An innovative concept in the effective utilization of sea water for dyeing of textile materials

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Abstract
Water is the ultimate and mostly used media during textile materials processing, especially in colouration. This study investigated the possibilities of using seawater for cotton and polyester fabrics dyeing. Single jersey fabrics made of 100 percent cotton and polyester were dyed using a standard recipe and two separate water source as dyeing mediums. It has been focused on the assessment of colour fastness to wash, perspiration, saliva, rubbing, water, light and colour difference value due to compare the efficiency of dyeing media. The results revealed that the cotton fabric dyed with seawater showed lighter shade than that of ground water sample. But for polyester fabric darker shade was obtained compared to ground water. The cotton sample dyed with sea water carried about 15% higher colour strength than ground water dyed sample but for polyester it was very negligible, only 3%. Moreover, the results of colour fastness to wash, perspiration, saliva, rubbing, water and light for seawater dyed samples of cotton and polyester were shown satisfactory outcomes having the grading of 4–5 in most of the cases. This exploration established that commercial dyeing processes were robust and can be practically transferable into the seawater medium for cotton and polyester fabrics.

Keywords: Colour fastness, Ground water, Seawater, Water consumption, Colour difference.

I. Introduction

About 71% of earth's surface is ornamented with water where only 1% of this water is fresh and suitable for humans for drinking [1]. Actually, seas and oceans consume about 96.5% of water on Earth where ground water consumes 1.7% and 1.7% of the water is in the ice caps. So, about 2.5% of this water is fresh, where 98.8% of that water is in ice caps or in ground layer [2, 3]. From this scenery, it is clearly visible that there is a huge scarcity of fresh water all over the world. About all of the textile industries in Bangladesh using the underground water for textile wet processing due to its ready availability and cost-effectiveness. Obviously, it consumes a large quantity of water for this purpose because there is a series of operation involved with textile wet processing e.g., scouring, bleaching, dyeing and finishing. So, day by day the ground water level is decreasing rapidly. These types of activities may cause serious threat for our next generation [4, 5]. Nearly, 70–150 L of fresh water is required to dye 1 kg of cotton fabric [6, 7]. Consequently, the water consumption of a dyeing industry having capacity 8 tons/day is about 880000 L per day. So, it is a high time to look forward in order to use surface water for industrial purposes. The surface water may come from rivers, canals and seas. Due to its availability and cheapness, water has been used almost in textile processing as medium. Seawater would serve as an alternative source of water in order to minimize the load of using ground water. But salinity is the main reason to use seawater for industrial purposes. Seawater has salinity of 3.5% as well as denser than ground water due to presence of dissolved salts [8]. So, it would be supportive for the salt involvement cost during the dyeing process because huge amounts of salt are required for dyeing treatment. Seawater may be one of the great opportunities and alternative resources for the dyeing sector as a dyeing medium. The advantages of seawater over the normal ground water are - it's low cost, easily available near the coastal area. For this reason, as a dyeing medium, seawater would capture an important position beside the groundwater. For dyeing of cotton goods reactive dyes are so much suitable and extensively used and whereas dyeing of polyester goods disperse dyes are used in the textile dyeing
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industries due to have good colour fastness properties and a wide range of shade can be achieved by these dyes [9,10, 11]. Because, the fastness properties of cotton knitted fabric are affected by its shade percentages [12]. Studies found that while introducing of seawater as a reactive dyeing media, the dyed fabrics give comparatively lighter shade along with nosignificant difference for various colour fastness parameter compared to ground water dyed sample. As the parameters of sea water dyed samples remain unchanged, so it may encourage the use of sea water as reactive dyeing media on a larger scale [12, 13, 14].

A few researchers have worked on seawater for cotton colouration [8,14, 15, 16]. Unfortunately, all of them have been analyzed only for cotton fabric. No work has been identified for polyester fabric colouration with seawater including comparison of cotton colouration. In this work, the aim was to utilize the seawater in dyeing of cotton and polyester fabric as well as compare the performances of dyed fabric using ground water. Colour fastness to wash, perspiration, saliva, rubbing, water and light of dyed samples were reported to evaluate the performance. The colour strength and colour coordinates were also investigated.

