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WASTE CHARACTERIZATION OF INDUSTRIAL PROCESSES OF BLEACHING AND SOFTENING OF JUTE

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ABSTRACT: Characterization of wastewater from industrial processes of bleaching and softening of jute has been carried out. Waste streams of these processes primarily contain residual process chemicals such as phosphate, chlorine and biodegradable jute fibres. Integrated waste streams of both the bleaching processes contain high concentration of phosphate while that from the two step bleaching process is also high in residual chlorine. The highly alkaline waste stream from the softening process exceed allowable limit for pH. Waste streams from these industrial processes may impair the water quality if discharged untreated into a surface water body, primarily due to the presence of biodegradable material as indicated by the high BOD content. Pollution may also result from the presence of high phosphate and solids contents and from the highly alkaline nature of the softening waste. Biological treatment employing oxidation pond systems appears to be a suitable technique for treating these wastes. However, dechlorination (for waste stream of two step bleaching process) and neutralization (for waste stream of softening process) may be required before treatment in oxidation pond. In addition phosphate removal may be required for the waste streams of the bleaching processes after treatment in oxidation pond.

KEYWORDS: Bleaching, softening, jute, environmental impact, industrial waste

INTRODUCTION

In recent years concern over environmental pollution resulting from the use and disposal of non-biodegradable synthetic fibres has revived interest in the use of jute. Over the last few decades, jute has been facing increasing competition from allied and synthetic fibres and its use has been reduced considerably. Traditional jute products, such as, sacks, hessian and carpet backing cloth have been seriously challenged in the export markets by synthetic products for many years. Efforts to diversify uses of jute are therefore necessary for the survival of jute industry as well as for the preservation of the environment. Such efforts, among other things require improvements in some physico-chemical properties of jute to overcome some of its inherent drawbacks.

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High rigidity, poor extensibility, high fibre shedding and short fibre lengths are some of the drawbacks of jute fibre. Jute products are, therefore, hairy, dusty and uncomfortable to feel and handle. Swelling reagents can penetrate into the crystalline regions of jute fibre through the amorphous regions thus making them accessible to chemicals, dyes, etc. and jute goods may become softer with better feel (Amin et al., 1996a). Jute products suffer from another problem. Due to the presence of lignin, jute fibre is photo-degradable and as a result colour fastness of jute is poor. Consumers are, therefore, reluctant to buy such jute products. Preferential removal of lignin from the surface layers of jute fibre using bleaching chemicals is therefore desirable. So successive bleaching and swelling treatments of jute with appropriate chemicals can provide jute fibre with improved physico-chemical properties to make value added and diversified end products that would be more acceptable to consumers. In view of this, attempts were made and three industrial processes such as one step bleaching process, two step bleaching process and softening process of jute have been developed and their practicability have been tested in mill scales (Amin et al., 1996a, b, c).

Environmental pollution from the wastes generated from bleaching and softening processes is a major concern. It is particularly true in view of the increasingly stringent environmental regulations that are being enforced in Bangladesh and elsewhere in the world. For a new industrial process it is essential to characterize the wastes generated from the process, assess environmental impact of the wastes, and develop appropriate treatment systems (if required). These are required for the acceptability of the industrial processes in question by the industrialists, beneficiaries and regulatory organisations.

This paper focuses primarily on the characterization of wastes generated in these industrial processes. Possible environmental impacts of the wastes and their treatment alternatives have been discussed briefly.

DESCRIPTION OF INDUSTRIAL PROCESSES AND WASTE STREAMS

One Step Bleaching Process

In this process, grey jute fabric mounted on the rollers of a closed jigger is run into hot water (at 60°C) containing 0.1% Lissapol (a wetting agent) for 15 minutes. The effluent from hot wash is referred to as waste stream 1 in this study. After hot wash, the jute fabric is washed in water at room temperature in a similar manner. The effluent from this wash is referred to as waste stream 2. The next step involves bleaching with hydrogen peroxide A composite liquor in water is prepared by mixing hydrogen peroxide, sodium silicate, trisodium phosphate, sodium hydroxide and Lissapol in optimum proportions.

Grey jute fabric washed earlier is run into this liquid for 90 minutes. The liquor is kept at room temperature for the first 15 minutes, at 60°C for the next 15 minutes, and at 80 to 90°C during the last 60 minutes. The effluent from this bleaching is waste stream 3. After bleaching, the jute fabric is washed, first in water at room temperature, then in hot water at 60°C, and finally in 0.1% acetic acid solution. The drained off water generated collectively from these washes is waste stream 4. The integrated waste stream of the one step bleaching process, referred to as IWS1, consists of waste streams 1, 2, 3, and 4. After bleaching in the jigger, the bleached fabric is padded to remove excess water and finally dried in a dryer.

