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Assessment of elemental Carbon, Nitrogen, Hydrogen and Sulphur in alluvial sediments of River Yamuna in Delhi region

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ABSTRACT

River Yamuna a major wetland on which significant portion of the population of Delhi depends for the daily requirements of water usage has been analyzed for elemental Carbon (C), Hydrogen (H),Nitrogen (N)and Sulphur(S) as well as the ratio of Nitrogen and Hydrogen with Carbon. Total of 18 samples were collected from 2 different sites of the Yamuna. Site APalla village where Yamuna enters in Delhi. Nine samples were collected from river bed vertically from 3 different locations with 3 samples from each location at varying depths. Same set of sampling was done at Site 2 Okhla barrage and 9 samples were collected from 3 various locations at different depths of river bed. Average percentage concentration of C, H, N and S at site A on the surface (0-2 cm) of river was 0.256, 0.223, 0.173 and 0.012 while at depth range of 26-32 cm and 59-80 cm was 0.3, 0.22, 0.2, 0.02 and 0.303, 0.189, 0.146 and 0.011 respectively. Average percentage concentration of C, H, N, and S at site B at the surface (0-2 cm) of river bed was measured as 0.216, 0.176, 0.15, and 0.024 and at depth range of 26-32 cm it was 0.52, 0.22, 0.16, and 0.061 while it was 0.33, 0.284, 0.19, and 0.0495 at an average depth of 62-69cm. C/N and C/H ratio ranged from 1.461 to 3.0769 and 1.194 to 2.1769 respectively at both the sites. The analysis of above data helps to determine the difference in concentration and deposition of elements at different vertical levels of strata of the river bed which ultimately increases our understanding about complex aquatic ecosystems and helps in conservation.

Key words*: River Yamuna, Carbon, Hydrogen, Nitrogen, Sulphur, CHNS analysis*

Introduction

River Yamuna travels a distance of 1376 km from its source near Yamunotri glacier to its convergence with Ganga River at city Prayagraj. 70% population of Delhi depends for daily usage of water on 48km stretch which passes through it (CPCB, 2006). River Yamuna which is an important wetland ecosystem of Delhi is facing a great threat of pollution from industrialization, unplanned urbanization, extensive agricultural practices and a very deprived waste water treatment and drainage system. Many studies have been done on various aspects of the river like heavy metal contaminants in river water and soil (Sehgal *et al*., 2012; Said *et al*., 2019), microbial communities (Sharma *et al.,* 2017) but comparatively less data is available for elemental CHNSin the sediments of the river bed. The aim of this study is to investigate the amount of CHNS at various depths of soil sediments and correlation of ratio of Nitrogen and Hydrogen with Carbon at different sites of river Yamuna in Delhi region. It is necessary

to identify the distribution and concentration of soil elements to study systematic conditions within sediments and how it affects the physicochemical nature of the soil which can ultimately help in conservation of such vital aquatic ecosystems.

Materials and Methods

A total of 18 samples were collected from two sites (Fig. 1) of River Yamuna in Delhi region. Site A was Palla village (28°85′61.7"N 77°20′80.2"E) which is located at north of Delhi and the point where river Yamuna enters in Delhi. Site B was near Okhla barrage (28°32′10.5"N 77°19′29.6"E) which is almost located at the last stretch of river Yamuna in Delhi.

Site 1 is comparatively free from pollutants and other anthropogenic activities beside agriculture in vicinity. Multiple samples were collected for better and authentic interpretation of results. Nine samples were collected at site A (Palla village) from 3 different locations on river and from each location 3 samples were taken at different depths of river bed. At location 1 samples were taken from surface (0-2 cm) and at the depth of 30-32 cm and 78-80 cm depth of the river bed. Again 3 samples were taken from location 2 and location 3 at the surface (0-2 cm) and depths of 30-32 cm, 74-76 cmand 26-28 cm, 59-61 cm respectively. Same set of sampling was done at Site B (Okhla barrage) with 9 samples in total from three different locations i.e. location 4, 5 and 6 at the surface (0-2 cm) and various depths of 30-32 cm, 76-78 cm and 30-32 cm, 67-69 cm and 26-28 cm and 62-64 cm respectively. The geographical location was taken by Garmin GPSMAP 76CSX global positioning system. 5–10 mg sub-samples were homogenized and dried in an oven at 105ºC (Relic *et al.,* 2010) and concentration Percentage of Carbon, Hydrogen, Nitrogen and Sulphur were analyzed by elementar EL cube CHNS elemental analyzer.

