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Sediment Characteristic and Concentration of Heavy Metals in Water and Sediment of the Effluent Discharging Water Body of Nagaon Paper Mill, Assam, India

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Abstract: The impact of Nagaon Paper Mill effluent on the sediment of the effluent discharging water course in water and sediment was studied. Analysis of bed sediment samples showed a general decreasing trend of pH, alkalinity, EC, organic carbon, and organic matter from sampling stations 1 to 6. Water holding capacity, water content, bulk density, Ca^{2+}, Mg^{2+}, and sulphate of bed sediment samples collected from sampling station 1 to 6 has an increasing trend. This means that the upstream of the *beel* was polluted with respect to reference sampling station at 7. It was revealed from the analysis of the results of heavy metals concentration in effluent, *beel* water and sediment that their concentration lies far below the tolerance limit. However, the heavy metals concentrations in beel water and sediment samples at different sampling stations were higher than the concentration of heavy metals at reference sampling station 7. Analysis of bed sediment samples showed a general decreasing trend of heavy metals viz., Cu, Cd, Pb and Zn from sampling station 1 to 6.

Key words: Sediment, paper mill effluent, heavy metals, *beel.*

Introducton

Effluent from paper industry contains variety of organic substances and toxic metals depending upon manufacturing process adopted. The most significant environmental issues in the pulp and paper industry result from the pulping and bleaching processes.

Study on the effect of pulp and paper mill waste on the sediment and water quality has already been carried out (Poykio et al., 2008; Chandra et al., 2006). The discharge of pulp mill effluent increases the concentration of cellulose, lignin and other insoluble chemicals on the bottom sediments of wastewater receiving bays (Nomikos, 1971; Forstner, 1979). Research pertaining to the treatment of paper mill effluent by various methods has been investigated (Sarkka et al., 2007; Salokannel et al., 2007). The effect of Nagaon Paper Mill effluent on the surrounding water course of the *beel* has already been reported elsewhere (Sarma et al., 2007).

Materials and Methods

Nagaon Paper Mill, one of the units of Hindustan Paper Corporation Ltd., an enterprise of government of India, is located at Jagiroad, about 60 km east of Guwahati, Assam. The mill is adopting alkaline sulphate (kraft) process for pulping bamboo. The effluent from the mill after treatment in ETP is discharged into a drain which comes through several *beel*s (natural water reservoir) and ultimately falls to river Kolong, a tributary of the mighty river Brahmaputra, after traversing a zigzag course of 25 km. The samples of water and sediments were collected

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from the *beel* water system. The sampling stations for collection of sediment samples were chosen at sampling station 1, 2, 3, 4, 5 6 and 7 (Table 1). The treated effluent was collected from sampling station 1 which is the outlet of the effluent discharging pipe and the water sample collecting stations were 2, 3, 4, 5, 6 and 7. Sediment samples were collected from bed of these *beel* with an average depth of 0-15 cm to see the impact of paper mill effluent on sediments of the *beel*. The results of different physico-chemical parameters of the effluent water and bed sediment samples are summarized in Tables 2 and 3.

All chemicals used were of analytical grade. Metals like sodium and potassium were determined with the help of flame photometer (systonic-121). The determination of heavy metals in water and bed sediment samples were done with the help of Atomic Absorption spectrophotometer after preserving the sample as per procedure (APHA, 1998). The determination of mercury in water and sediment samples was carried out with the help of mercury analyzer. pH of the bed sediment samples was measured, taking samples as such, making paste of the sample with water at 1:2.5 and 1:5 proportions (Table 2). Parameters like pH and EC were determined immediately after collection of samples using digital pH and conductivity meter respectively. For all other parameters of sediment, samples were completed as soon as possible in the laboratory after preservation of samples as per the procedure described (Khopkar, 1998; Trivedy et al., 1986; Upadhyay et al., 2002).