Two Step Bleaching Process

The first step in this process involves hot wash in water, similar to one step bleaching process and the effluent from this wash is also referred to as waste stream 1. The next step involves bleaching with calcium hypochlorite (or bleaching powder) by running the fabric for 30 minutes into a solution containing specified concentrations of calcium hypochlorite and aluminum sulphate. The effluent from hypochlorite bleaching is waste stream 5. Afterwards, the jute fabric is bleached with hydrogen peroxide by following the same procedure as in one step bleaching. The effluent from this bleaching is waste stream no.6. The bleached jute fabric is then washed in the same manner as in one step bleaching and the wastewater generated is referred to as waste stream 7. The integrated waste stream of the two step bleaching process consisting of waste streams 1, 5, 6 and 7 is referred to as IWS2. After two step bleaching in the jigger, the bleached jute fabric is padded to remove excess water and then dried in a dryer.

Softening of Jute

For softening, the bleached jute fabric obtained from the two step bleaching process and mounted on the jigger is run into a solution containing 10% sodium hydroxide for 30 minutes at room temperature. The effluent from this process is waste stream no. 8. The jute fabric is then washed, first with water at room temperature, then in hot water and finally with 0.1% acetic acid solution. The wastewater generated collectively from these washes is waste stream 9. The integrated waste stream of the softening process, IWS3, consists of waste stream nos. 8 and 9. After softening, the softened jute fabric is padded to remove excess water and then dried in a dryer.

CHARACTERIZATION OF WASTE STREAMS

Methodology

In this study, for the purpose of sample collection, the one step bleaching process was run with 106 m of grey jute fabric, the two step bleaching process was run with 160 m of grey jute fabric, and the softening process was run with the jute fabric (160 m) bleached earlier with the two step bleaching process. These experimental runs were conducted at the research facility of Bangladesh Jute Research Institute (BJRI) in Dhaka. Waste streams generated in the bleaching and softening processes and their approximate volumes for each run conducted during this study are listed in Table 1. Of the nine waste streams listed in Table 1, five streams (Nos. 1, 3, 5, 6, 8) were likely to carry the most waste load. These five waste streams and the integrated waste streams of the three processes (IWS1, IWS2, and IWS3) were selected for characterization through laboratory analysis. Integrated waste streams of the bleaching and softening processes were prepared by combining the constituent waste streams in the ratio of their total volumes. Parameters for laboratory analysis were selected based on the chemicals used in the bleaching and softening processes and discharge guidelines for industrial effluents (Department of Environment, 1991).

Table 1. Identification of waste streams generated in the bleaching and softening processes

Process	Activity	Waste Stream	Vol. per run (Litres)
ONE STEP BLEACHING	Hot water wash	Waste stream 1	250
	Cold water wash	Waste stream 2	250
	Bleaching with hydrogen peroxide	Waste stream 3	250
	Washing	Waste stream 4	750
	Integrated waste stream of one step process	Waste stream IWS1	1500
TWO STEP BLEACHING	Hot water wash	Waste stream 1	250
	Bleaching with calcium hypochlorite	Waste stream 5	250
	Bleaching with hydrogen peroxide	Waste stream 6	250
	Washing	Waste stream 7	750
	Integrated waste stream of two step process	Waste stream IWS2	1500
SOFTENING	Softening by sodium hydroxide	Waste stream 8	250
	Washing	Waste stream 9	2000
	Integrated waste stream of softening process	Waste stream IWS3	2250

Wastewater samples were collected in clean acid-washed container. Samples for analysis of colour, BOD, and phosphate were collected in half-litre plastic containers and were refrigerated immediately. Samples for analysis of COD were collected in half-litre plastic containers to which concentrated sulphuric acid were added at the rate of two millilitres per litre of sample (for preservation). All laboratory analysis were performed at the Environmental Engineering Laboratory, BUET following Standard Methods (AWWA, 1985). Phosphate concentration was determined with a spectrophotometer (Hach DR-EL/4) and sodium (Na) concentration was determined with an atomic absorption spectrophotometer (Shimadzu AA-680). Maximum aluminum (Al) concentration was estimated based on the quantity of aluminum sulphate used in hypochlorite bleaching.

