INVESTIGATION OF WASTE COTTON FIBRE AS TREATMENT MATRIX FOR TEXTILE EFFLUENTS

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ABSTRACT

The investigation of waste cotton wool, as is and after modification with mineral acids, as a treatment matrix for textile effluents is reported. 50% aqueous HNO_3, 33% aqueous HCl, 25% aqueous H_2SO_4, commercial HNO_3 and a 1+1 mixture of 25% aqueous HNO_3 and 25% aqueous H_2SO_4 were investigated as modifying reagents. The cotton samples obtained after modification and the unmodified sample were applied as adsorbents in open gravity flow chromatographic columns for treating effluent from a textile factory. The improvements in effluent properties after treatment were used to evaluate the performance of each adsorbent. While every matrix investigated reduced the absorbance of the test effluent, the modified wool matrix obtained with commercial HNO_3 and the 1+1 aqueous mixture of 25% HNO_3 and 25% H_2SO_4 yielded the greatest reduction in effluent absorbance at the wavelength of maximum absorption. These matrices, by implication, achieved the greatest colour removal from the effluent. Other parameters like solids content of the effluent also improved significantly after treatment with the matrices. These materials are suitable to incorporate into industrial effluent treatment matrix, especially for textile effluent treatment, to remove colour and other offensive parameters like solids content.

INTRODUCTION

The cost of effluent treatment in the textile and other industries in Nigeria remains high and effluents are still being discharged without stipulated treatment[1-3]. Intense coloration is a typical nuisance parameter in textile effluents and the removal of colour and other offensive parameters from them relying on inexpensive matrices and procedures has been focused on[3]. The inclusion of cotton wool in a mixed matrix for textile effluent decoloration has been suggested[3]. The purpose of this article is to evaluate both cotton wool and matrices obtained by chemically modifying it as potential matrices for textile effluent treatment. The cellulose in cotton fibre has been described[4] as a non-polar organic compound of large molecular weight with a chain structure extremely inert to chemical action. The molecule, however, has three dipolar hydroxyl groups in each glucose residue and occurring at regular intervals along the surface of the polymeric chain. Gross properties of cotton fibre suggest that the molecular chains are, in some places, held together lengthwise by various forces, forming tightly packed bundles known as crystalline regions while in other places known as amorphous regions, they are less firmly

held and can be readily separated. Water, for example, is strongly attracted to and readily penetrates the amorphous regions forcing the strands apart so that the entire fibre becomes penetrated by minute pores and channels through which dissolved solutes can infuse the bundle. The intake of water causes swelling of the cellulose fibres rendering them spongy in nature[5]. It is the possibility of solutes in water infusing the cellulose fibres that informs the modification of cotton wool using various acids for efluent treatment. Waste cotton wool is an abundant fallout of the operations in the textile industry and a possibility to channel it back into use in effluent treatment would yield cost saving.

EXPERIMENTAL

Materials

All chemicals applied in this work were of analytical grade and water used was distilled water. The reagent solutions applied in cotton fibre modification included 50% (v/v) aqueous nitric acid (I); 33% (v/v) aqueous HCl (II); 25% (v/v) aqueous sulphuric acid (III); commercial HNO_3 (IV) and an aqueous equi-mixture (V) of 25% HNO_3 and (III). The cotton wool investigated was

waste cotton wool rejected from spinning operations in Zaria Industries Limited, a tarpaulin manufacturing industry in Nigeria. The textile effluent used to evaluate the performance of the cotton modification products was a mixture of effluents sourced from various operation units in United Nigeria Textiles Limited, Kaduna and stored in a plastic bottle until needed. The columns applied in this work were open gravity flow glass columns 28.0cm long with 1.1cm internal diameter, plugged at the bottom with glass wool.

Modification of cotton wool

The cotton wool was teased with a plastic comb to loosen up the fibres and remove dust and other debris. 250g of the blown cotton wool was reacted in turns with 1 l of one of the reagent solutions I - V enumerated earlier, heating on a steam bath for 1h repeating the process for all four reagent solutions. The product (P) in each case was filtered, washed free of acid and air-dried. The products were labelled P_I - P_V respectively corresponding with the reagent solutions used to obtain them, and similarly numbered I - V earlier.

Determination of effluent characteristics

The spectral characteristics of the pooled textile effluent were determined by scanning its uv - visible spectrum on a Corning 253 colorimeter. The λ_{max} (660nm) and the corresponding absorbance for the effluent before and after treatment with the cotton wool modification products are indicated in Table 1.

Table 1. Test effluent characteristics

	Untreated	After treatment				
		P_I	P_{II}	P_{III}	P_{IV}	P_V
Absorbance at 660nm	0.68	0.20	0.22	0.05	0.005	0.18
Total solids (mg/l)	3742	2887	2437	2293	2013	2000

To determine the solids content of the effluent sample, 50ml of it was evaporated to dryness on a steam bath in a pre-weighed clean and dry pyrex evaporating dish. The residue was weighed after cooling in a desiccator. The weight of the empty dish was subtracted from that of the dish with the residue to obtain the solids content in 50ml of the effluent[6,1]. The average of the triplicate

determinations is reported in Table 1.