Table 1: Sampling stations 1-7 of the study area

Sampling station	*Name of stations*	*Distance from NPM (km)*
1	Outlet of lagoon	0
2	Elenga beel	3
3	Chakomako	6
4	Ajuri	11
5	Malobari	18
6	Italapar (confluent point)	25
7	Upstream of river Kolong (Haliamukh)	6

Results and Discussion

Impact of Nagaon Paper Mill Effluent on Sediment of Beel

The water holding capacity of the bed sediment samples of the *beel* at sampling station 1 was 53.83% and the value increases up to station 4 (101.3%) and again decreases to 68.26% at sampling station 6. However, water-holding capacity of unpolluted sediment samples at sampling station 7 was quite high 112.47%. Pandey et al. (1992) also reported the similar findings.

The water content on dry basis of sediment sample varied between 72.83% and 212.83% (sampling stations 1 to 6). The average value of water content on dry basis was 214.16% at station 7. This indicates that the bed sediments texture were different in different sampling station. A decrease of 141.33% of water content at station 1 as compared to station 7 seems to be due to discharge of effluent of Nagaon Paper Mill. Similarly, the reduction of water content value of the soil treated with industrial effluent was also observed (Shroff, 1997).

An increasing trend of bulk density of bed sediment samples, collected from *beel* water system, was observed from sampling stations 1 to 6. The average value of bulk density varies between 1.62 gm/cm^3 at station 1 and 1.81 gm/cm^3 at sampling station 6 and the value get increased gradually from station to station as one moves towards the downstream of the *beel*. However, the average value of bulk density at sampling station 7 was 1.86 gm/cm^3. This may be attributed to the effects of direct accumulation of large quantities of inorganic and organic materials towards the upstream of the *beel*. Moreover, the effect was further enhanced due to interaction of sodium with the complex compounds of soil. This is in accordance with the earlier report (Dhevagi et al., 2002). The adverse effect on soil properties however gets progressively decreased with dilution of added effluents.

The average pH value of experimental bed sediment samples, collected from stations 1 to 6 of *beel* water system, ranged from 8.31 to 6.25, showing a general decreasing trend whereas pH of sediment sample at sampling station 7 was 5.99 (as such), 6.39 (1 : 2.5) and 6.26 (1 : 5). The higher value of the pH towards the upstream of the *beel* as compared to downstream may be the effect of accumulation of large quantity of sodium salt coming out of the effluent of the paper mill (Narasima Rao et al., 1992).

The average value of electrical conductivity of bed sediment samples of the *beel* water system was found to be within the range of 206 to 346 µS. All values of electrical conductivity of bed sediments of *beel* system were higher than the value at the sampling station 7 (191 µS). The higher electrical conductivity values reported in the present research work as compared to sampling station 7 may be due to the deposition of higher amount of inorganic salts on the bed of the *beel* from wastewater of the mill. Similar, results of EC of bed sediments were also reported (Shroff, 1997). The EC values also confirm the accumulation of salt on the bed of the *beel*.

Table 2: Physico-chemical parameters of bed sediment at various sites

Parameter	*Sampling stations*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
WHC (%)	53.83	58.2	77.09	101.3	86.68	68.26	112.47
Water content (%)	72.83	72.53	93.32	203.1	211.13	212.83	214.16
Bulk Density (gm/cm^3)	1.62	1.65	1.68	1.74	1.76	1.81	1.86
pH (as such)	8.06	7.56	7.28	6.51	6.4	6.43	5.99
pH (1:2.5)	8.13	8.14	6.84	7.09	6.43	6.25	6.39
pH (1:5)	8.23	8.31	6.85	7.03	6.46	6.28	6.26
EC (µS)	206	225	316	346	311	317	191
Oil and grease (mg/kg)	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Alkalinity (mg/kg)	1441.3	1210	1150	1123.8	153.8	138.8	137.5
Mercury (mg/kg)	0.0005	BDL	BDL	BDL	BDL	BDL	BDL
Chloride (mg/kg)	5.5	5.5	11.3	7.0	10.5	11.3	0.315
Calcium (mg/kg)	2.8	2.8	2.8	3.5	4.0	2.5	3.0
Sulphate (mg/kg)	0.188	0.115	0.215	0.185	0.188	0.15	0.265
Organic carbon (%)	1.285	0.335	0.365	0.228	0.22	0.193	0.173
Organic matter (%)	2.175	0.575	0.63	0.378	0.333	0.333	0.298