Analysis of Results and Discussion

Table 2 shows results of laboratory analysis of waste streams 1, 3, and IWS1 from the one step bleaching process. Table 2 also shows allowable limits of industrial effluents for discharge into surface water bodies. Waste streams from one step bleaching process primarily contain residual chemicals used in the process and biodegradable jute fibres. Added chemicals and degradable jute fibres are responsible for high values of TS, TDS and TSS in these streams. High concentration of PO_4 in waste stream 2 and IWS1 results from the presence of trisodium phosphate while high Na concentration is due to the presence of sodium silicate and sodium hydroxide in the bleaching liquor. High BOD_5 and COD values result primarily from the presence of degradable jute fibres.

From consideration of environmental impact, waste treatment and disposal, characteristics of IWS1 are of primary importance. Values of TS, TDS, BOD_5 and COD in IWS1 are significantly lower than those in waste stream 3 because of dilution with wash water. However, these values exceed allowable limits for discharge into surface water. Higher concentration of PO_4 (exceeding allowable limit) in the IWS1 compared to waste stream 3 is probably due to adsorption of phosphate onto jute fabric which came out only after subsequent washing. Higher value of TSS in IWS1 compared to waste streams 1 and 3 is most likely due to the presence of large amount of jute fibres in wash waters.

Table 3 shows results of laboratory analysis of waste streams 5, 6, and IWS2 from the two step bleaching process. High BOD_5 and COD values in these waste streams result primarily from the presence of biodegradable jute fibres and these fibres along with added chemicals are responsible for high values of TS, TDS, and TSS. Residual chlorine, aluminum and sulphate in waste stream 5 and IWS2 come from the

Table 2. Characteristics of waste streams from one step bleaching process

Parameter	Unit	Concentration Present			EQS (1991)*
		Waste Strm. 1	Waste Strm. 2	Waste Strm. IWS1	
Temperature	°C	60	90	-	40, 45#
pH	-	5.6	7.0	6.5	6 - 9
Colour	TCU	410	940	290	Light Brown
Turbidity	NTU	120	272	140	-
Total Solids (TS)	mg/L	2057	9948	2754	2250
Total Dissolved Solids (TDS)	mg/L	1777	9706	2364	2100
Total Suspended Solids (TSS)	mg/L	280	242	390	150
BOD_5	mg/L	720	2000	1100	50
COD	mg/L	940	2500	1300	200
Phosphate, PO_4^{3-}	mg/L	-	30.0	76.0	5.0
Sodium, Na^+	mg/L	-	50.6	47.9	-

* Environmental Quality Standard of Bangladesh (DOE, 1991)
# 40 °C during summer, and 45 °C during winter

Table 3. Characteristics of waste streams from two step bleaching process

Parameter	Unit	Concentration Present			EQS (1991)*
		Waste Strm. 5	Waste Strm. 6	Waste Strm. IWS2	
Temperature	°C	34	85	-	40, 45#
pH	-	6.6	6.8	6.4	6 - 9
Colour	TCU	170	175	165	Light Brown
Turbidity	NTU	445	470	275	-
Total Solids (TS)	mg/L	12,874	8954	4582	2250
Total Dissolved Solids (TDS)	mg/L	11,268	6384	3612	2100
Total Suspended Solids (TSS)	mg/L	1606	2570	970	150
BOD_5	mg/L	2000	1600	800	50
COD	mg/L	2500	3100	1300	200
Residual Chlorine	mg/L	35.5	-	61.5	1.0
Sulphate, SO_4^{2-}	mg/L	74	-	132	1000
Aluminum, Al	mg/L	10.4	-	1.73	1.0
Phosphate, PO_4^{3-}	mg/L	-	230.0	37.0	5.0
Sodium, Na^+	mg/L	-	50.1	48.1	-

* Environmental Quality Standard of Bangladesh (DOE, 1991)
# 40 °C during summer, and 45 °C during winter

added chemicals in the hypochlorite bleaching liquor. In IWS2, values of TS, TDS, PO_4, BOD_5, and COD are significantly less than those in waste streams 5 and 6 because of dilution with wash waters, but they all exceed allowable limits for discharge into surface water bodies. Higher concentration of residual chlorine and sulphate in the IWS2 compared to waste stream 4 (from hypochlorite bleaching) is probably due to the adsorption of these chemicals onto jute fabric which came out only after subsequent washings.

