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Review article Innovative concepts in reactive dyeing of cotton using sea water

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Abstract

The article reviews some newly developed concepts in reactive dyeing of cotton using sea water. Attempts have been made using sea water as a substitute for dyeing of cotton with reactive dyes of various shades and extents of salt contents. A comparative investigation has been conducted using hot brand reactive dye with normal water, RO water and sea water (with and without salt). In another study, sea water has been used as dyeing medium for dyeing of cotton textiles with reactive dyes. Sea water has been treated with calcium oxide/sodium carbonate to remove sodium and calcium ions. The results indicate that addition of specified concentration of sodium chloride is necessary for increase in dye exhaustion in pre-treated sea water instead of a higher concentration (3 times the other) of sodium chloride as required in the conventional dyeing method.

Key words: Cotton, Reactive dyeing, Sea water, Electrolyte load, Fastness rating, Water conservation.

1 Introduction

Seawater has a salinity of ~35,000 ppm, equivalent to 35 gram of salt per liter (or kilogram) of water. There are two ways for origin of seawater, one is from rain water which is staged for many years and the other is from oceans and rivers. On average, seawater in the oceans has a salinity of about ~3.5% (35 g/L) This means that every kilogram (roughly one liter by volume) of seawater has approximately 35g of dissolved salts [predominantly sodium (Na^+) and chloride (Cl^-) ions. Average density at the surface is 1.025 kg/L. Seawater is denser than both ground water and pure water density 1.0 kg/L at 4 °C (39 °F)] because the dissolved salts increase the mass by a larger proportion than the volume. The freezing point of seawater decreases as salt concentration increases and at a typical salinity, it freezes at about −2 °C (28 °F). Sea water would serve as an alternate source of water in order to save a large quantity of normal water. It would be of great concern where normal water rich in salt content could be avoided, thereby reducing the cost of salt involved [1]. Hence, this indicates the possibility of establishing new processing mills, especially dyeing mills in the sea shores, which will further claim the advantage of less severe effluent water treatment [2].

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 [3].

2 Sea water in reactive dyeing of cotton

When the mills are in the sea shore, the tertiary treatment of effluent water for removing the salt content could be eliminated. In the primary and secondary treatments, the objectionable color, BOD and COD values would be greatly reduced to the acceptable level [4]. In the tertiary treatment like reverse osmosis process, the salt is removed from the effluent to reduce the total dissolved solids to the acceptable level. But if the effluent is to be discharged in sea, the salt content need not be removed [5]. Hence, costly reverse osmosis process and its installation in the mill could be avoided. This, in turn, saves a lot of investment in industry and also could be considered safe as far as pollution control board's norms are concerned [6]. The major issue of effluent treatment which is found to be very costlier in processing industries could be reduced to a greater extent using this alternative method. This method not only reduces the water scarcity, but also reduces the other problems of effluent treatment. Bifunctional dyes also require a definite quantity of salt which is less than that of hot brand mono functional dyes [7]. In this context, the attempts were made in dyeing, and trials have been taken up with latest classes of reactive dyes using sea water to optimize the level of salt required to be added for these dyeing using the same procedure as being used for normal water, except for the quantity of salt addition [8,9]7,8. If the dyeing obtained from sea water is at par in quality with that of normal water, several advantages could be claimed. Hence, in this research work, dyeing using ground water, RO water and sea water with different shade classes of reactive dyes has been carried out. The dyed fabrics have been tested for quality parameters, such as color strength; color fastness to washing; color fastness to dry and wet rubbing; color fastness to perspiration; color fastness to light; and tensile strength.

It is inferred that the sea water can be used as an alternative source for dyeing as it produces excellent results in all aspects. The dyed samples using sea water possess similar color strength as compared to the dyed samples with ground water and RO water [10]. The exhaustion and fixation are found better in case of sea water dyeing. The color fastness properties, in general, are good for sea water dyeing; in some cases the ratings are comparable and in most case the ratings are similar compared to the ground water and RO water dyeing. The perspiration fastness ratings are also found to be similar for sea water dyeing. The wash fastness ratings in terms of change of color and staining on white are found to be good for sea water dyeing. When tensile strength properties are compared, the sea water dyed material does not degrade much compared, to the ground water dyed materials. Therefore, it is inferred that the severity is less in the case of sea water dyeing. Hence, there is a huge potential of using the sea shore area for establishing new processing mills.

3 Use of pretreated sea water

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 [11]. 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 [12]. 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, 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 [13]. 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 [14].

In the present study, it is hypothesized that why the sea water which contains 25 -37 g/L salts cannot be 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 dyeing6 and dyeing of cotton with hot brand reactive dye [15-18]. 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.

Cotton materials require water and huge amount of salt for dyeing with anionic dyes such as reactive and 0direct 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 [19]. 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.

4 Conclusion

It is inferred that the exhaustion and fixation of the dye are better in case of sea water dyeing. The wash, rub and perspiration fastness are good for sea water dyeing and in some cases the ratings are comparable and in most case the ratings are similar to that of the ground water and RO water dyeing. 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.

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