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# Rain, River, and Sea Water as Alternatives to Ground Water in the Fabric Coloration Industry

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**Abstract**
High consumption of water has resulted in a worldwide water disaster. The bulk of Bangladesh's textile industry is still not following the circular economy at the needed level. During the past two decades, as production and demand increased, so did the sector's usage of resources and energy to meet the objective of generating foreign currency, making it very difficult to achieve sustainability goals by 2030. This work investigates the possibilities of environmentally friendly alternative water sources in the coloration of cotton (cellulosic) and polyester (synthetic) fabrics. The standard recipe for three different shades % focused on their color fastness to rubbing, wash, and perspiration. Compared with groundwater or conventional water sources by the Bangladeshi industry, the result is amazing for sea, river, and rainwater. Though cotton fabrics show very poor color fastness properties 2-3 in most cases, polyester showed excellent results 4-5. It has also been discovered that in all circumstances, the same formula generates around 40-60% of the same qualities as traditional coloration with no additional adjustments to the recipe. This investigation determined that industrial dyeing processes may be realistically transferred into different water mediums to reduce groundwater use and achieve responsible consumption and sustainable development goals (SDG 12).

***Keywords*:** Water, Consumption, Fabrics, Coloration, Water level, Sustainability, Reduction, Bangladesh.

## Introduction

The textile sector, concentrated in informal industrial clusters, leads to overexploitation of groundwater, water pollution, and energy supply difficulties. Regardless of environmental efforts, using non-biodegradable colors and harmful chemicals pollutes water and land. Dhaka, home to more than 70% of Bangladesh's textile industries, is dealing with water shortages and pollution, which has been compounded by economic expansion and worldwide textile demand. Excessive use of ground freshwater raises worries about the availability of safe drinking water, and Dhaka's reliance on groundwater threatens environmental damage and biodiversity. The industry's large daily use of 4.1 billion liters of groundwater necessitates study into other sources such as rain, rivers, and seawater to continue expansion while minimizing environmental damage.

Bangladesh will have 165.16 million people in 2022 and is anticipated to increase by 6.9% in economic and human growth as per the World Bank report (The World Bank, 2022). As the economy expanded, so did the standard of life, literacy, and food. The clothing or ready-made garment (RMG) business employs 4 million people, with women accounting for 80% of the workforce. RMG represents over 90% of total exports. In 2015, Bangladesh accounted for 5.1% of the global garment export market (Sagris and Abbot, 2015). The RMG industry's export share has increased from 75.14% in 2000-2001 to 81.16% in 2020-2021, and this trend is expected to continue, with a 10% increase over the preceding year (BGMEA, 2021). Bangladesh was predicted to have many textile wet processing plants. Because of chemical consumption, wastewater production and outflow, and water and steam generation, wet dyeing and finishing equipment have the industry's highest environmental impact. The worldwide demand for fresh water is expected to grow by 20-30% by 2050, adding to the list of nations facing freshwater scarcity (Ercin and Hoekstra, 2013).

Most textile units are in informal, diverse, under-serviced industrial clusters, where small and medium industrial units from various sectors coexist alongside residential units. Consequently, the environmental implications of WDF textile units are confined to groundwater overexploitation, water pollution, and energy supply (Bhattacharya, 2019). Chemicals are often employed in the cleaning and dyeing of textiles. Heavy metals pollute textile effluents (Bhardwaj, 2021). Non-biodegradable petroleum-based dyes and hazardous chemicals that attach colors to fabrics exacerbate the problem. Textile dyeing accounts for 20% of global water contamination caused by synthetic colors. Bangladesh's textile sector is the most polluting. Dyeing and finishing, as important drivers of pollution in the fashion supply chain, are to blame (Dey and Islam, 2012). These elements enacted stringent legislation. Companies are developing greener textile dyeing techniques, which still need to be at the satisfactory level environmentalists claim because of limitations and closures (Mogilireddy, 2018).