Table 4 shows results of laboratory analysis of waste stream 8 and IWS3 from the softening process. Since softening is done with highly alkaline liquor containing 10% sodium hydroxide, waste stream 8 is also highly alkaline and exceeds allowable limits for pH, TS, BOD_5, and COD. The very high concentrations of TS and Na in this stream comes from the added sodium hydroxide, whereas high values of BOD_5 and COD result from the presence of biodegradable jute fibres. It should be noted that TDS for this waste stream could not be determined because this highly alkaline wastewater could not be filtered with the filter paper used for filtering wastewater samples. However, since turbidity value is low, majority of the total solids (TS) appears to be present in dissolved state. In IWS3, values of TS, Na, BOD_5, and COD are significantly less than those in waste stream 8 because of dilution with wash water although they exceed allowable limits for discharge into surface water bodies. The very high TSS in IWS3 is most likely due to the presence of biodegradable jute fibres.

Table 4. Characteristics of waste streams from softening process

Parameter	Unit	Concentration Present		EQS (1991)*
		Waste Strm. 8	Waste Strm. IWS3	
Temperature	°C	34	-	40, 45#
pH	-	12.4	12.0	6 - 9
Colour	TCU	1020	295	Light Brown
Turbidity	NTU	60	25	-
Total Solids (TS)	mg/L	1,52,385	36,432	2250
Total Dissolved Solids (TDS)	mg/L	-	22,078	2100
Total Suspended Solids (TSS)	mg/L	-	14,354	150
BOD_5	mg/L	5700	2200	50
COD	mg/L	6900	2400	200
Sodium, Na^+	mg/L	45,440	9740	-

* Environmental Quality Standard of Bangladesh (DOE, 1991)
# 40 °C during summer, and 45 °C during winter

POSSIBLE ENVIRONMENTAL IMPACTS

In the present study, the bleaching and softening processes were carried out in a laboratory. An industrial or mill scale project would be of comparable size in terms of equipment and chemicals used. The wastewater generated from the bleaching and/or softening process in such an industry would most likely be discharged into nearby streams or rivers. In this study, possible environmental impacts have been evaluated based primarily on the discharge of the integrated waste streams of the industrial processes into natural streams and rivers.

The primary impact resulting from the discharge of untreated wastewater into a surface water body is on the water quality. Wastewater containing high organic content undergo biochemical oxidation in receiving water to which they are discharged, thereby decreasing levels of dissolved oxygen (DO) in these waters and rendering them unsuitable for support of their biota and flora. Fish require the highest levels of DO, invertebrates lower levels of DO and bacteria the least. For instance, for a diversified warm water biota, including fish, the DO concentration should be at least 5 mg/L.

The wastewater generated from bleaching and softening processes are high in organic content as indicated by the high values of BOD_5 and COD. These oxygen demanding wastewater if discharged untreated into surface water bodies would deplete DO of water resulting in pollution of the water bodies. The Environmental Quality Standard (EQS) of Bangladesh (Department of Environment, 1991) suggest that wastewater containing BOD_5 in excess of 50 mg/L should not be discharged into open water bodies. The BOD_5 values in the integrated waste streams are 1100 mg/L for one step bleaching process, 800 mg/L for the two step bleaching process and 2200 mg/L for the softening process. These wastewater require treatment to bring down the organic content to acceptable limits prior to discharge into open water bodies.

Both bleaching processes generate effluents with high PO_4 concentration. Phosphate concentration is 76 mg/L in the integrated waste stream of one step bleaching process and 37 mg/L in the integrated waste stream of the two step bleaching process, while Bangladesh EQS limits the concentration to only 5 mg/L for discharge into surface water bodies. The disposal of wastewater which are rich in phosphates often result in abundant blooms of algae and attached aquatic plants. Such overgrowth and subsequent death of these plants commonly leads to the deterioration of an otherwise high quality water to the point where it may be unsuitable for domestic, industrial or recreational uses or for the support of desirable fish or other lives .

Wastewater generated from bleaching and softening processes contain very high solids concentration both in dissolved and suspended states. Dissolved inorganic substances may exert adverse effects on aquatic animal and plant life and may also cause irrigation problems in the agriculture industry. Assuming that the dissolved substances are non-toxic, the damage to the aquatic life is primarily related to the process of osmosis. Solids content of wastewater generated from the industrial processes is of the order of 6 to 10 times the tolerance limit set by the Bangladesh EQS and hence the wastewater must be treated before discharge.

Excessive sodium (Na) ion concentration may lead to adverse effects on soils and plants by breaking up soil aggregates and causing the soil to become highly impermeable. High concentrations of colour and turbidity in the wastewater would lead to gross aesthetic damage. Aluminum ion at high concentrations is highly toxic to aquatic life. The toxic action of Al on fish results primarily from its ability to cause mucus clogging of the gills, leading to respiratory distress and death. High values of residual chlorine in the wastewater may adversely affect certain aquatic life.