II. Colour fastness to wash

Colour fastness to wash was introduced to evaluate the colour change of produced sample as well as the colour staining. The outcomes of colour fastness to wash for dyed samples have been determined. The results of colour fastness to wash of samples were very good to excellent. CGW, CSW, PGW and PSW were shown to change in colour due to wash and results indicate the good to excellent grade. But considerably staining has ascended on nylon for PGW. Simultaneously, slightly staining was observed on all multi-fibre except polyester for PGW and PSW. However, cotton samples dyed with sea and groundwater exhibited better wash fastness grade in staining compared to polyester samples dyed with sea and ground water but the same scenario was noticed for all specimens in colour change. These seawater dyed sample gives a distinctly higher rating because the fixation of dye molecules is better in this medium. For cotton fabric, the reason might lie in ionic phenomenon between dye and fibre. Basically nucleophilic CGW, CSW, PGW and PSW were shown to change in colour due to wash and results indicate the good to excellent grade.

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Colour fastness to perspiration (acid/alkali)

The evaluation of fastness to perspiration has been determined. The overall results of colour fastness to perspiration of samples in both alkaline and acid medium were very good to excellent. It is necessary to evaluate the rating of perspiration fastness as perspiration is an agency that can destroy the colour from the fabric surface. All the samples were shown in the same rating (good to excellent) in case of change in colour as well as staining excluding PGW due to alkaline perspiration. Slightly colour change occurred only for PGW. On the other hand, for acid perspiration nosamples were shown different grades and indicated well to excellent grade (4–5). The reason for higher perspiration rating for all dyed material is that the dyes have excellent withstands capacity against the activity of acid and alkali perspiration.

Colour fastness to saliva

The colour fastness to saliva has been determined. The overall results of colour fastness to saliva of samples were very good to excellent. No changes appeared for CSW and PSW due to the introduction of seawater instead of ground water. The all dyed specimens i.e. CGW, CSW, PGW, and PSW were shown good to excellent grades in colour change and staining against saliva. The reactivity level of dyemolecules with fabrics is higher than that of saliva that’s why all dyed samples showed higher saliva rating.

Colour fastness to rubbing and light

The grade of colour fastness to rubbing and light of the samples have been determined. The overall results of colour fastness to rubbing of samples are very good to excellent. Wetchanging properties are shown lower than dry rubbing. CGW and CSW showed excellent dry rubbing and good wet rubbing properties whereas PGW and PSW were same in dry and wet rubbing. However, both cotton and polyester samples dyed with seawater were indifferent in grading compared to the samples dyed with ground water. It has been inferred that the rub fastness ratings are equal for seawater dyed material compared to ground water dyed fabrics.
This might be happened due the higher dye fixation into the fibre through dye-fibre strong bond formation. In water, reactive dyes and cellulose fibres both are electronegative. So, there is an electrostatic repulsion between them. To minimize this repulsion, a dyeing promoter must be used. During cotton dyeing with reactive dyes, different salt serves as a dyeing promoter. The positive charge of salt shows electrostatic attraction to cellulose fibres and adsorbed by cellulose fibres. Thus, the presence of salt increases the exhaustion of dyes to the cellulose fibre and followed by enhance the fixation rate of dyes into the fibre [29]. It has been found that seawater contains sodium, magnesium, calcium and potassium ions [18, 19]. These ions are also act as the positive site as like as the positive site of salt. Therefore, using seawater along with Glubers salt facilitates the exhaustion rate of dyes into the cellulose fibres and gives better rubbing fastness.

In presence of light, textile colourants absorb a certain wavelength and then prone to some fading. So, the rating of colour fastness to light is also a major concern. Regarding light fastness, the sample orders were found as CGW < CSW < PGW/PSW. So, this order proclaimed that seawater dyed cotton fabric displayed higher light fastness values than that of ground water dyed sample. Significant fading occurred for CGW during light exposure. But the value was unchanged for polyester dyed samples in both sea and ground water medium (see in Table 16). Thereason for the improvement of light fastness in case of seawater dyed cotton fabric is that seawater contains comparatively more metal components which may present on the surface of the dyed sample and interfere with the fading during exposure to light [21].

