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Assessment of soil quality of Silghat region of Assam (India) affected by jute mill solid waste

Pronil K. Borah, Sanjib Chetry, Dharmendra K. Sharma, Palash M. Saikia^{*}

Soil and Water Quality Testing Centre, Department of Chemistry, Darrang College, (Tezpur) Assam, India

ABSTRACT

Physico-chemical Analysis of the soil of the dumping yard of Assam Cooperative Jute Mill situated at Silghat of Nagoan district of Assam, India were carried out to assess the extent of chemical pollution due to jute mill waste. Soil samples were collected from ten different locations of the dumping sites and their physico-chemical parameters were analyzed. The soil of the jute mill dumping yard was found to be slightly acidic with an average pH of 6.20. The moisture content of the samples was found to be 40-60%. C/N ratio of the samples ranges from 18.43 to 26.89. Electrical conductivity of 1:5 suspensions of the soil samples ranges from 1.02 to 3.02 mScm⁻¹ indicating high concentration of ions. Concentration of Cl⁻, SO₄²⁻ and NO₃⁻ in the soil samples increases in the order NO₃⁻ < SO₄²⁻ < Cl⁻. The soil samples were found to be highly enriched with Na (74.88 mg/Kg), K (89.81 mg/Kg) and Ca (254.12 mg/Kg). Correlation studies indicate strong positive correlation between organic carbon content (C_{org}) with all the three metals. pH had negative correlation while positive correlation was observed for electrical conductivity with all the metals. UV-visible spectroscopic studies revealed the presence of appreciable amount of undesirable organic matter like polycyclic aromatic hydrocarbon (PAH) in the soil samples. The acidic nature of the soil makes it a suitable sink for metals and can lead to their bioaccumulation and biomagnifications. The study reveals the toxicological affect of jute mill solid waste on the soil quality of the investigated region.

Keywords: Assam Co-operative Jute Mill (Silghat), correlation studies, UV-visible spectroscopic studies, Polycyclic aromatic hydrocarbon

INTRODUCTION

The Assam Co-operative Jute Mills Ltd., situated on the south bank of the river Brahmaputra at Silghat in the Nagaon district of Assam (Latitude $26^{\circ} 36' 52''$ N, Longitude $92^{\circ} 56' 14''$ E) is one of the two jute mills of India in the co-operative sector. It was commissioned in the year 1970. At present it proves to be a successful cooperative venture and an ISO 9001:2000 certified company.

The Jute industry in India generates around 40,000 t of processing wastes as by product, commonly known as cadies [1]. The major constituent of cadies is unspinnable short jute fibers. Other constituents of this waste are parts of finished product, dyed stuff, batching oil, inorganic dirt and leftover chemicals [2]. Traditionally cadies was utilized by jute industries along with coal as fuel for boiler to generate steam which was required to run the sizing and calendaring machine. However with technological advancement and change in processing technology steam boilers are no longer indispensible. Moreover the jute cadies are not efficient fuel due to their low calorific value, thermal efficiency and bulk density [1, 3]. Attempts have been made to use jute cadies for making composites, laminated

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sheets, papers and adhesive bonded non woven fabric [2, 3]. However most of them failed to make any promising impact due to huge production cost and less efficiency of the products. Hence huge quantity of this fibrous industrial waste is often discarded as refuse in open landfills.



Figure 1. Map of India and Assam showing the Nagaon District

The Assam Cooperative Jute Mill has been dumping the jute cadies by product since its commission in various locations on the bank of river Brahmaputra close to the mill (most of these locations are extensively cultivated with rice and tuber root vegetables). Very often they are burnt to reduce the volume. Though jute fibers are eco friendly and biodegradable, jute cadies are enriched with various chemicals, oils and dyes and proves to be a potential threat for soil and water pollution if dumped on open surface or near water bodies [1,4]. One of the most important pollutants of cadies is phenolic compounds. Such organic compounds are highly persistent and can eventually contaminate both animal and human food chain [5]. To increase the softness, flexibility and improve the spinnability, jute fibres are conventionally softened before the carding stage of spinning operations by an emulsion of petroleum oil (b.p. 270-450 °C) known as jute batching oil (JBO) along with a chemical emulsifier and water in different proportions (oil : emulsifier : water = 20.0 : 1.0 : 79.0) for the production of fine yarns [6]. JBO hydrocarbons consist of n-alkanes, isoalkanes (e.g., pristane, phytane) and aromatics. The n-alkanes are degradable by bacterial action and they do not exist in nature. But the pristane, phytane, etc., resist bacterial action and accumulate in the nature in an un degradable state. Hence, they are harmful and are also not eco-friendly [2, 7, 8]. The Poly Aromatic Hydrocarbons (PAH) fraction of the JBO is recognized as chemical carcinogens and carries harmful effects [9, 10, 11]. Hence the present study was undertaken to analyze the physico-chemical parameters and assess the affect of the jute mill solid waste on the soil quality of the region.