Statistical analysis

In this study, we have performed statistical analysis using the Statistical Package for Social Sciences (SPSS 19.0) software package in direction to understand the relationship and interaction of elements with each other.

Results

Per cent concentration of total Carbon, Hydrogen,

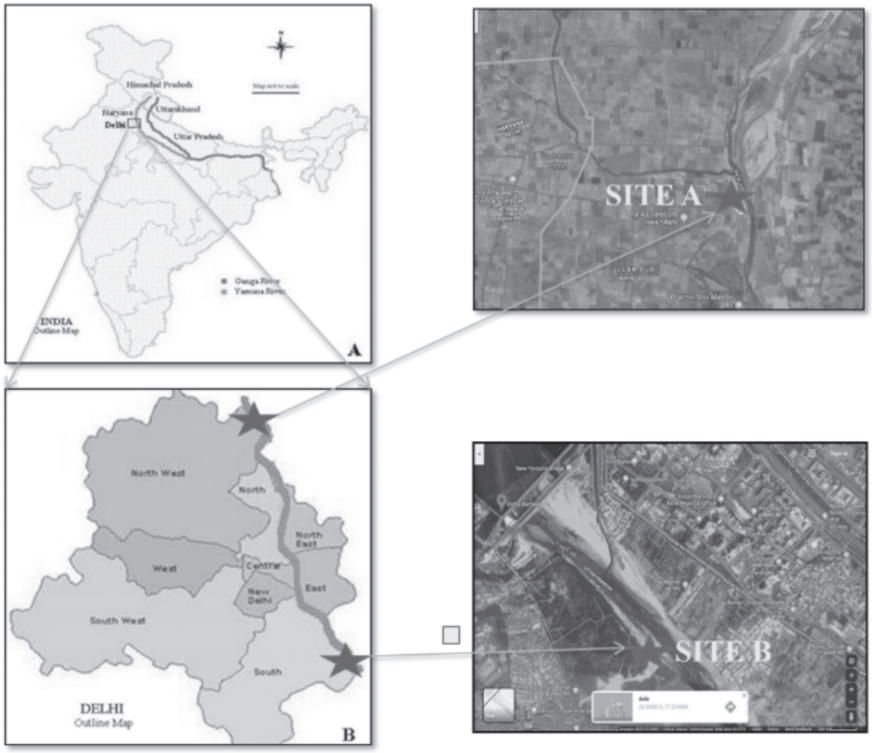

Fig. 1. Location of Site A (Palla village) and Site B (Okhla barrage) of River Yamuna in Delhi

Nitrogen and Sulphur in all 18 samples from both the sites is shown in Tables 1-2 and Figs. 2-3.

Total Carbon at Site A ranged from 0.11 to 0.45 % while Hydrogen, Nitrogen and Sulphur ranged between 0.132-0.299 %, 0.09-0.28 % and 0.01-0.024 % respectively. Site B percentage range varied from 0.17 to 0.33% in case of Carbon and from 0.126-0.371%, 0.09-0.29% and 0.017-0.104% of Hydrogen, Nitrogen and Sulphur respectively. [Results of Sample taken from depth 76-78 cm at location 4 was not recorded because of technical error]

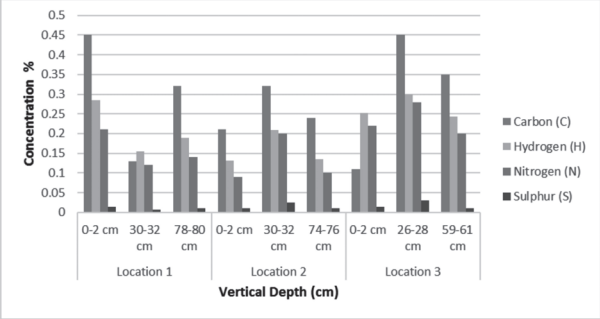

Fig. 2. Elements Concentration % of Three Locations at Site A (Palla Village)

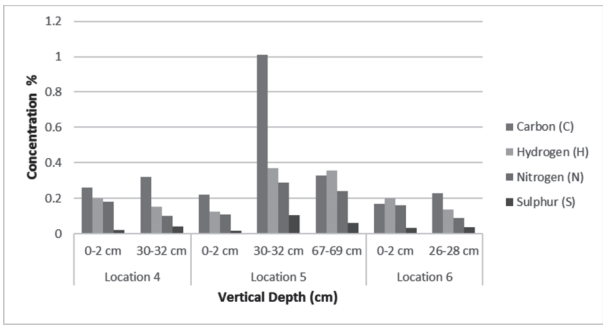

Fig. 3. Elements Concentration % of Three Locations at Site B (Okhla barrage)

The C/N and C/H ratios of both the sites are shown in Tables 3-4 and Figures 4-5.

