Indian Journal of Fibre & Textile Research
Vol. 45, September 2020, pp. 319-325

Dyeing of cotton with reactive dyes using pre-treated sea water

A S M Raja[a], A Arputharaj, T Senthilkumar, S Saxena & P G Patil

Chemical and Biochemical Processing Division, ICAR-Central Institute for Research on Cotton Technology, Adenwala Road, Matunga, Mumbai 400 019, India

Received 24 June 2019; revised received and accepted 11 December 2019

The present study explores the use of sea water as dyeing medium for cotton textiles with reactive dyes. Sea water has been pre-treated with calcium oxide/sodium carbonate to remove calcium and magnesium ions. The findings show that the addition of 20 g/L of sodium chloride is required to increase the exhaustion of dye in pre-treated sea water instead of 60 g/L of sodium chloride as required in conventional dyeing method. SEM , KESF and EDAX analyses show no significant difference on the surface of pre-treated sea water dyed and conventional dyed fabrics. It is also found that there is no significant difference in the wash and light fastness properties between pre-treated sea water dyed fabrics and conventional dyed fabrics. The developed process is in the direction of addressing sustainability issues of textile processing industries.

Keywords*:* Cotton, Dyeing, Reactive dyes, Sea water, Water conservation

1 Introduction

Cotton processing industries mostly uses ground and surface water for processing. Water is one of the essential elements for the survival of human beings. Due to increase in the population and climatic change, the water resources are constantly depleting and hence this creates water scarcity problem. The sustainability of these industries is at the risk due to the fast depleting of ground water in their area and climate change leads to uneven rain pattern[1]. Local communities present in the cotton processing area have greater awareness about the water scarcity problem and started resisting the use of normal water for industrial purposes[2]. In order to circumvent the above problem, cotton processing industries have to either drastically reduce the water usage or explore the possibility of using the already used water. By using dyeing machines which require ultra-low level liquor ratio, water usage can be reduced. Several waterless technologies for dyeing of cotton have been attempted like supercritical fluid processing, plasma processing, etc[3]. However, the adoption of these technologies for natural fibre like cotton is still at infancy stage due to the intricacies in the chemical structure of cotton. Regarding the alternate source for water as dye medium, organic solvents were used as medium of dyeing cotton in place of water. Polar and non-polar solvents, such as perchloro ethylene, trichloroethylene, dimethyl formamide and polyethlene glycol reverse micelle system[4], have been attempted to dye cotton. However, the use of these solvents is not considered as an eco-friendly alternative due to the toxicity and higher cost involved in it.

Reactive dyes are widely used to dye cellulosic materials due to their brilliant shades and all-round fastness properties. These dyes have reactive functional group capable of forming covalent bond with the hydroxyl groups of cellulose under certain *p*H conditions. Cotton develops weak negative charge in the aqueous dyeing bath and repel the anionic reactive dyes. Under this condition, the reactive dyes tend to hydrolyse in the water. The hydrolysed dye cannot form covalent bond with cotton and reduces the fatness properties. In order to overcome these problems, large amount of inorganic electrolytes, like sodium chloride and sodium sulfates are added as dye bath additive for exhaustion of dyes on cotton. For dyeing 1 kg of cotton with reactive dyes, addition of up to 0.6 kg electrolytes is required. The electrolytes are released as effluent after dyeing and increase the total dissolved solids (TDS). The industries have to employ series of treatment processes to reduce the TDS but the cost of such treatment is huge, affecting the profitability[5].

In the present study, it is hypothesized that why the sea water which contains 25 -37 g/L salts cannot be

[a]Corresponding author.
E-mail: asmraja16475@gmail.com

used for dyeing of cotton material. Previous research indicated that it is possible to achieve level dyeing on wool fabric using sea water as the dyeing media for Remazol reactive dyeing[6] and dyeing of cotton with hot brand reactive dye[7,8]. The electrolyte content in sea water is expressed in terms of salinity (gram of salt/ kg of water). The major ions present in sea water are chloride (Cl^-), sodium (Na^+), sulphate (SO_4^{2-}), magnesium (Mg^{2+}), calcium (Ca^{2+}) and potassium (K^+). The Na^+ and Cl^- ions present in the sea water are useful for dyeing of cotton. However, the presence of Ca^{2+} and Mg^{2+} ions can affect the dyeability of the cotton and also lead to scale formation in the dyeing machine which will affect the wear and tear of the machine. Based on the above, the present study explores the use of sea water as medium for dyeing cotton with reactive dyes simulating the salt added during the process to facilitate dye uptake. To the best of our knowledge, there is no such study reported in the literature about the use of sea water for dyeing of cotton which is abundantly available.