Table 3: Heavy metals in treated effluent, water and sediment *samples at various sites

Metals (mg/L)/	*Sampling stations*						
*mg/kg**	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Hg	0.0006	BDL	BDL	BDL	BDL	BDL	BDL
Pb	0.63(0.873)	0.33(0.828)	0.0027(0.798)	0.091(0.77)	0.08(0.36)	0.065(0.35)	0.03(0.007)
Cd	0.19(0.43)	0.086(0.28)	0.074(0.28)	0.044(0.2)	0.024(0.25)	0.016(0.15)	0.005(0.15)
Cu	0.076(0.45)	0.011(0.38)	0.009(0.4)	0.007(0.3)	0.006(0.28)	0.004(0.33)	0.003(0.28)
Zn	0.106(10.3)	0.099(8.7)	0.088(8.0)	0.081(8.0)	0.074(7.6)	0.068(6.9)	0.064(5.9)
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL

BDL = below detection limit

* Concentration of heavy metals of sediment is given inside bracket.

In all the sampling stations, oil and grease contents of the sediment samples were found below the detection limit.

The average values of alkalinity in the sediment sample were within the range of 1441.3 to 138.8 mg/kg from sampling stations 1 to 6, whereas alkalinity at sampling station 7 was 137.5 mg/kg. Alkalinity values show in general a decreasing trend except a sharp drop of value at station 4, after that the values remain almost constant in the remaining stations (Figure 1a). The high alkalinity of bed sediments as compared to reference sampling station at 7 may be due to discharge of alkaline effluent (Sarma et al., 2007) of Nagaon Paper Mill. These were in conformity with pH values.

A very small concentration of Hg (0.0005 mg/kg) in the sediment samples was detected at sampling station 1 and Hg concentration was found to be below the detection limit in the remaining sampling stations.

The range of chloride content in the sediment samples from sampling stations 1 to 6 was 5.5-11.3 mg/kg (average value) and the value at sampling station 7 was 0.315 mg/kg. The high value of chloride content in the sediment samples could be due to discharge of high chloride containing effluent.

Calcium concentrations in the sediment samples from sampling stations 1 to 6 were found to be in the range of 4.0-2.5 mg/kg and at station 7 was 3.0 mg/l. The high value of calcium in the paper mill effluent amended soil was also reported (Nemade et al., 1997).

In the present investigation the average concentration of the sulphate ions was found to be in the range of 0.215 to 0.115 mg/kg from stations 1 to 6 and 0.265 mg/kg at reference station 7. The concentration of the sulphate ions in all the bed sediment samples was found less than the reference station. This implies that there is no enhancement of sulphate ions in the sediment samples due to paper mill effluent.

The average value of organic carbon in the bed sediment samples ranged between 1.285 and 0.193% from sampling stations 1 to 6 against 0.173% at the reference station 7. The organic carbon content values showed a decreasing trend from station 1 to station 6 (Figure 1b). This shows a deposition of suspended and dissolved organic substances present in the effluent on the bed of the *beel*. Similar observations were also reported by some of the researchers (Juwakar et al., 1987).

Heavy Metals in the Treated Effluent, Water and Bed Sediments Samples

A very small concentration of mercury (average 0.0006 mg/l) was detected in the treated effluent at sampling station 1 and afterwards Hg was neither detected in water of the *beel* from sampling station 2 onwards and nor in the water of the river at station 7. This concentration of Hg was much below the limit prescribed by BIS (0.01 mg/l) for industrial water discharged into the inland surface water.

The average concentration of lead in treated effluent, at sampling station 1 was 0.63 mg/l. The concentration in water samples from sampling stations 2 to 6 varied from 0.33 mg/l to 0.0027 mg/l. This concentration was found to be higher than the average concentration of lead at sampling station 7 (0.03 mg/l). This means that the concentration of lead in the watercourse of *beel* had increased due to discharge of effluent. However, in the present study, all the values of lead were within the tolerance limit. Some researchers (Nemade et al., 1997) have reported a much higher concentration of lead in pulp and paper mill effluent in comparison to present findings.