The variation between the ratio of Nitrogen and Hydrogen with Carbon has been also recorded. C/N ratio ranged from 0.494-2.1254 and from 0.433-1.7838 in case of C/H at Site A while C/N and C/H ratio at Site B varied from 1.0237-3.472 and 0.8223-2.7341 respectively.

Table 1. Elements Concentration % of Three Locations at Site A (Palla village)

Elements	Depths at Location 1 (cm)			Depths at Location 2 (cm)			Depths at Location 3 (cm)		
	0-2 cm	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
				Concentration %					
Carbon (C)	0.45	0.13	0.32	0.21	0.32	0.24	0.11	0.45	0.35
Hydrogen (H)	0.284	0.155	0.189	0.132	0.209	0.135	0.253	0.299	0.243
Nitrogen (N)	0.21	0.12	0.14	0.09	0.2	0.1	0.22	0.28	0.2
Sulphur (S)	0.013	0.007	0.011	0.01	0.024	0.01	0.013	0.03	0.011

Table 2. Elements Concentration % of Three Locations at Site B (Okhla barrage)

Elements	Depths at Location 4 (cm)			Depths at Location 5 (cm)			Depths at Location 6 (cm)		
	0-2 cm	30-32	76-78	0-2	30-32	67-69	0-2	26-28	62-64
				Concentration %					
Carbon (C)	0.26	0.32	E	0.22	1.01	0.33	0.17	0.23	0.33
Hydrogen (H)	0.202	0.153	E	0.126	0.371	0.358	0.202	0.136	0.21
Nitrogen (N)	0.18	0.1	E	0.11	0.29	0.24	0.16	0.09	0.14
Sulphur (S)	0.022	0.04	E	0.017	0.104	0.06	0.033	0.039	0.039

[E-Shows error]

Table 3. C/N and C/H Ratios of Three Locations at Site A (Palla village)

Ratio (%)	Depths at Location 1 (cm)			Depths at Location 2 (cm)			Depths at Location 3 (cm)		
	0-2	30-32	78-80	0-2	30-32	74-76	0-2	26-28	59-61
C/N	2.1254	1.1501	2.2375	2.19	1.62	2.3089	0.494	1.613	1.7171
C/H	1.5808	0.8669	1.7143	1.5696	1.5326	1.7838	0.433	1.4954	1.4376

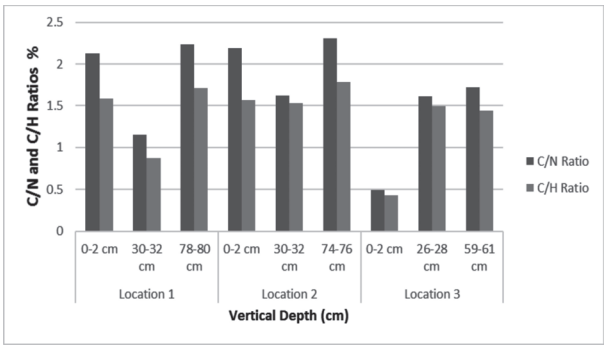

Fig. 4. C/N and C/H Ratios % of Three Locations at Site 1 (Palla Village)

Different descriptive statistics have been calculated as shown in Table 5 and Table 6 for Site A and Site B. We observed that all elements concentrations have less variations at Site A (Table 5) in comparison to Site B (Table 6).

To reveal the correlation between different elements we have conducted Pearson correlation test. From Table 7, the correlation analysis suggests significant positive correlation between Nitrogen and Hydrogen ($p < 0.01$) and between Sulphur and Nitrogen ($p < 0.05$) at site A.

Table 8 shows significant positive correlation between N and C ($p < 0.05$) and between N and H (p

Table 4. C/N and C/H Ratios of Three Locations at Site B (Okhla barrage)

Ratio (%)	Depths at Location 4 (cm)			Depths at Location 5 (cm)			Depths at Location 6 (cm)		
	0-2	30-32	76-78	0-2	30-32	67-69	0-2	26-28	62-64
C/N	1.4516	3.1508	E	2.0066	3.472	1.38	1.0237	2.6081	2.3696
C/H	1.2698	2.0713	E	1.7178	2.7341	0.9184	0.8223	1.7254	1.5812

[E-Shows error]

Table 5. Elements concentrations Descriptive Statistics for Site A (Palla village)