2 Materials and Methods

2.1 Materials

Ready for dyeing (RFD) plain 100% cotton woven fabric with 90 g/m^2 weight was purchased from local market of Mumbai, India. The fabric was free from any finishing chemical as well as impurities. Five reactive high exhaustion (HE) dyes, namely Blue HERD (CI Reactive Blue 160) , Red HE7B(CI Reactive Red 141), Green HE4B(CI Reactive Green 19), Orange HER(CI Reactive Orange 84) and Navy Blue HER (CI Reactive Blue 171), supplied by M/s Colourtex Industries Pvt, Ltd, Mumbai, India were used for dyeing cotton fabrics. Analytical grade sodium chloride (assay 99.9%), sodium carbonate (assay 99.5%), calcium oxide (assay 99.2%) and hydrochloric acid (assay 35%) were used for dyeing and other treatments. Sea water was collected from the Arabian sea, Mumbai, India in the geographic coordinates 18°59'58.5"N & 72°47'21.4"E with the help of local fisherman. Water was collected well away from sea shore to avoid the contamination of man-made impurities. For comparative studies, Mumbai Municipal Corporation water with TDS of 70 ppm and hardness less than 25 ppm was used for dyeing, which is denoted as normal water in this article.

2.2 Sea Water Pre-treatment

One liter of sea water was taken in a beaker. Initially, 10 g of calcium oxide was added with constant stirring for 5 min. After that 10 g of sodium carbonate was added and the bath was kept for 30 min to allow the settlement of added chemicals. Then the water was filtered using Whatmann filter paper and used for further dyeing.

2.3 Characterization of Water

Sea water, pre-treated sea water and normal water samples used for dyeing were evaluated for different properties, such as hardness, potassium, sulphate, chloride, calcium harness, magnesium, magnesium hardness, phosphate, alkalinity, zinc and iron using standard procedure with conductive principle and Palintest Photometer 7100 (M/s Palintest, USA). The total hardness which is the measure of calcium, magnesium and sulphate ions was tested using EDTA titrimetric method with Eric chrome black D as an indicator at pH 10.5. TDS of the water was determined using Eutech CON 2700 TDS tester. Chemical oxygen demand (COD) was tested using silver sulphate digestion followed by titration method and biochemical oxygen demand (BOD) was determined by five days incubation method.

2.4 Dyeing of Cotton Fabrics

The cotton fabrics were dyed with five different reactive dyes using laboratory IR beaker dyeing machine (M/s RB Electronics, Mumbai, India). The dye bath was prepared using water with the MLR 1:15 and required amount of dye (2% owm) was added to the beaker. Wetted out and squeezed cotton fabric was introduced into the beaker. Then the beaker was tightly closed and kept on the rotating shaft of the dyeing machine. The temperature of the bath was increased to 80°C and kept as such for 20 min. After that, temperature of the bath was reduced to 50°C and 15 g/L sodium carbonate was added to facilitate the reaction between dye and cotton. The temperature was again raised to 80°C and process continued for 20 min. After that, the temperature was reduced to 40°C and the dyed fabric was removed from the beaker. Then it was subjected to soaping treatment using non-ionic detergent followed by hot and cold washes. Finally, the fabric was dried and used for further evaluation. A control dyeing experiment on cotton fabric was done using normal water in which 60 g/L sodium chloride was taken along with the dye solution for comparative purpose. In the case of sea water experiments, sea water, pre-treated sea water and pre-treated sea water with 20g/L sodium chloride were used as medium for dyeing. The addition of

20g/L NaCl was done based on the electrolyte content of sea water which is in between 30-40 g/L and 60 g/L electrolyte required for conventional dyeing. The dyeing was carried out as per the earlier mentioned procedure. The dyed cotton samples were designated as given in Table 1.