The average concentration of cadmium in the treated effluent was found to be 0.19 mg/l at sampling station 1. Similar result of cadmium concentration in the effluent of paper mill was reported earlier (Sharma et al., 1986). The cadmium concentrations in the water samples between sampling stations 2 to 6 were ranged 0.086 mg/l to 0.016 mg/l. These values of cadmium concentration at various sampling stations were found to be much below the permissible limit for industrial waste water to be discharged from industries, which has been set at 2.0 mg/l (ISI, 1983). The impact of paper mill effluent containing cadmium and other heavy metal on fish health has already been studied (Roy et al., 2002).

The average value of copper concentration of treated effluent at the station 1 was 0.076 mg/l and the value ranged between 0.011 and 0.004 mg/l from sampling stations 2 to 6 in the water course of the *beel*. The average concentration of copper at sampling station 2 (0.011 mg/l) was higher than at sampling station 7 (0.003 mg/l) which could be due to mixing of effluent with water of the beel. The copper concentration was dropped sharply from station 1 to 2. However, after sampling station 2, a gradual decreasing trend was observed from sampling stations 2 to 6 (Figure 1c) and at sampling station 6 the concentration of copper was quite comparable with the value at sampling station 7. The concentration of copper at sampling station 1 lies far below the maximum permissible limit as prescribed by ISI (1983) for industrial effluent discharge into the inland surface water, which is 3 mg/l. It is to be noted that there was no specific input containing more amount of copper in the manufacturing process of pulp and paper (USEPA, 1988).

The concentration of zinc in the effluent after treatment was 0.106 mg/l. Some earlier workers (Nanda et al., 1999) have also reported about the contamination of paper mill effluent with zinc. The concentration of zinc in the watercourse regularly decreases from 0.099 mg/l at sampling station 2 to 0.068 mg/l at sampling station 6 (Figure 1d). The concentration of zinc was much below the recommended guideline value for public water supplies. The acceptable limit for drinking water as set by WHO (1984) was 5.0 mg/l. Water containing 4 mg/l of zinc has a bitter or astringent taste.

In the present study arsenic concentration in water sample was found below the detection limit of the Atomic Absorption spectrophotometer for all the samples. The analysis of sediment samples showed a concentration range of lead between sampling stations 1 and 6 as 0.873 to 0.35 mg/kg. and at reference sample site 0.007 mg/kg. This clearly indicates a higher concentration of lead in the sediment samples as compared to reference site.

The cadmium concentration in the sediment samples of *beel* water system were found to be in the range 0.43-0.15 mg/kg between sampling stations 1 and 6 and 0.15 at sampling station 7. A decreasing trend appeared towards the downstream of the *beel*.

The values of copper concentration in the sediment samples were 0.45 mg/kg at sampling station 1 and 0.38 mg/kg at sampling station 6 respectively. The concentration of copper shows a decreasing trend towards the downstream of the *beel* (Figure 1e) and shows that the impact of effluent with respect to Cu concentration decreases as one moves away from the effluent discharging point. The value at reference sampling site 7 was 0.28 mg/kg is lower than that at site 6.

A uniformly decreasing trend (Figure 1f) of the concentration of zinc in the sediment samples which varied between 10.3-6.9 mg/kg from sampling stations 1 to 6. These values of zinc were higher than the value of