WASTE TREATMENT OPTIONS

The bleaching and softening processes of jute have their adverse effects primarily on the surface water quality from discharge of wastewater of high organic content. Such effects can be minimised by adopting simple biochemical treatment methods.

Integrated waste streams of the bleaching and softening processes would have to be treated before discharge into a surface water body. Since the organic matters in the waste streams are, primarily, biodegradable jute fibres, biological treatment would be effective for reducing BOD_5 and COD values. From consideration of simplicity of construction, effectiveness and economy, biological treatment employing oxidation ponds appear to be a suitable technique for treating all the waste streams provided sufficient land area is available. Due to the presence of phosphate in the integrated waste streams of the one step bleaching process, it may be required to remove excess phosphate after treatment in oxidation pond(s). This can be accomplished by addition of metal salts of aluminum and iron (e.g., alum, sodium aluminate, ferric chloride, ferrous chloride, and ferric sulphate) which react with phosphorus to form insoluble precipitates. Phosphorus removal can also be achieved by the addition of lime. In addition to these chemical processes, some recently developed biological phosphorus removal alternatives (e.g., Phostrip process, Modified Bardenpho process, etc.) are also available (USEPA, 1987), but it would be difficult to combine them with the oxidation pond systems. For the integrated waste stream of the two step bleaching process, it may be required to dechlorinate it before treatment in oxidation pond. Dechlorination can be effected with a variety of reducing agents such as, sulphur di-oxide, bisulphites, sulphites, or thiosulphates. For highly alkaline integrated waste stream of the softening process, it may be required to neutralize it before treatment in oxidation pond.

CONCLUSIONS

The industrial bleaching and softening processes generate a number of waste streams. In this study, five important waste steams and the integrated waste streams of the bleaching and softening processes were characterized through laboratory analysis. Integrated waste streams of the industrial processes primarily contain residuals of the chemicals used in these processes and biodegradable jute fibres. In the integrated waste stream of the one step bleaching process the wastewater parameters of primary concern are TDS, TSS, PO_4, BOD_5 and COD, all of which exceed the Bangladesh EQS for discharge into a surface water body. For the integrated waste stream of the two step bleaching process, in addition to the above parameters, residual chlorine is also of concern. For the softening process the parameters exceeding EQS are pH, TDS, TSS, Na, BOD_5 and COD.

Results of laboratory analysis suggest that the industrial effluents of the bleaching and softening processes, if discharge untreated into a surface water body, may cause substantial pollution. Integrated waste streams of the bleaching and softening processes, therefore, need to be treated before discharge into a surface water body. Since the processes are of much industrial importance for diversified uses of jute, proper attention is needed for treatment of these wastewater so that the processes do not suffer in the long run under any circumstances. Biological treatment employing oxidation ponds appears to be a suitable method for treatment of the integrated waste streams of the industrial processes. The oxidation pond method of treatment, however, requires considerable land. In case of land constraint, biological treatment employing suitable activated sludge system can be used. The appropriate waste treatment option should, therefore, be determined on a case by case basis. It is recommended that industries adopting these bleaching and softening processes should conduct environmental impact assessment taking into consideration particular environmental setting of the industry in question. Although possible environmental impacts have been assessed in this study, a case by case environmental impact assessment is required for industries before they go into operation.

REFERENCES

American Water Works Association, AWWA (1985), Standard Methods for the Examination of Water and Wastewater, 16th Edition, AWWA, APHA, WPCF.

Amin, M. N., Begum, M., Shahjahan, M., Rahman, M. S., Baksh, M. T. (1996a), "A bleaching process for increasing whiteness and lightness of kenaf and kenaf-jute blended fabrics, Cellulose Chem. Tech., *in press*.

Amin, M. N., Shahjahan, M., Begum, M., Rahman, M. S., Baksh, M. T., Rahman, K. A., Kamaluddin, M. (1996b), Manual for Bleached Jute/ Kenaf Fabrics for Application in Shopping Bags, Volume I, published by IJO/CFC, April, 1996.

Amin, M. N., Shahjahan, M., Begum, M., Rahman, M. S., Baksh, M. T., Rahman, K. A., Kamaluddin, M. (1996c), Manual for Bleached/ Softened Jute/Kenaf Fabrics for Application in Upholstery, Volume II, published by IJO/CFC, April, 1996.

Department of Environment, DOE (1991), Environmental Quality Standards (EQS) for Bangladesh

U.S. Environmental Protection Agency (1987), Design Manual: Phosphorus Removal, EPA/625/1-87/001