2.5 Evaluation of Colour Strength and Colour Difference

The uniformity of the dyeing was observed subjectively. The colorimetric values (L*, a*, b*, hue and *K*/*S*) of dyed samples and whiteness index of pre-treated fabric were evaluated using Premier Colourscan computer colour matching system (M/s Premier Colorscan Instruments Pvt. Ltd., Mumbai) at D65 illuminant/ 10° observer according to AATCC Evaluation Procedure 6. The colour difference (ΔE) was calculated using colour coordinate values of sea water/pre-treated sea water and normal water dyed fabrics. If the colour difference is more than ±1, it was inferred that there was significant colour difference exists between the sea water/pre-treated sea water samples and the control fabrics.

2.6 SEM and EDX Analysis

The surface properties of the dyed samples were observed using a Philips XL-30® scanning electron microscope (SEM). The samples were coated with a thin layer of gold to get conductivity using a sputter coater and scanned under SEM with an accelerating voltage of 10 kV. Energy-dispersive X-ray spectroscopy (EDAX) analytical technique was used (EDX- 8000, M/s Shimadzu, Japan) for the elemental analysis of the samples. Both SEM and EDAX analyses were carryout to find out the changes in the surface of dyed cotton fabrics.

2.7 Evaluation of Surface Roughness

Kawabata Evaluation System (KES –FB4®) was used to determine any changes in the surface roughness of the dyed cotton fabrics due to the use of sea water as dyeing medium. KES-FB4 was used in this study for evaluating surface friction and its variation such as coefficient of friction (MIU) and geometrical roughness (SMD), which indirectly indicates the surface roughness of the textile materials. Higher average MIU and SMD values indicate more roughness in the evaluated surface.

Table 1 — Different dyeing conditions of cotton fabric

Sample ID	Dyeing medium	Electrolyte (NaCl), g/L
A	Normal water	60
B	Normal water	-
C	Sea water	-
D	Pre-treated sea water	-
E	Pre-treated sea water	20

2.8 Measurement of Fastness Properties of Dyed Fabrics

The light, wash and rub fastness values of the dyed samples were done as per the standard methods, namely ISO 105(CO3), AATCC 16E and IS 766 test methods respectively. For all the fastness testings, the ratings were given from 1 to 5. The fastness rating of 5 indicates excellent fastness and the rating of 1 indicates very poor.

3 Results and Discussion

3.1 Dyeing Properties of Sea Water

The collected sea water was analysed for salinity which is found to be 37g/L. The result of dyeing of cotton using normal water with 60g/L sodium chloride (control) and normal water without salt (blank control) and untreated sea water is given in Table 2. It is observed that the *K*/*S* value of sea water dyed samples shows 41%, 31%, 19%, 13.5% and 44.6% lesser *K*/*S* values as compared to normal water dyed samples with the addition of 60 g/L salt for the dyes CI Reactive Blue 160, CI Reactive Red 141, CI Reactive Green 19, CI Reactive Orange 84 and CI Reactive Blue 171 respectively. The normal water dyed samples without the addition of salt show very less dye uptake as compared to sea water dyed

Table 2 — Colour characteristics of cotton fabrics (Sample A, Sample B and Sample C)

Dye	Sample	L*	a*	b*	*K*/*S*	ΔE*
CI Reactive Blue 160	A	52.19	-4.51	-23.95	3.07	-
	B	59.64	-4.39	-19.98	1.68	8.44
	C	58.43	-3.77	-20.96	1.81	7.22
CI Reactive Red 141	A	51.29	50.06	-6.49	5.12	-
	B	57.02	45.67	-7.74	3.01	7.32
	C	55.31	46.86	-7.78	3.52	5.29
CI Reactive Green 19	A	36.65	-13.83	-2.44	8.28	-
	B	42.29	-14.36	-2.54	4.62	8.66
	C	39.94	-13.24	-4.59	6.72	3.98
CI Reactive Orange 84	A	65.01	42.62	40.73	4.73	-
	B	67.87	41.61	39.98	3.73	3.12
	C	67.04	39.67	41.07	4.09	3.60
CI Reactive Blue 171	A	45.66	-6.244	-17.78	4.26	-
	B	53.90	-7.497	-16.301	2.46	8.46
	C	54.26	-7.31	-15.99	2.36	8.64

*For ΔE calculation, sample A is considered as standard.

samples as well as normal water dyed samples with salt. Cellulose polymer in cotton is weak acid and so develops negative charge when it is immersed in the water. When reactive dyes are dissolved in water, they dissociate into dye anion and sodium cation. At initial stage dye molecule moves towards the cellulose molecule due to affinity of the dyes. After sometime, an electrical double layer is developed in the cellulosic fibre, which results in a negative zeta potential. This electrical double layer becomes barrier for the dye uptake on the fibre which can be reduced by adding electrolytes.