In Bangladesh, waterborne infections account for up to two-thirds of all illnesses. Water pollution is a key concern in the textile industry; thus, laws and effluent limits have been tightened. The standards for dense solids, pH, BOD, COD, and heavy metals still need to be fulfilled (Rahman and Haque, 2011). Encouragement of automation and equipment upgrades and effective water reuse would aid the textile manufacturing sector in optimizing operations (Sandin and Peters, 2018). To stay up with industrial changes, textile wastewater treatment necessitates cross-sectoral learning. Although the issue has been handled, awareness and long-term coordination remain essential.

Textile manufacturing and disposal are crucial environmental processes in one of the world's most polluting industries. One of their most serious problems is excessive water use (Jia et al., 2020). Due to being the best solvent for coloring textiles and in combination with other substances (Allwood et al. 2006), toxic emissions are caused by wet treatment procedures. These pollute not just the water but also the land, the ecology, and the health of the people (Li and Hu, 2012). Water is severely contaminated in terms of ethics, health, and the environment, and wastewater treatment by effluent treatment plants adds to the expenses (Shirvanimoghaddam et al., 2020).

Dhaka is home to over 70% of the country's washing, dyeing, and finishing (WDF) textile factories, with the balance in Mymensingh and Chittagong. WDF textile mills in Dhaka and Chittagong are near water bodies and have easy access to services, infrastructure, and markets (DWASA 2021). As Bangladesh's economic and human growth drives up demand and exports to the rest of the globe, proper water risk management is becoming more important because it is a main natural resource utilized extensively in the textile industry. Less monsoon rain might aggravate Bangladesh's water shortage and drought. Textile and home applications may have to compete for water as the population grows and diets change. It would exacerbate water scarcity and poor water quality. Abundant research on different aspects of textile waste recycling and repurposing has been undertaken in many countries. In today's environmentally concerned world, reusing and recycling are excellent methods of recovering resources and getting the most out of bits and pieces (Li and Hu, 2012). However, recycling and recovering natural resources such as water present many financial, technological, educational, legal, infrastructural, and cost-effective issues (Handoko and Pah, 2019). It may also vary depending on parameters such as recycling time and chemicals employed throughout the procedure. In textile production, for example, around 8000 chemicals are utilized. Recovery of fresh water before disposal into the environment incurs additional costs (Khan and Islam 2015).

As fresh drinking water is one of the most necessities, its usage in manufacturing facilities, particularly in the textile industry in Bangladesh, and hence pollution, has researchers concerned about the future supply of clean drinking water. Despite the different approaches to wastewater treatment, the continuing use of groundwater in these businesses is expanding daily with the worldwide demand for textile products. Significant environmental and economic benefits may be obtained by limiting the excessive use of ground freshwater (Haque 2018).

Increased worldwide demand for RMG encourages careless groundwater use, shrinking by 3 meters per year. The protection of groundwater is critical for environmental pollution and the existence of other species. Dhaka requires 2.5 billion liters of water daily, with subterranean aquifers providing 78%. Dhaka WASA now has 923 deep tube wells, a 4% increase over 2018. Private deep tube wells also supply water. Rivers and lakes cover 22% of the land. Dhaka's groundwater level has plummeted due to its reliance on it. Every year, Dhaka loses 2-3 meters of water (DWASA 2021).

If demand grows at the expected pace, the rate might reach 3.9 meters per year this year and 5.1 meters by 2030. If nothing is done, groundwater levels will drop to 100 to 150 meters by 2050 (Islam 2021). According to International Finance Corporation (IFC) research, Bangladesh's textile industry consumes 4.1 billion liters of groundwater daily (DBL 2021; Chen 2021). Despite ongoing attempts to reduce it, the textile sector consumes significant energy, resources, and waste.