MATERIALS AND METHODS

Location of the Study Area

Silghat is a small town in the Nagoan District of Assam, India. The dumping yard of Assam Cooperative Jute Mill (Latitude 26° 36′ 52″ N, Longitude 92° 56′ 14″ E) is a region of around one square km on the southern bank of river Brahmaputra. The map of India showing the state of Assam is presented in Figure 1. The map of Nagaon District of

Assam showing Silghat region is presented in Figure 2. The soil of the area is alluvial plain soil. They are grey to yellowish grey and are unaltered alluvian representing sand, silt and humus rich bog clay. Mineral weathering and geochemical changes are nominal. They are slightly alkaline to acidic in nature.



Figure 2. Map of Nagaon District of Assam (India) showing the Silghat region

Sample Collection

Soil samples were collected from a depth of 5-10 cm. 20 samples were collected from various location of the dumping site at a distance of around 200m. The soil samples were collected in September, 2011 and stored in 1L air tight plastic containers. They were then air dried, grounded and sieved through 2mm sieve.

Electrical conductivity and pH determination,

Electrical conductivity and *p*H of aqueous extract of the samples was determined using Weiber μ -processor conductivity meter and Systronics MK VI digital *p*H meter. Aqueous extract was prepared by mixing 20g of the air dried sample with 100cm³ of double distilled water in a 200cm³ beaker. The mixture was stirred for 30 minutes at 40°C using a hot plate with magnetic stirrer. The mixture was then allowed to stand for one hour. The partly settled suspension was then used for the *p*H and conductivity measurement [12].

CHN Analysis

CHN analysis was done using Perkin Elmer 2400 CHN Analyser. An inductively coupled plasma optical emission spectrophotometer (ICP-OES), model Perkin Elmer Optima 2100DV, was used to determine the heavy metals in the sample solutions. A scanning electron microscope combined with energy dispersive X-ray spectroscopy (SEM-EDX), make JEOL model JSM-6390LV, was used to record the EDX spectra. Spectrophotometric analysis of the samples was carried out using Thermo Scientific UV1 double beam spectrophotometer.

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Analysis for Na, K, Ca

Concentration of Na and K in the soil samples were determined by using Labtronics digital flame photometer. Concentration of Ca was determined by titration method proposed by Piper [13]. For analysis of Na, K, and Ca, solutions were prepared by wet digestion with nitric acid and sulphuric acid. 1 gm of the sample was taken in a 300 ml flat bottomed Kjeldahl digestion flask containing 10 ml of concentrated H_2SO_4 and 10 ml of concentrated HNO_3 . The samples were then digested carefully over a hot plate at low heat (~60°C), avoiding excessive frothing until brown fumes ceases to be evolved and much of the water is driven off. The flask is then allowed to cool, added a further 10 ml of HNO₃ and digested further until white fumes of sulphuric acid are produced. The process is repeated until a clear and colourless digest is obtained. The resulting digest was heated by heating at 100° C for 3-5 minutes and cooled. The solution is then diluted with water until the concentration of the sample becomes about 1ppm. About 10 ml of the solution is taken for analysis [12, 13].

UV-VIS Spectroscopic studies

UV-Vis spectroscopic studies were carried out using Thermoscientific UV1 double beam spectrophotometer with thermostated cell holder. All analysis was carried out at 298K and double distilled water was used with spectroscopic grade methanol for preparing the sample solutions. 1:5 extract of the soil samples were prepared in 20% methanol, centrifuged for 1 hour and filtered using whatman 40 filter paper. The filtrate was used for spectroscopic analysis.