From the results, the *K*/*S* values of sea water dyed fabric samples in all cases are higher as compared to normal water dyed samples without salt. However, the dye uptake of above samples is comparatively lesser than that of control dyeing, when 60 g/L of salt is added.

Table 2 shows that colour difference between normal water with 60 g/L salt and normal water without salt used dyed fabrics is more than 5 units in all the dyes. The colour difference values for dyed fabrics in which sea water is used as medium are found ranging from 3.6 units to 8.8 units as compared to normal water dyed samples. Since, the colour difference value is >3, it is inferred that the dye uptake in case of sea water dyed fabrics is very less as compared to control dyed fabrics.

Regarding the uniformity of produced colour shades, the dyed cotton fabrics using untreated sea water show lot of unevenness in dyeing and patchy dyeing is also observed. The precipitate of dye is seen all over the fabric. This may be the reason for large variation in colour difference and k/s values among the dyed fabrics. The cause of uneven dyeing is due to precipitation of dyes by the Ca, Mg and their carbonate ions present in the sea water. The hardness of sea water which is the measure of presence of carbonate and non-carbonate ions of Ca and Mg is determined using EDTA titration method and found to be 6500 ppm as compared to 20 ppm in normal water used in the present study. The industrial norms for the water to be used for dyeing should be well below 500 ppm for getting even shades. The results indicate that Ca^{2+} and Mg^{2+} ions present in the sea water precipitate the dyes in the dye bath and resist the uptake on the fabric which results in uneven dyeing on cotton fabric and more colour difference compared to control dyed samples.

3.2 Dyeing Properties of Pre-treated Sea Water

Based on the previous results, it is inferred that untreated sea water cannot be used for dyeing of cotton as such and requires some pre-treatment to remove the hardness. Accordingly, a pre-treatment process has been optimized based on lime-soda process of water softening to remove the hardness of sea water. Calcium oxide and sodium carbonate have been used in pre-treatment to remove both Ca^{2+} and Mg^{2+} hardness. The pre-treatment process has been optimized, by which 10 g/L of each of the above chemicals is found to reduce the hardness of sea water to 300 ppm. When calcium oxide and sodium carbonate are added to sea water, calcium oxide precipitates both calcium and magnesium carbonate ions responsible for hardness, whereas sodium carbonate precipitates non-carbonate based hardness-causing chemicals, such as calcium sulphate and magnesium sulphate. The precipitate contains mixture of calcium and magnesium hydroxide.

The results of chemical composition testing of sea water, pre-treated sea water and normal water are given in Table 3. It is observed that the hardness of sea water is drastically reduced due to pre-treatment. The calcium hardness is reduced from 282 ppm to 6 ppm which is almost equal to normal water (4.5 ppm). Magnesium hardness and magnesium content in sea water are reduced to 100 ppm and 25 ppm from 7500 ppm and 1800 ppm respectively. The drastic reduction of Ca^{2+} and Mg^{2+} ions in sea water due to pre-treatment enable it to be used as a medium for dyeing. There is no significant reduction in potassium, zinc and iron content due to pre-treatment. The potassium content in pre-treated sea