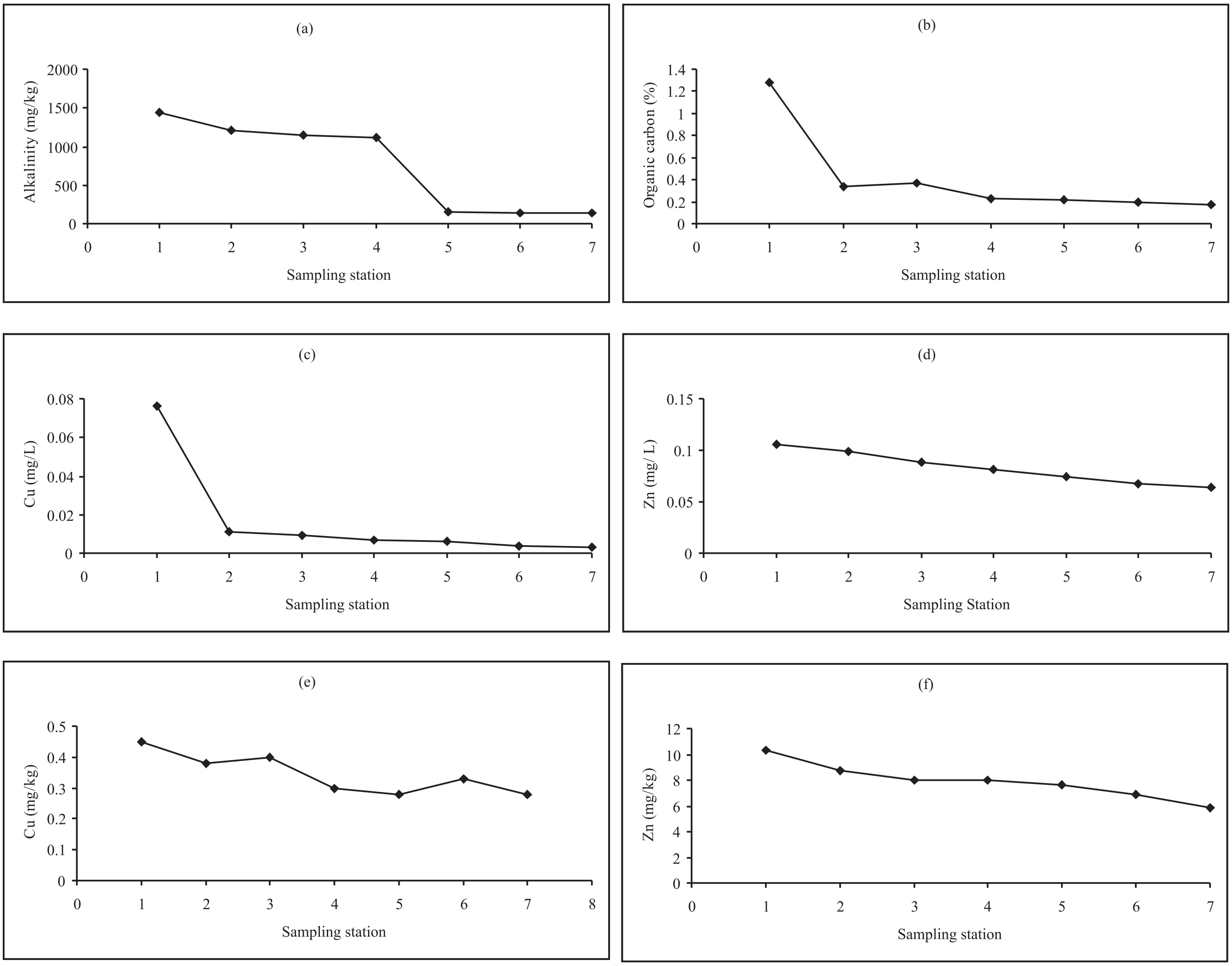

Figure 1: Variation of (a) alkalinity in sediment (b) organic carbon in sediment (c) Cu in treated effluent (d) Zn in treated effluent (e) Cu in sediment and (f) Zn in sediment.

zinc concentration of sediment sample collected from reference sampling site at 7.

Conclusion

It reveals from the analysis of the sediment samples that the quality of sediments has changed to a certain extent towards the upstream of *beel*. This could be partly due to deposition of pollutants from paper mill effluent. Analysis of sediment samples collected from bed of the paper mill liquid waste discharging course showed presence of heavy metals like copper, cadmium, lead, and zinc. The effluent of paper mill contains heavy metals like copper, cadmium, lead, zinc and lead with a concentration much below the permissible limit for industrial waste to be discharged from industries.

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