Elements	Minimum	Maximum	Average	Std. Deviation	Variance
Carbon (C)	.110	.450	.287	.124	.015
Hydrogen (H)	.132	.299	.211	.063	.004
Nitrogen (N)	.090	.280	.173	.064	.004
Sulphur (S)	.007	.030	.014	.007	.000

Table 6. Elements concentrations Descriptive Statistics for Site B (Okhla barrage)

Elements	Minimum	Maximum	Average	Std. Deviation	Variance
Carbon (C)	.170	1.010	.359	.270	.073
Hydrogen (H)	.126	.371	.220	.095	.009
Nitrogen (N)	.090	.290	.164	.071	.005
Sulphur (S)	.017	.104	.044	.027	.001

Table 7. Correlations of different Elements at Site A (Palla village)

Elements	Correlation	Carbon	Hydrogen	Nitrogen	Sulphur
Carbon	Pearson Correlation	1			
	Sig. (2-tailed)				
Hydrogen	Pearson Correlation	.617	1		
	Sig. (2-tailed)	.077			
Nitrogen	Pearson Correlation	.549	.958**	1	
	Sig. (2-tailed)	.126	.000		
Sulphur	Pearson Correlation	.568	.595	.755*	1
	Sig. (2-tailed)	.111	.091	.019	

* Correlation is significant at the $p < 0.05$ level (2-tailed)
** Correlation is significant at the $p < 0.01$ level (2-tailed)

Table 8. Correlations of different Elements at Site B (Okhla barrage)

Elements	Correlation	Carbon	Hydrogen	Nitrogen	Sulphur
Carbon	Pearson Correlation	1			
	Sig. (2-tailed)				
Hydrogen	Pearson Correlation	.706	1		
	Sig. (2-tailed)	.050			
Nitrogen	Pearson Correlation	.744*	.961**	1	
	Sig. (2-tailed)	.034	.000		
Sulphur	Pearson Correlation	.920**	.832*	.787*	1
	Sig. (2-tailed)	.001	.010	.020	

* Correlation is significant at the p < 0.05 level (2-tailed)
** Correlation is significant at the p < 0.01 level (2-tailed)

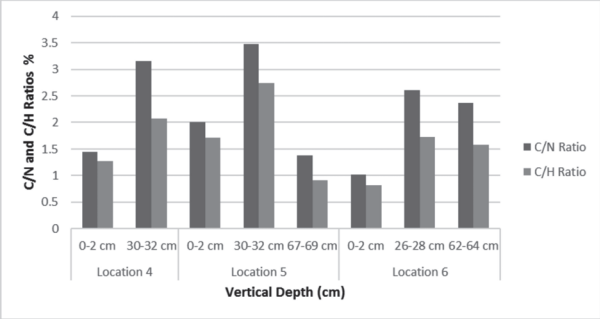

Fig. 5. C/N and C/H Ratios % of Three Locations at Site B (Okhla barrage)

< 0.01). We also observed that S is significantly correlated with C (p < 0.01), N (p < 0.05) and H (p < 0.05) at Site B.

Discussion

The concentration of Carbon, Hydrogen, Nitrogen and Sulphur with other trace elements susceptible to many reactions like nitrification, denitrification, co-precipitation, sulfide oxidation and hence directly affects pH (Relic *et al.,* 2010). Combined amounts of C in the atmosphere and vegetation is lesser Than the total amount of 1500 Pg carbon (1Pg= 1015 g) present in top soil up to 1 m depth and the soil carbon normally falloffs alongside depth of sediments (Jobbagy and Jackson 2000; Goidts and Wesemael, 2007). Total organic carbon is comparatively well studied as compared to total Carbon in sediments. Soil Organic Carbon (OC) is vital for plant nutrients and in conserving the soil integrity (Solanki and Chavda, 2012). Soils with <0.20% organic carbon indicates very less amount; 0.21%-0.40% indicates low OC; 0.41%-0.80% as medium and > 0.80% is considered as high OC (Jaiswal, 2006). During present study, the Carbon % results at Site A showed the higher concentration of carbon at all the locations as compared to site B. This factor is positively correlated with available Nitrogen and Sulphur which confirm that high amount of OC increases nutrient availability (Prusty *et al.,* 2009). Even hydrogen shows a close link between hydrogen and carbon cycles (Paul *et al.,* 2016). The amount of Hydrogen affects pH and the accessibility of other elements in soil andat high and low pH valuesnutrient deficiencies can be observed; Therefore, Hydrogen plays an important role in the development of plants. The percentage of Hydrogen kept varying with depths at both the site A and site B. Site A has the higher amount of Hydrogen % in almost all the three locations as compared to site B. Nitrogen concentration of the sediments critically influencesthe productivity and biodiversity of an aquatic system (Kumar *et al.,* 2012). In the present study, Site A has the higher amount of Nitrogen % in soil as compared to site B. Percentage amount of Nitrogen kept varying with depth at both the site A and site B. Organic matter presents in the soil affects the proportion of Nitrogen in the soil (Baruah, 1997). Due to diverse heterogeneity of soil it is very challenging to perceive the changes in soil N and C contents exactly (Mitsch and Gosselink, 2000). Nitrogen is one of the important limiting elements of wetland ecosystem and plays a significant role in primary productivity (Song *et al.,* 2012; Jobbagy and Jackson, 2000). Transport of sulphate from the water column into the sediments is influenced by Evapotranspiration induced advection (Choi *et al.,* 2006). Oxidation of Fe-Sulfides can lead to decreased total S content in sediments (Relic *et al.,* 2010). It could be a possible reason for low concentration of S at Site A. Sulphur showed higher values at site B as compared to site A. This may be as a result of the accumulation of sewage and industrial pollutants at this site.