Table 3 — Chemical constituents of different water

Chemical constituents	Amount, ppm		
	Sea water	Pre-treated sea water	Normal Water
Potassium	220	225	1.0
Sulphate	190	155	100
Chloride	33600	31700	10
Calcium hardness	292	6	4.5
Magnesium	1800	25	1.0
Magnesium hardness as $CaCO_3$	7500	100	10
Phosphate	4.5	10.7	8.6
Zinc	0.09	0.07	0.44
Iron	0.3	0.3	0.25
TDS	37000	39000	70
COD	10	30	5
BOD	5	5	2

water is found higher as compared to fresh water. However, the presence of high amount of potassium is expected to give positive influence for dyeing. The sulphate and chloride contents of sea water are reduced by 18% and 5.6% due to pre-treatment. While dyeing, about 60 g/L of sodium chloride is added for uptake of reactive dyes. Hence, higher chloride content in the pre-treated water can be considered as beneficial factor. The sulphate content of pre-treated water is higher as compared to normal water but it is within the limit of 150 ppm. The phosphate content of sea water is increased due to pre-treatment from 4.5 ppm to 10.7 ppm. Higher phosphate content in water is expected to act as corrosion inhibitor. The TDS content of sea water is 37000 ppm as compared to 70 ppm in the case of normal water. However, during dyeing, large amount of sodium chloride is added and the TDS of conventional bath would be 60000 ppm. The COD and BOD values of sea water, pre-treated sea water and normal water are found within the range suitable for dyeing.

The pre-treated sea water is used for dyeing, and such dyed fabrics are compared with fabrics dyed with normal water plus 60 g/L salt. The *K*/*S* and colour difference values of such dyed fabrics are shown in Table 4. It is observed that the *K*/*S* values of pre-treated sea water dyed samples are 9.7%, 12%, 3%, 2.7% and 9% lesser as compared to normal water dyed samples with the addition of 60 g/L salt for the dyes, namely CI Reactive Blue 160, CI Reactive Red 141, CI Reactive Green 19, CI Reactive Orange 84 and CI Reactive Blue 171 respectively. The dyed fabrics using sea water without pre-treatment show 41%, 31%, 19%, 13.5% and 44.6% lesser *K*/*S* values than control dyed fabrics. Due to the pre-treatment, the dye uptake of the fabric increases many folds in all the used dyes. However, still such dyed fabrics show significantly lesser *K*/*S* values as compared to control dyed fabrics. Subjective assessment of dye shades shows uniformity in dyeing and there is no problem of patchy dyeing in the fabrics as occurred in the case of untreated sea water.

From Table 4, it is found that the colour difference values of pre-treated sea water dyed fabrics are more than that of the normal water dyed control fabrics with the addition of salt. For comparable dyeing effect, the colour difference should be < 1. From the result, it is inferred that pre-treated sea water though produces uniform shades, the uptake of dye on the fabrics is less as compared to normal water dyed control fabrics with the addition of salt. The salinity of sea water is 37000 ppm, out of which about 6000-7000 ppm of calcium and magnesium ions are removed during pre-treatment. The remaining salt concentration is about 30000 ppm which is roughly equal to 30 g/L of sodium chloride. Generally, reactive dyeing of cotton requires 60 g/L for exhaustion of dyes. This may be the reason for less dye uptake in the pre-treated sea water based dyeing.

3.3 Optimization of Dyeing Conditions of Pre-treated Sea Water

In order to match the normal water dyeing, attempt has been made to dye the fabrics using pre-treated sea water with the addition of 20 g/L of sodium chloride. The *K*/*S* and colour difference values of such dyed fabrics are shown in Table 4. It is observed that the *K*/*S* value of pre-treated sea water dyed samples with the addition of 20 g/L salt showed 2.9%, 3.3%, 5.3% lesser *K*/*S* values as compared to normal water dyed samples with 60 g/L salt for the dyes, namely CI Reactive Blue 160, CI Reactive Red 141, CI Reactive Green 19, CI Reactive Orange 84 and CI Reactive Blue 171 respectively. The other two dyes, namely Green HE4B and Orange HER show higher *K*/*S* values which

Table 4 — Colour characteristics of cotton fabrics (Sample A, Sample D & Sample E)

Dye	Sample	L*	a*	b*	*K*/*S*	ΔE*
CI Reactive Blue 160	A	52.19	-4.51	-23.95	3.07	-
	D	52.54	-4.43	-23.81	2.77	1.44
	E	52.54	-4.43	-23.81	2.98	0.38
CI Reactive Red 141	A	51.29	50.06	-6.49	5.12	-
	D	52.71	49.46	-6.65	4.5	1.54
	E	51.46	49.55	-6.61	4.95	0.55
CI Reactive Green 19	A	36.65	-13.83	-2.44	8.28	-
	D	37.41	-14.21	-3.091	8.03	1.07
	E	35.76	-13.98	-2.94	8.98	1.0
CI Reactive Orange 84	A	65.01	42.62	40.73	4.73	-
	D	65.52	43.98	40.93	4.6	1.46
	E	65.07	43.15	41.45	4.86	0.89
CI Reactive Blue 171	A	45.66	-6.244	-17.78	4.26	-
	D	47.18	-6.71	-17.50	3.88	1.6
	E	46.56	-6.425	-17.78	4.03	0.91