3.5. Colour fastness to water

Table 17 illustrates the grading of colour fastness to water. The overall results of all samples were shown very good to excellent. In case of colour fastness to water, no samples were in different grades for colour change and staining. Good to excellent grade was obtained by applying both seawater and ground water as dyeing medium simultaneously (see in Table 17).

3.6. Measurement of colour co-ordinates

The colour coordinates of the dyed samples were evaluated by spectrophotometer using D65, TL83 illuminant and 10 observer settings considering the seawater dyed samples as standard and others as sample batches. The colour co-ordinate values of tested samples are given in Table 18.

Table 18 depicted that the total colour difference value is out of range, i.e., more than 1 for cotton dyed fabrics. Hence the result of colour matching is rejected. On the other hand, the total colour difference values in the range of 1 i.e., the result is accepted for colour matching for polyester dyed fabrics with seawater medium. It has been also observed that for the same recipe in cotton fabrics dyeing, dyes absorption is less for seawater dyed samples than ground water dyed samples whereas polyester fabrics absorb more dyes in seawater medium and shade difference with ground water treated fabric is in the acceptable range. The physical appearance of CGW, CSW, PGW and PSW are illustrated in Figure 4.

The dyeing behavior of cotton fabric completely depends on the interaction between fibre and dye molecules. So, the medium of dyeing plays a vital role during cotton dyeing as a medium influences the movement of reactive dyes. It is well known that seawater contains comparatively more metal and the hardness of seawater is also very high due to the presence of these metals. The hardness of seawater is the major factor that influences the dyeing characteristics of cotton fabric, and may lead to poor shade and poor quality of dyed samples.

On the other hand, there is no chemical interaction between dye and fibre for polyester fabric dyeing like cotton. Disperse dyes are physically bound into polyester fibre which is facilitated by free volume of polymer molecules by means of high temperature. So, the dyeing medium has a little influence on the characteristics of dyeing.

3.7. Colour strength (K/S)

Colour strength of all dyed samples was measured by reflectancespectrophotometer using Kubelka-Munk theory of reflectance. Figure 5 illustrates the colour strength of dyed samples.

The order of colour strength values for cotton samples were found as CGW < CSW and for polyester PGW < PSW. The K/S value of CGW, CSW, PGW, and PSW were 7.9, 9.1, 18.1 and 18.7 respectively. Colour strength was increased for both cotton and polyester dyed specimens while seawater was used as medium. The maximum colour strength has been noticed at 560 nm for cotton fabrics and at 520 nm for polyester fabrics. The colour strength was increased 15.19% for cotton while dyed fabrics as seawater medium compared with dyed samples as ground water. On the other hand, the colour strength was increased 3.31% for polyester while dyed fabrics as seawater medium compared with dyed samples as ground water. So, colour yield significantly increased for seawater dyed materials for cotton fabric rather than polyester (see in Figure 5). Seawater contains sodium, magnesium, calcium and potassium ions [18, 19]. These ions minimize the electrostatic charge between dyes and fibre.
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Thus, they serve as a dyeing promoter. So, the presence of ions increases the exhaustion of dyes onto the cellulose fibre and followed by enhancethe fixation rate of dyes into the fibre [29,30]. Finally, gives the shade with higher colour strength.

III. Conclusions

Cotton and polyester are the most common and popular fabric. So, the dyeing of cotton and polyester consume huge amount of ground water and thereby the searching of an alternative water source is the demand of the time. This project describes the influence of seawater on cotton and polyester fabric dyeing with reactive dyes and disperses dyes respectively. The result shows that seawater dyed cotton fabric with 2% owf of reactive dyes is lighter than ground water dyed samples whereas seawater dyed polyester fabric with 1% owf of disperse dyes are darker than ground water dyed samples with an acceptable range. It is visualized that washt, perspiration, saliva, rubbing, water, light fastness is very good for both fabric samples. This exploration established that commercial dyeing processes were robust and can be practically transferable into these seawater medium.

References

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