However, this research aims to see whether rain, river, and seawater are feasible alternatives to heavy groundwater use in the Bangladeshi textile industry. It has been revealed that, with proper management, these water sources might be utilized by industry to avert desertification of green areas while still sustaining agricultural growth. This compares fabrics dyed with seawater, river water (Karnaphuli and Padma rivers), and rainwater to those dyed with groundwater and rates color depth and rubbing and washing fastness for various shade percentages.

## Materials and Methods

### Materials

Sample water from the sea beach of Chittagong, Karnaphuli River, Padma River, rainwater, and groundwater from 1000 meters were collected. After microfiltration, water from these different sources was used to dye 100% cotton and 100% polyester knitted fabrics with similar recipes of three different color shades. The fabrics were dried and relaxed for 24 hours at room temperature. Drimarin Red X-CBN reactive dye, Terasil Red WW-3BS disperse dye, sequestering agent, leveling agent, wetting agent, dispersing agent, acetic acid (CH3COOH), salt, soda, sample water from sea, river, rain, and ground for dyeing were used. For washing fastness testing Na-parborate and Na-EC phosphate were used, and for perspiration fastness testing L-Histidine monohydrochloride, NaCl, and di-sodium hydrogenophospate.

### Methods

Using electric balance, 5 gm of sample fabrics of 100% cotton and 8 gm of 100% polyester fabrics were taken first. Dyeing was performed using 1%, 2%, and 3% shade for cotton fabric with Drimarin Red X-CBN reactive dye. On the contrary, dyeing was performed using 0.625%, 1.25%, and 1.825% shade for polyester fabric with Terasil Red WW-3BS disperse dye. In these cases, all recipes were prepared with the respective sample water to know the difference between using water during the dyeing procedure. After dyeing, the color fastness properties of the dyed fabric were analyzed. Finally, the variation of fastness properties compared with the groundwater using a rating scale and graphical method.

**Standards and Instruments**

The specific tests were ISO 105-X12, color fastness to rubbing (105-X12 2016); ISO 105-C02, color fastness to washing (105-C02 1989), ISO 105- E04, and color fastness to perspiration (105-E04 2013). A sample dyeing machine, rubbing tester, light box, dryer, and spectrophotometer (X-rite, USA) were used in this experiment.

## Results and Discussions

All fabric samples are tested using a spectrophotometer with D65, TL84, and F02 illuminants, with the samples colored with groundwater representing the standard. The respected elliptical tolerance of visual difference (CMC DE), color strength (%), and metamerism (msTL84 and F02) are investigated to determine the acceptable conditions for the coloration of cotton and polyester fabrics with alternative water sources.

**Color co-ordinates, metamerism, and strength properties**

Table 1: Shades obtained by the different water resources as the medium of coloration of 100% cotton and 100% polyester fabrics.

| *Cotton* | | | | *Polyester* | | | |
|---|---|---|---|---|---|---|---|
| Medium | *Shade%* 1% | 2% | 3% | *Medium* | *Shade%* 0.63% | 1.25% | 1.83% |
| *CG* | | | | *PG* | | | |
| *CRa* | | | | *PRa* | | | |
| *CRiK* | | | | *PRiK* | | | |
| *CRiP* | | | | *PRiP* | | | |
| *CSe* | | | | *PSe* | | | |
| *CSeW* | | | | | | | |

**Here, CG, CRa, CRiK, CRiP, CSe, CSeW represents the medium for coloration of 100% cotton fabric using groundwater, rainwater, Karnaphuli River water, Padma River water, sea water with recipe salt and without recipe salt respectively. Again, PG, PRa, PRiK, PRiP, PSe represents the medium for coloration of 100% polyester fabric using groundwater, rainwater, Karnaphuli River water, Padma River water, sea water with recipe salt respectively.*

**For cotton fabrics data color results**

Table 2: Data color result by Spectrophotometer for cotton fabrics.