A very preliminary study revealing the inorganic elements and pollutants in the Yamuna River bank soil in Delhi was studied by Farago *et al.,* (1989). Carbon content as well as organochlorine pesticides in fluvial sediments of river Yamuna was studied by Parween *et al.* (2014). Das *et al.* (2018) explained about the available Nitrogen and Sulphur by using K-jeldahl method in River Yamuna in Allahabad city. Organic Carbon and available nitrogen in different horizons of Yamuna River Bank at Prayagraj was studied by Dogo *et al.* (2019). Total Carbon (TC) and Total Nitrogen (TN) concentrations in dried sediment of Meenachil river basin in Kerala is studied by George & Joseph, (2017). Comparatively less emphasis has been given on CHNS studies on Indian river sediments while it has been extensively done all over the world on many rivers. Organic carbon and nitrogen with C/N ratios of river sediments were discussed by Dinelli *et al.* (2005) in Arno river, Italy. CHN analysis on sediments of São Francisco River basin in Brazil was done by Rezende *et al.* (2011). Relic *et al.* (2010) explained distribution of total CHNS content in relation to other heavy metals at different depths of alluvial sediments of Danube River, Serbia. The ratio of C/N and total N content in various depths of Yellow River was studied by Li *et al.* (2014). CHNS distribution in Sediments of the River Horna´d, Slovakia was explained by Findora´kova *et al.* (2017) and C and N content in comparison to Heavy-Metal from surface sediments of the Minho River Estuary, Spain by Homens *et al.,* (2013).

Ratio of Total Organic Carbon and Nitrogen can increase during diagenesis (Hunt *et al.,* 2000). Sometime high value of Carbon and Nitrogen ratio is associated with lower N content and not because of large proportions of Carbon (Remon *et al.,* 2005, Trembaly and Gagne 2007). Less than 1.0 % value of Hydrogen and total Organic Carbon ratio indicates aromatic character of the organic matter and values greater than 1.0% indicate a lower content of organic matter and shows the aliphatic nature of organic matter which can be possibly contributed by bacterial and algal organic matters (Meyers and Ishiwatari, 1995). According to Steelink (1985) the presence of non-humic substances represented by values greater than 1.3 %. Exposure to air or by inorganic oxidation can also decline these values (Ortiz *et al.,* 2004). In the present study significant relationships between elements demonstrate that they have good paragenetic association. Similar statistical analysis has been done by Li *et al.,* (2014) in Yellow River, China and by Relic *et al.,* (2010) in Danube River in Serbia.

Conclusion

The river Yamuna is a very dynamic ecosystem which is different from any static system like of ponds and lakes and facing high threat of pollution in many parts of Delhi. Percentage concentration of CHNSin River bed soil varies at different depths at both the sites. River bed mainly consists of sand therefore less concentration of C, H, N, S elements as compared to any other type of soil. Site A is having higher amounts of Carbon, Hydrogen, Nitrogen concentration except Sulphur as compared to Site B at various depths of river bed. This can be a result of heavy domestic and industrial pollution at site 2 which interferes with the chemical composition of the soil and effects its quality and adds extra amount of Sulphur in river soil through polluted water. The concentrations of CHNS with other trace elements susceptible to many physicochemical reactions and hence directly affect pH and quality of soil. Present study could be useful for researchers working on the river sediments which can ultimately help in conservation of rivers and other wetlands.

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