetic Plain and dies out into lower Gangetic plain in the east. Thus this region is transition region and separating the upper and lower Gangetic plain from north and south respectively.

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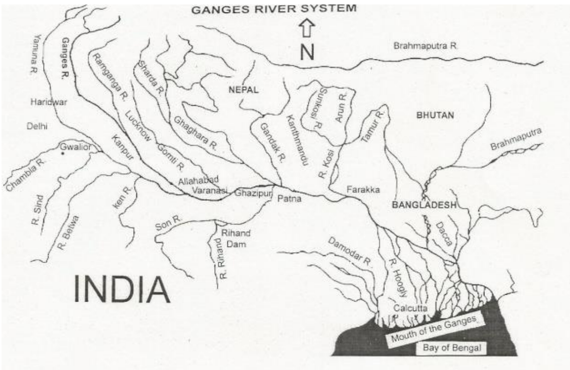

Materials and Methods

The sediment samples were collected from Ganges river basin in the middle Gangetic plain at three locations, viz., upstream at Varanasi, midstream at Ghzipur and downstream at Patna. Sample were collected twice once in pre-monsoon period (April, 1999) and other in post-monsoon period (October, 1999). At river bed approximately one metre PVC pipes were hammered to ground and then taken out along the sediments. The pipes were cut into pieces at 10 cm interval. The samples were sealed in the plastic bags, brought to the laboratory and kept at 4°C temperature until analysis could be carried out. The sediments were dried at room temperature. The carbon was analyzed by using Coulomat (702) Carbon Analyzer. Samples treated with H_2O_2 were used for inorganic carbon where as untreated samples were used for total carbon. The difference is considered as organic carbon. Nitrogen was analyzed by Kjeldahl digestion method of Anderson and Ingram (1993). Phosphorous fractionation was carried out by selective solvent method (Berner and Ji-Long Rao, 1994). Extracted fraction were analyzed by single solution phosphomolybdate blue method (Koroleff, 1976), using spectrophotometer (Cecil 594). All the phosphorous fractions were summed up to get the total phosphorous.

Table 1. Distribution of C, N and P in Pre and Post-monsoon Core Sediments of Varanasi

Depth (cm)	Pre-monsoon Samples						Post-monsoon Samples					
	C_{inorg} (%)	C_{org} (%)	C_{total} (%)	N (%)	C_{org}/N	Total P (μg/g)	C_{inorg} (%)	C_{org} (%)	C_{total} (%)	N (%)	C_{org}/N	Total P (μg/g)
10	1.13	1.20	2.33	0.28	4.3	890	0.92	1.14	2.06	0.12	9.5	680
20	1.58	1.26	2.84	0.19	6.6	860	1.11	1.03	2.14	0.13	7.9	705
30	1.56	1.34	2.90	0.25	5.4	920	1.40	0.91	2.31	0.18	5.1	705
40	1.47	1.28	2.75	0.23	5.6	790	1.28	0.84	2.12	0.14	6.0	685
50	1.69	1.19	2.88	0.18	6.6	740	1.22	0.73	1.95	0.12	6.1	590
60	2.12	1.12	3.24	0.15	7.5	880	1.80	0.92	2.72	0.13	7.1	805
70	2.05	1.08	3.13	013	8.3	860	1.30	0.62	1.92	0.11	5.6	610
80	1.65	1.07	2.72	0.11	9.7	790	1.53	0.53	2.06	0.08	6.6	685
Average	1.66	1.19	2.85	1.80	6.8	841	1.32	0.84	2.16	0.13	6.7	683

Table 2. Distribution of C, N and P in Pre and Post-monsoon Core Sediments of Ghazipur

Depth (cm)	Pre-monsoon Samples						Post-monsoon Samples					
	C_{inorg} (%)	C_{org} (%)	C_{total} (%)	N (%)	C_{org}/N	Total P (μg/g)	C_{inorg} (%)	C_{org} (%)	C_{total} (%)	N (%)	C_{org}/N	Total P (μg/g)
10	0.94	1.01	1.95	0.22	4.6	640	0.66	1.03	1.69	0.10	10.3	825
20	0.68	1.34	2.02	0.19	7.1	780	0.64	0.94	1.58	0.12	7.8	780
30	0.64	1.19	2.13	0.20	7.5	750	0.72	0.82	1.54	0.13	6.3	805
40	0.72	1.40	2.12	0.15	9.3	600	0.75	0.42	1.17	0.09	4.7	670
50	1.21	1.16	2.37	0.14	8.3	740	0.63	0.65	1.28	0.08	8.1	625
60	0.86	1.18	2.04	0.16	7.4	660	0.71	0.40	1.11	0.06	6.7	620
70	1.01	1.19	2.20	0.16	7.4	730	0.72	0.38	1.10	0.05	7.6	560
80	0.84	0.95	1.79	0.12	7.9	670	0.75	0.36	1.11	0.06	6.0	590
90	1.53	0.65	2.18	0.09	7.2	790	1.05	0.30	1.35	0.04	7.5	645
Average	0.94	1.12	2.09	0.16	7.4	706	0.74	0.59	1.33	0.08	7.2	680

Table 3. Distribution of C, N and P in Pre and Post-monsoon Core Sediments of Patna