RESULTS AND DISCUSSION

The physico-chemical parameters of the analyzed soil samples are shown in Table 1.

Table 1: Physico-chemical parameters of the soil samples

Sr. No.	Parameters	Soil Samples									
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1.	pН	6.02	6.15	6.45	5.98	5.60	6.80	5.53	6.98	7.00	5.40
2.	Electrical Conductivity (mS/cm)	2.12	2.08	2.02	2.34	2.45	1.98	2.56	1.67	1.02	3.02
3.	Chloride (mg/Kg)	12.50	8.30	7.80	12.80	13.20	7.30	13.56	6.80	6.30	14.01
4.	Sulphate (mg/Kg)	6.56	5.34	5.01	7.02	7.12	4.23	7.34	4.01	3.84	7.50
5.	Nitrate (mg/Kg)	0.09	0.06	0.04	0.12	0.16	0.04	0.18	0.03	0.02	0.20
6.	C _{org} (%)	4.02	3.42	3.23	4.67	4.84	3.10	4.90	3.08	3.02	5.02
7.	C/N ratio	20.26	21.02	22.76	18.84	18.43	25.07	18.76	26.89	29.48	19.56
8.	Na (mg/Kg)	84.56	67.34	76.34	65.34	88.78	63.67	75.45	65.45	65.43	96.45
9.	K (mg/Kg)	90.23	88.76	87.65	79.05	84.35	78.34	93.23	96.43	87.65	112.45
10.	Ca (mg/Kg)	295.62	256.67	234.45	223.67	298.87	213.89	254.89	234.89	225.76	302.45

The soil of the jute mill dumping yard was found to be slightly acidic with an average pH of 6.20. The acidic nature of the soil favours bioaccumulation and biomagnifications of heavy metals [14]. The electrical conductivity of the 1:5 soil suspensions was found to be in the range of 1.02 to 3.02 mScm⁻¹. The high value of electrical conductivity indicates the presence of appreciable amount of ions in the soil samples [15]. Chloride content of the samples were determined by rapid titration method [13].Concentration of sulphate and nitrate in the soil samples were determined according to the method proposed by Mussa et al. [16] and Kolo et al. [17]. The average values of chloride, sulphate and nitrate in the soil samples were found to be 10.26 mg Kg⁻¹, 5.80 mg Kg⁻¹ and 0.094 mg Kg⁻¹ respectively as shown in Table 2.

Table 2 Statistics of the elements and physicochemical parameters in soil samples (n=10)

	pН	EC	Corg	Cl.	SO4 ²⁻	NO ₃	Na	K	Ca
Maximum	7.0	3.02	5.02	14.01	7.50	0.20	96.45	112.45	302.45
Minimum	5.4	1.02	3.02	6.30	3.84	0.02	63.67	84.35	223.67
Mean	6.20	2.12	3.93	10.32	5.80	0.09	74.88	89.81	254.12
Median	6.08	2.10	3.72	10.40	5.95	0.07	71.39	88.20	244.89
SD	0.56	0.51	0.80	3.10	1.39	0.06	10.98	9.25	31.89

The anion holding capacity of the soil increases with decrease in pH [16]. The random distribution of the anions can be therefore attributed to the unequal distribution of soil pH. Organic carbon content of the soil was determined by the Walkley and Black rapid titration method [13, 18]. It was observed that the percentage of organic carbon content

of the soil samples varies from 3.02 to 5.02. The C/N ratio of the samples ranges from 18.43 to 29.48 with an average organic carbon content of 3.93%. The high C/N ratio is probably due to the biodegradation of jute fibers and cadies.

The soil samples were found to be highly enriched with Na (average 84.05 mg Kg⁻¹), K (average 89.81 mg Kg⁻¹) and Ca (average 254.12 mg Kg⁻¹). Sodium is the most important element, which influence the soil quality and plant growth either by affecting the permeability of soil by clogging or replacing other cations [19].

For proper environmental monitoring and assessment, effective and correct method of data interpreting is necessary [20]. Statistical analysis like correlation studies can be used to effectively identify and assess the sources of contamination [14, 21, 22, 23]. Pearson Correlation (PC) matrix for the analyzed physico-chemical parameters of the soil as influenced by jute mill solid waste are presented in Table 3. From the calculated matrix strong positive correlation of electrical conductivity was observed with chloride content (r = 0.856) and organic carbon content(r = 0.841) of the soil samples. *p*H showed negative correlation with electrical conductivity (r = -0.899).