*For ΔE calculation, sample A is considered as standard.

implies darker colour than the control dyed fabric. Due to the addition of 20 g/L salt, colour intensity of dyed fabrics using pre-treated sea water is found almost equal to control dyed fabrics. Table 4 shows that the colour difference values between dyed fabrics with pre-treated sea water plus 20 g/L salt and normal water dyed with 60 g/L salt are less than one unit in case of all the five dyes. From the results, it is interpreted that there is no visible difference in colour between the two sets of dyed fabrics for all the five dyes used in this study. The addition of 20 g/L of sodium chloride is required to increase the exhaustion of dye as in the case of control normal water used dyeing.

3.4 SEM and EDAX analysis

To find out surface morphology of the dyed fabric, SEM analysis has been carried out (Fig. 1). From the SEM analysis, it can be clearly seen that the fabric dyed with normal water (Sample A) has clear surface. However, fabric dyed with untreated saline water (Sample B) shows huge amount of salt deposition on its surface which may be due to the precipitation of calcium and magnesium salts during dyeing. When the fabric is dyed with pre-treated water (Sample E), very few salt deposits is noticed in the dyed fabric which indicates that pre-treatment is mandatory process to use saline water for dyeing. This result is supported by the EDAX analysis of the dyed samples which shows 0.34% calcium in sea water dyed fabric as compared to 0.06% and 0.1% calcium in normal water and pre-treated sea water dyed fabrics respectively.

3.5 Evaluation of surface roughness

KESF analysis results are given in Table 5 which shows that normal water dyed fabric (Sample A) gives comparatively lesser MIU and SMD values than sea water dyed (Sample B) and pre-treated sea water dyed (Sample E) fabrics. The sea water dyed fabric shows maximum surface roughness as compared to normal water dyed fabric. Since cotton fabric already has its own surface roughness due to the yarn structure and hairiness[9], it would be further increased due to the deposition of other salts present in the sea water in the case of Sample B. Higher MIU values in Sample B are also attributed to uneven surface resulted by the deposition/agglomeration of salts on the dyed cotton fabric. Pre-treatment of sea water significantly reduces the surface roughness in Sample E which results in very few deposition of salt which are already confirmed by SEM and EDAX analysis.