Evaluation of cotton modification products for treating textile effluents

To pack a column, 50g of the cotton or its modification products P_I - P_V was mixed with water and allowed to stand for 1h forming a slurry. The slurry was packed into a column and flushed with about 50ml of water to condition it for use.

To evaluate the performance of a matrix, a set of six columns of it was applied; the capacity of the matrix to remove colour from an effluent was determined by running 20ml fractions of the test effluent through a column of the matrix and measuring the absorbance of the eluate collected from each fraction. The results are presented for the six matrices tested in this work in Table 2 for the first four 20ml fractions.

Table 2. Matrix performance on test effluent fractions

Effluent volume (ml)	Absorbance after					Unmodified cotton
	P_I	P_{II}	P_{III}	P_{IV}	P_V	
20	0.02	0.08	0.04	0.04	0.01	0.68
40	0.05	0.07	0.08	0.09	0.06	0.68
60	0.06	0.07	0.07	0.07	0.09	0.68
80	0.06	0.07	0.07	0.07	0.05	0.68

The efficiency of a matrix in removing colour from an effluent was also determined by observing the number of times the same effluent fraction needed to be recycled through the same column before the effluent absorbance was reduced to a minimum value or zero[7,8]. For this purpose, 30ml of the test effluent and eluates successively collected from it were recycled repeatedly through a column of the matrix and the absorbance of each eluate measured. The results for the six test matrices are presented in Table 3 for comparison.

Table 3. Effect of recycling same effluent fraction through a column

Cycle no.	Absorbance after Column matrix					Unmodified cotton
	P_I	P_{II}	P_{III}	P_{IV}	P_V	
1	0.09	0.08	0.08	0.09	0.09	0.68
2	0.08	0.08	0.06	0.07	0.05	0.68
3	0.07	0.07	0.06	0.06	0.04	0.68
4	0.07	0.06	0.04	0.04	0.02	0.68

The total bulk of the matrix required to scrub a certain volume of effluent free of colour was estimated by passing the fixed volume of effluent through a succession of similar columns, measuring the absorbance of the eluate between the columns until the absorbance was reduced to a minimum or zero. In this work, 80ml of the test effluent was passed through a succession of four columns collecting the eluate from each column into the next in each case. Executed for all the test matrices, this process yielded the results presented in Table 4. Replicate observations gave similar trends to those presented in this table.

Table 4. Absorbance changes in a succession of columns.

Matrix	Column no. in sequence			
	1	2	3	4
P_1	0.08	0.07	0.06	0.04
P_{II}	0.08	0.07	0.07	0.06
P_{III}	0.08	0.07	0.05	0.03
P_{IV}	0.06	0.05	0.05	0.03
P_V	0.06	0.04	0.04	0.02
Unmodified cotton	0.68	0.68	0.68	0.68

To evaluate each matrix with respect to effluent solids reduction, the procedure described earlier was applied to determine the solids content of the eluate collected after passing 80ml of the test effluent through a column of a test matrix. These result were subtracted from the solids content of the untreated effluent to obtain the solids reduction achieved with each test matrix. The results are presented in Table 5.

Table 5. Effluent solids reduction by matrices.

Matrix	P_1	P_{II}	P_{III}	P_{IV}	P_V	unmodified cotton
% solid removal	22.8	34.9	38.7	46.2	46.6	0

RESULTS AND DISCUSSION

All the reagents applied in this work have successfully overcome the chemical inertness[4] of cotton wool and produced a smooth lard-like gel coloured either pale yellow or dirty white; they all yield modified cotton wool matrices that treat textile effluents to various degrees. In application each reagent tested has achieved a considerable reduction in the absorbance of the test effluent; this observation implies the removal of colour from the effluent by all the matrices (Tables 1 - 4). The results also indicate that the matrices P_{IV} and P_V produced by commercial nitric acid and a 1+1 mixture of 25% aqueous solution of it with 25% aqueous sulphuric acid display a superior effluent decolouration to the matrices produced by the other reagents tested in this work. There is little to choose between the performances of these two reagents as indicated in Tables 1 - 4. Beside removing colour from effluent, the results of Table 1 and Table 5 indicate that the cotton wool modification products also reduce the solids content of the test effluent. With respect to this function, the results also indicate that the two matrices P_{IV} and P_V are superior to the other matrices tested in this work; they reduce the effluent solids content by 46.2% and 46.6% respectively. The 0.4% difference between the solids reduction of these two matrices may be compromised for the advantage of using only nitric acid in obtaining matrix P_{IV} over matrix P_V which is a mixture of two chemicals. A cost saving would be achieved with very little compromise in performance.

CONCLUSION

Cotton wool modified with commercial nitric acid or a 1+1 aqueous mixture of 25% nitric acid and 25% sulphuric acid has the capacity to remove colour and solids from textile effluents and may be incorporated into effluent treatment matrices. Up to 46.6% solids can be removed and only 0.4% solids removal would be compromised by using nitric acid only as modifying reagent instead of the optimum reagent mixture indicated in this work.

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