Figure 3. Spectra of the 1: 5 extract of the soil samples in 20% methanol at 298 K. 1 (S1); 2 (S7); 3 (S1); 4 (S1); 5 (S1); 6 (S1); 7 (S1); Dotted (1 ppm solution of β -naphthol).

	E.C.	pН	Cl.	Corg	C/N	Na	K	Ca
E.C.	1							
pH	-0.899	1						
Cl	0.856	-0.944	1					
Corg	0.841	-0.939	0.976	1				
C/N	-0.881	0.929	-0.878	-0.853	1			
Na	0.687	-0.748	0.729	0.669	-0.583	1		
K	0.402	-0.358	0.328	0.308	-0.098	0.603	1	
Ca	0.609	-0.740	0.708	0.635	-0.605	0.916	0.553	1

Table 3 Correlation coefficient of physico-chemical parameters of soil as influenced by jute mill solid waste

A strong positive correlation was observed between Na and K (r = 0.603) and between na and Ca (r = 0.916). This may be due to significant geochemical association of Na with K and Ca [23]. The geochemical association of Na–K–Ca in the soil shows that these metals are deposited from anthropogenic sources, since there is no known geogenic source which can contribute to this type of association in the study area [24].

Spectra of the methanolic extract of the soil samples in 20% methanol is shown in Figure 3. The spectra were compared with that of a standard solution of β -naphthol which is a common starching ingredient used for jute yarn. For the standard β -naphthol solution (mg/L) in methanol three characteristic absorption bands were observed at 218nm, 280 nm and 345 nm as shown in Figure 3. Characteristic absorption spectrum of poly aromatic compounds in the UV usually contains two bands; one at around 280 nm due to the aromatic ring and the other in the range 300-360 nm [25]. It was observed that seven of the soil samples exhibited the characteristic bands of phenolic compounds. The absorbance of the samples at different characteristic wavelength is presented in Table 4.

	λ / nm							
Soil Sample	218	240	280	345				
<u>S</u> 1	2.724	2.878	1.850	0.943				
S2	2.461	-	0.447	0.443				
S 3	2.344	-	0.324	0.326				
<u>S</u> 4	2.253	-	0.098	0.023				
S5	2.891	-	0.568	0.360				
<u>S</u> 6	1.895	-	0.232	0.216				
S7	2.371	2.740	1.146	0.594				
β -naphthol solution [*]	3.345	-	1.293	0.779				
* 1 / 1 / 200/ 1 1								

* 1mg/L solution in 20% methanol

In case of S1 and S7 a 240 nm peak was observed which was absent in other samples. The presence of the 280nm and 345nm bands in the spectra of the samples and the high absorbance in the region of 200-300nm clearly indicate the presence of undesirable phenolic compounds like β -naphthol and polycyclic aromatic hydrocarbons (PAH) which are highly persistent in the environment [5, 14]. They can be easily absorbed by the green plants, which are primary producers in the ecosystem. As they move up the food chain from producers to consumers, they endanger public health by bioaccumulation in plant (eg., tissues of root crops widely cultivated in the region) and animal tissues and can cause physiological and neurological disorders [26]. Accumulation of poly aromatic hydrocarbons and heavy metals in rice plants (*Orya sativa* L.) is viewed as a recognized disaster in regions where rice is a staple food [27].

CONCLUSION

The results of the present investigation clearly indicate the adverse affect of jute cadies and waste generated from Assam Cooperative Jute Mill of Silghat on the soil quality of the region. The physico-chemical analysis indicate that the soils have the potential to accumulate heavy metal load which have a tendency to bio-magnify and induce long term adverse environmental impact. Apart from appreciable accumulation of Na, K and Ca in the soil which has enhanced the soil quality, the presence of phenolic compounds and PAH has rendered the soil unsuitable for agricultural purpose. The present study indicates that the untreated jute mill solid waste has adversely affected the soil quality of the region and necessitates periodic monitoring and assessment of the soil and plants of the region.

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