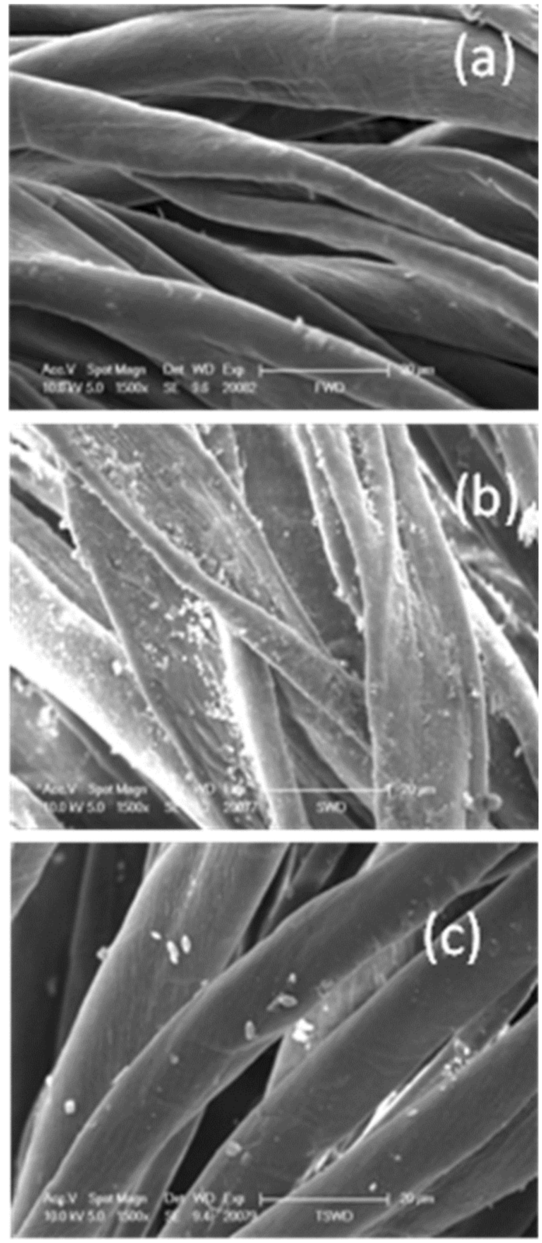

Fig. 1 — SEM of (a) normal water dyed (Sample A), (b) sea water dyed (Sample B), and (c) pre-treated sea water dyed (Sample E).

Table 5 — Surface analysis of cotton fabrics

Sample	MIU	SMD
A	0.296	3.62
B	0.450	5.83
E	0.342	4.43

3.6 Evaluation of Fastness Properties

The wash and light fastness values of normal water dyed (Sample A) and pre-treated sea water dyed fabrics (Sample E) are given in Table 6. It is observed that there is no significant difference between control dyed and pre-treated sea water dyed with 20 g/L salt

Table 6 — Fastness properties of dyed cotton fabrics

Reactive dye	Sample	Wash fastness (change in colour)	Wash fastness		Light fastness	Rub fastness	
			Staining on cotton	Staining on viscose		Dry	Wet
CI Reactive Blue 160	A	4	4	4	4	4-5	4
	E	3-4	4	4	4	4-5	4
CI Reactive Red 141	A	4	4	4	4	4-5	3-4
	E	4	4	4	4	4-5	3-4
CI Reactive Green 19	A	4	4	4	4	4-5	4
	E	4-5	4	4	4	4-5	4
CI Reactive Orange 84	A	4	4	4	4	4-5	4
	E	4-5	4	4	4	4-5	4
CI Reactive Blue 171	A	4	4	4	4	4-5	4
	E	4	4	4	4	4-5	4

fabrics. Both sets of fabric show very good wash fastness rating of 4 except in the case of Blue HER1 which shows one grade lower wash fastness. The light fastness rating is also found very good with the grading of 4 for both sets of fabrics. There is no difference in both dry and wet fastness rating in both sets of dyed fabrics for all the dyes. From the results, it is concluded that there is no difference in the fastness properties between pre-treated sea water dyed fabrics and normal water dyed fabrics.

4 Conclusion

Cotton materials require water and huge amount of salt for dyeing with anionic dyes such as reactive and direct dyes. Sea water with fairly good amount of salinity can be used for dyeing instead of normal water with simple pretreatment and small addition of salt. The pre-treatment for sea water can be carried out using common chemicals which are non-toxic in nature. The cost involved for the treatment of sea water can be compensated through the use of by-product chemicals such as calcium and magnesium carbonate for making valuable products. Based on the above, it is concluded that the use of sea water for dyeing of cotton is technically viable and economically feasible.

References

1 Saxena S, Raja A S M & Arputharaj A, *Textiles and Clothing Sustainability* (Springer, Singapore) 2017, 43.
2 Verma A K & Saksena D N, *Asian J Exp Biol Sci,* 12 (2010) 419.
3 Banchero M, *Color Technol*, 129 (2013) 2.
4 Wang Y, Lee C H, Tang Y L & Kan C W, *Cellulose*, *2*(2016)965.
5 Khatri A, Peerzada M H, Mohsin M & White M, *J Clean Prod*, 87 (2015) 50.
6 Broadbent P J, Carr C M , Rigout M, Kistamah N, Choolun J, Radhakeesoon C L & Uddin M A, *Color Technol*, 1349 (2018) 156.
7 Devanand G & Parthiban M. *Indian J Fibre Text Res*, 1 (2019)122.
8 Zerin I, Foisal A B M., Datta E & Rana M S, *IOSR-JPTE*, 4(2017) 32
9 Semnani D, Hasani H, Behtaj S & Ghorbani E, *Fibres Text East Eur,* 3(2011) 55.