| *Fabrics Code** | *Illuminants (10 Deg)* | *L** | *a** | *b** | *C** | *H** | *ΔE** | *Metamerism* | *CMC DE* | *Strength* |
|---|---|---|---|---|---|---|---|---|---|---|
| *CRa1* | *D65* | 0.11 | -2.65 | -1.19 | -2.31 | -1.78 | 2.91 | | 1.25 | 92.79% |
| | *msTL84* | -0.11 | -2.19 | -1.53 | -1.91 | -1.86 | 2.67 | 0.61 | | |
| | *F02* | 0.28 | -1.92 | -0.83 | -1.49 | -1.47 | 2.11 | 0.83 | | |
| *CRa2* | *D65* | -2.70 | 1.32 | 1.70 | 1.02 | 1.89 | 3.45 | | 1.65 | 130.99% |
| | *msTL84* | -2.55 | 0.63 | 1.94 | 0.46 | 1.98 | 3.26 | 0.75 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *F02* | -2.88 | 0.90 | 1.36 | 0.46 | 1.56 | 3.31 | 0.57 | | |
| *CRa3* | *D65* | -0.69 | 0.63 | 0.99 | 0.52 | 1.05 | 1.36 | | 0.67 | 109.27% |
| | *msTL84* | -0.60 | 0.39 | 1.11 | 0.36 | 1.12 | 1.32 | 0.29 | | |
| | *F02* | -0.75 | 0.46 | 0.85 | 0.24 | 0.94 | 1.22 | 0.23 | | |
| *CRiK1* | *D65* | 0.19 | -0.59 | -0.33 | -0.50 | -0.45 | 0.70 | | 0.31 | 96.83% |
| | *msTL84* | 0.11 | -0.55 | -0.46 | -0.47 | -0.54 | 0.72 | 0.16 | | |
| | *F02* | 0.18 | -0.49 | -0.35 | -0.34 | -0.50 | 0.63 | 0.10 | | |
| *CRiP1* | *D65* | 4.00 | -3.65 | -1.57 | -3.17 | -2.39 | 5.64 | | 2.50 | 67.72% |
| | *msTL84* | 3.64 | -2.73 | -2.16 | 2.33 | -2.59 | 5.03 | 1.15 | | |
| | *F02* | 4.19 | -2.71 | -1.17 | -2.09 | -2.08 | 5.13 | 1.04 | | |
| *CRiK2* | *D65* | -1.51 | 1.18 | 1.00 | 0.99 | 1.19 | 2.16 | | 1.01 | 118.77% |
| | *msTL84* | -1.37 | 0.77 | 1.23 | 0.66 | 1.29 | 1.99 | 0.48 | | |
| | *F02* | -1.61 | 0.88 | 0.81 | 0.60 | 1.04 | 2.01 | 0.37 | | |
| *CRiP2* | *D65* | 2.87 | -1.43 | -1.32 | -1.15 | -1.56 | 3.47 | | 1.64 | 77.66% |
| | *msTL84* | 2.74 | -0.70 | -1.52 | -0.52 | -1.59 | 3.21 | 0.76 | | |
| | *F02* | 3.04 | -0.94 | -1.00 | -0.56 | -1.25 | 3.33 | 0.60 | | |