Depth (cm)	Pre-monsoon Samples						Post-monsoon Samples					
	C_{inorg} (%)	C_{org} (%)	C_{total} (%)	N (%)	C_{org}/N	Total P (μg/g)	C_{inorg} (%)	C_{org} (%)	C_{total} (%)	N (%)	C_{org}/N	Total P (μg/g)
10	2.06	1.23	3.29	0.18	6.8	910	1.12	0.96	2.08	0.12	8.0	715
20	1.48	1.12	2.60	0.16	7.0	860	0.96	1.42	2.38	0.25	5.7	660
30	1.85	1.01	2.86	0.14	7.2	910	1.06	0.86	1.92	0.12	7.2	725
40	1.65	0.89	2.54	0.14	6.8	740	1.35	0.79	2.14	0.09	8.8	770
50	1.24	1.02	2.26	0.15	7.3	720	1.30	0.80	2.10	0.10	8.0	735
60	1.44	0.95	2.39	0.13	7.2	780	1.38	0.76	2.14	0.11	6.9	760
70	1.70	0.86	2.56	0.12	6.4	840	1.40	0.70	2.10	0.08	8.8	730
80	1.54	0.77	2.31	0.12	6.4	860	1.55	0.58	2.13	0.05	11.6	700
90	1.61	0.70	2.31	0.11	7.3	810	1.48	0.46	1.94	0.04	11.5	745
Average	1.62	0.95	2.57	0.139	6.9	825	1.29	0.81	2.10	0.11	8.5	726

Result and Discussion

The distribution of carbon, nitrogen and phosphorous in core sediments collected from Ganges river at three locations viz. Varanasi, Ghazipur and Patna is given in table 1, 2 and 3 respectively. Inorganic Carbon (C_{inorg}) ranged from 1.13% to 2.12% at Varanasi 0.64% to 1.53% in Ghazipur and 1.24% to 2.06% in Patna, pre-monsoon core sediments; whereas the same for post-monsoon sedimentws were 0.92% to 1.53% in Varanasi, 0.66% to 1.05% in Ghazipur and 0.96 to 1.55 in Patna. Organic carbon (C_{org}) was found to be decreasing with the depth due to the age of the sediment and extent of anaerobic decomposition. It also showed a distinct temporal variability, the post-monsoon concentrations were much lower due to suitable condition of decomposition of certain fraction of organic matter during monsoon period. Total carbon was found to be comparable in all three locations. However, much higher concentrations were found at Patna. It also showed a clear temporal variability, the concentrations were much lower in post-monsoon sediments. The substantial part of total carbon was found to be inorganic in origin. Inorganic carbon content was found to be increasing with depth, suggesting its enrichment in the form of carbonate minerals (calcite, aragonite etc.), which is unstable in surface environment. Due to the mineralization upon compaction and burial and loss through anaerobic decomposition mainly in the form of methane, organic carbon was found to be consistently decreasing with the depth in all samples. Nitrogen content in the middle Gangetic plain is very low as compared to other temperate rivers. Nitrogen content was directly influenced by the amount of organic matter, as more than 90 percent of nitrogen is associated with organic matter (De, 2000), derived from soil run off (Hedges *et al*., 1986). Nitrogen was found to be decreasing with the depth as mineralization of organic nitrogen and their subsequent leaching. Nitrogen was much higher at Patna, than Varanasi and Ghazipur, due to organic matter discharge in the river in the form of sewage and soil run off. A well-marked temporal variability was found in the distribution of nitrogen. Monsoon season greatly enhances the mineralization rate, results in giving lower values in post-monsoon season.

Phosphorous in all three core sediments were found to be comparable. Highest value is found in Patna sediments followed by Varanasi and Ghazipur. It also showed temporal variability as concentration in post-monsoon period is generally lower, due to influence of high channel flow and dilution. Concentrations were found to be decreasing with the depth. It suggests gradual release of exchangeable and iron-bound phosphorous under anaerobic condition formed by compaction and burial (Furumai and Ohgaki, 1989; Mc Glathery *et al*., 1994 and Zwoslman, 1994. The similar result was reported by Abdullah, 1995 for Yamuna River, the biggest tributary of river Ganges. A distinct spatial pattern was obtained in the distribution of phosphorous. Due to anthropogenic contribution which is present at greater extent in Varanasi and Patna could have contributed a higher phosphorous content than Ghazipur.

C_{org}/N ratio is of great importance in evaluating the anthropogenic input of nitrogen in the inorganic form, particularly in the form agricultural run off. . In pre-monsoon sediment at Varanasi C_{org}/N ranged from 4.3 to 9.7; the same were 4.6 to 9.3 and 6.4 to7.3 for Ghazipur and Patna respectively. In post-monsoon sediments the values ranged from 5.1 to 9.5 for Varanasi, 6.0 to 10.3 for Ghazipur and 5.6 to 11.6 for Patna. C_{org}/N ratio shows spatial and temporal variability. In vertical column of the sediments C_{org}/N is mostly increasing due to leaching out of the labile nitrogen after mineralization. The C_{org}/N ratio is higher in post-monsoon sediments due to run off of the organic matter during monsoon period when flood plains become a part of river flow system, which reduces the rate of mineralization (Simon, 1989).

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