| *CRiK3* | *D65* | -0.67 | 0.34 | 0.66 | 0.26 | 0.70 | 1.00 | | 0.50 | 108.00% |
| | *msTL84* | -0.63 | 0.15 | 0.71 | 0.13 | 0.71 | 0.96 | 0.19 | | |
| | *F02* | -0.70 | 0.23 | 0.56 | 0.09 | 0.60 | 0.93 | 0.16 | | |
| *CRiP3* | *D65* | 2.83 | -0.22 | -1.84 | 0.03 | -1.86 | 3.39 | | 1.73 | 78.44% |
| | *msTL84* | 2.80 | 0.43 | -1.91 | 0.53 | -1.88 | 3.41 | 0.66 | | |
| | *F02* | 3.01 | 0.04 | -1.55 | 0.46 | -1.48 | 3.39 | 0.43 | | |
| *CSe1* | *D65* | -0.92 | 0.55 | 0.35 | 0.47 | 0.46 | 1.13 | | 0.51 | 108.69% |
| | *msTL84* | -0.87 | 0.27 | 0.45 | 0.20 | 0.49 | 1.02 | 0.31 | | |
| | *F02* | -1.01 | 0.34 | 0.22 | 0.25 | 0.32 | 1.09 | 0.26 | | |
| *CSeW1* | *D65* | -0.02 | 1.11 | 0.29 | 1.02 | 0.52 | 1.53 | | 0.66 | 112.70% |
| | *msTL84* | -0.89 | 0.84 | 0.50 | 0.76 | 0.61 | 1.32 | 0.37 | | |
| | *F02* | -1.14 | 0.87 | 0.07 | 0.76 | 0.36 | 1.43 | 0.35 | | |
| *CSe2* | *D65* | -2.99 | 0.37 | 1.41 | 0.13 | 1.46 | 3.33 | | 1.61 | 129.13% |
| | *msTL84* | -2.94 | -0.22 | 1.50 | -0.36 | 1.48 | 3.31 | 0.61 | | |
| | *F02* | -3.22 | 0.13 | 1.02 | -0.18 | 1.01 | 3.38 | 0.52 | | |
| *CSeW2* | *D65* | -2.89 | 1.13 | 1.82 | 0.82 | 1.98 | 3.60 | | 1.74 | 132.65% |
| | *msTL84* | -2.74 | 0.48 | 2.08 | 0.30 | 2.11 | 3.47 | 0.72 | | |
| | *F02* | -3.13 | 0.76 | 1.42 | 0.31 | 1.59 | 3.52 | 0.60 | | |
| *CSe3* | *D65* | 2.47 | 0.15 | -1.88 | 0.40 | -1.84 | 3.11 | | 1.58 | 82.02% |
| | *msTL84* | 2.52 | 0.72 | -1.84 | 0.82 | -1.80 | 3.20 | 0.58 | | |
| | *F02* | 2.57 | 0.39 | -1.77 | 0.85 | -1.60 | 3.15 | 0.29 | | |
| *CSeW3* | *D65* | 2.88 | 0.28 | -1.71 | 0.50 | -1.65 | 3.36 | | 1.70 | 79.69% |
| | *msTL84* | 2.95 | 0.92 | -1.60 | 1.00 | -1.55 | 3.48 | 0.65 | | |
| | *F02* | 3.03 | 0.50 | -1.48 | 0.87 | -1.29 | 3.41 | 0.35 | | |

**CRa1, CRa2, and CRa3-1%, 2%, and 3% shade with rain water; CRiK1, CRiK2, and CRiK3-1%, 2%, and 3% shade with Karnaphuli River water, CRiP1, CRiP2, and CRiP3-1%, 2%, and 3% shade with Padma River water, CSe1, CSe2, and CSe3-1%, 2%, and 3% shade with sea water with recipe salt; and CSeW1, CSeW2, and CSeW3-1%, 2%, and 3% shade with sea water without recipe salt respectively for cotton fabrics. Again, color co-ordinates L-lightness, a, b-parameters for color difference, C-Saturation, H-Tone, and ΔE-color difference.*

Color strength of cotton fabrics dyed with rainwater at 1% shade was 92.79% with CMC DE value 1.25 and Metamerism 0.61 for msTL84 light source and 0.83 for F02 light source, respectively (Table 2). Fabrics dyed with rainwater at 2% shade color strength have a CMC DE value of 1.65 and a Metamerism of 0.75 for msTL84 light source and 0.57 for F02 light source, respectively. On the other hand, dyeing with rainwater at 3% shade yielded 109.27% color strength with CMC DE value 0.67 and Metamerism 0.29 for the msTL84 light source and 0.23 for the F02 light source, respectively.

The color strength of cotton fabrics dyed with Karnaphuli River water at 1% shadow (Table 2) was 96.83% with a CMC DE value of 0.31 and a Metamerism of 0.16 for the msTL84 light source and 0.10 for the F02 light source, respectively. Cotton fabrics dyed with Karnaphuli River water at 2% shade had a color strength of 118.77%, a CMC DE value of 1.01, and a Metamerism of 0.48 for the msTL84 light source and 0.37 for the F02 light source, respectively. Color strength was 108.00% for fabrics dyed with Karnaphuli River water at 3% shade, with CMC DE value 0.50 and Metamerism 0.19 for the msTL84 light source and 0.16 for the F02 light source, respectively.

The color strength of cotton fabrics dyed with Padma River water at 1% shade (Table 2) was 67.72% with a CMC DE value of 2.50 and a Metamerism of 1.15 for the msTL84 light source and 1.04 for the F02 light source, respectively. Cotton fabrics dyed with Padma River water at 2% shade had a color strength of 77.66%, a CMC DE value of 1.64, and a Metamerism of 0.76 for the msTL84 light source and 0.60 for the F02 light source, respectively. Color strength was 78.44% for cotton fabrics dyed with Padma River water at 3% shade, with a CMC DE value of 1.73 and Metamerism 0.66 for the msTL84 light source and 0.43 for the F02 light source, respectively.

The color strength of cotton fabrics dyed with seawater and recipe salt at 1% shade (Table 2) was 108.69% with a CMC DE value of 0.51 and a Metamerism of 0.31 for the msTL84 light source and 0.26 for the F02 light source, respectively. Cotton fabrics dyed with seawater at 2% shade exhibited a color strength of 129.13%, a CMC DE value of 1.61, and a Metamerism of 0.61 for the msTL84 light source and 0.52 for the F02 light source, respectively. And, dyed with seawater at 3% shade, the color strength was 82.02% with a CMC DE value of 1.58 and a Metamerism of 0.58 for the msTL84 light source and 0.29 for the F02 light source, respectively.

The color strength of cotton fabrics dyed with sea water without extra salt at 1% shade (Table 2) was 112.70% with a CMC DE value of 0.66 and a Metamerism of 0.37 for the msTL84 light source and 0.35 for the F02 light source, respectively. Cotton fabrics dyed with sea water without adding salt at 2% shade had a color strength of 132.65%, a CMC DE value of 1.74, and a Metamerism of 0.72 for the msTL84 light source and 0.62 for the F02 light source, respectively. Furthermore, cotton fabrics dyed with sea water without salt at 3% shade showed 79.69% color strength with a CMC DE value of 1.70 and Metamerism 0.65 for the msTL84 light source and 0.35 for the F02 light source.

Thus, the coloration of cotton fabric for dark shade (3%) with rain and river water (Karnaphuli) is acceptable, while for light shade (1%), River and seawater are within the acceptable limit concerning groundwater. If metamerism is considered, Padma River water and seawater (without additional recipe salt) for medium to dark shade (2-3%) can be accepted as per the result.

**For polyester fabrics data color results**

Table 3: Data color result by Spectrophotometer for polyester fabrics

| *Fabrics Code** | *Illuminants (10 Deg)* | *L** | *a** | *b** | *C** | *H** | *ΔE** | *Metamerism* | *CMC DE* | *Strength* |
|---|---|---|---|---|---|---|---|---|---|---|
| *PRa1* | *D65* | -0.95 | 1.48 | 1.11 | 1.47 | 1.13 | 2.08 | | 0.95 | 111.78% |
| | *msTL84* | -0.79 | 1.29 | 1.34 | 1.34 | 1.29 | 2.02 | 0.34 | | |
| | *F02* | -1.03 | 1.06 | 0.89 | 1.03 | 0.93 | 1.73 | 0.48 | | |
| *PRa2* | *D65* | -0.68 | 0.71 | 0.68 | 0.79 | 0.59 | 1.20 | | 0.55 | 108.81% |
| | *msTL84* | 0.62 | 0.53 | 0.75 | 0.67 | 0.63 | 1.11 | 0.20 | | |
| | *F02* | 0.78 | 0.54 | 0.45 | 0.59 | 0.37 | 1.05 | 0.31 | | |
| *PRa3* | *D65* | -1.11 | -0.10 | 0.64 | 0.03 | 0.65 | 1.28 | | 0.66 | 109.21% |
| | *msTL84* | -1.13 | -0.28 | 0.62 | -0.09 | 0.67 | 1.32 | 0.18 | | |
| | *F02* | -1.28 | -0.09 | 0.36 | -0.01 | 0.37 | 1.33 | 0.33 | | |
| *PRiK1* | *D65* | -3.68 | 2.51 | 2.87 | 2.53 | 2.85 | 5.30 | | 2.46 | 144.77% |
| | *msTL84* | -3.40 | 2.11 | 3.42 | 2.31 | 3.30 | 5.27 | 0.74 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *F02* | -3.78 | 1.76 | 2.84 | 1.73 | 2.86 | 5.05 | 0.76 | | |
| *PRiP1* | *D65* | -2.78 | 2.62 | 2.43 | 2.62 | 2.42 | 4.52 | | 2.08 | 134.28% |
| | *msTL84* | -2.52 | 2.20 | 2.91 | 2.35 | 2.79 | 4.44 | 0.69 | | |
| | *F02* | -2.91 | 1.83 | 2.29 | 1.79 | 2.32 | 4.12 | 0.81 | | |
| *PRiK2* | *D65* | 4.94 | -2.35 | -4.28 | -2.68 | -4.08 | 6.94 | | 3.42 | 60.00% |
| | *msTL84* | 4.65 | -1.58 | -4.92 | -2.27 | -4.64 | 6.95 | 1.04 | | |
| | *F02* | 5.21 | -1.55 | -4.12 | -1.90 | -3.97 | 6.82 | 0.86 | | |
| *PRiP2* | *D65* | -0.88 | 0.64 | 1.00 | 0.76 | 0.91 | 1.47 | | 0.72 | 110.08% |
| | *msTL84* | -0.81 | 0.45 | 1.12 | 0.67 | 1.01 | 1.46 | 0.23 | | |
| | *F02* | -1.00 | 0.47 | 0.78 | 0.57 | 0.71 | 1.35 | 0.30 | | |
| *PRiK3* | *D65* | -0.63 | -0.56 | -0.13 | -0.57 | -0.02 | 0.85 | | 0.37 | 102.87% |
| | *msTL84* | -0.66 | -0.47 | -0.18 | -0.50 | -0.05 | 0.83 | 0.11 | | |
| | *F02* | -0.65 | -0.38 | -0.15 | -0.40 | -0.06 | 0.76 | 0.18 | | |
| *PRiP3* | *D65* | -1.13 | 0.18 | 0.92 | 0.36 | 0.87 | 1.47 | | 0.76 | 111.55% |
| | *msTL84* | -1.15 | -0.02 | 0.90 | 0.23 | 0.87 | 1.46 | 0.20 | | |
| | *F02* | -1.30 | 0.13 | 0.63 | 0.26 | 0.58 | 1.45 | 0.34 | | |
| *PSe1* | *D65* | -8.81 | 5.29 | 7.56 | 5.66 | 7.29 | 12.76 | | 5.99 | 247.96% |
| | *msTL84* | -0.82 | 4.12 | 8.84 | 5.06 | 8.34 | 12.74 | 1.85 | | |
| | *F02* | -0.92 | 3.65 | 7.33 | 4.00 | 7.15 | 12.32 | 1.70 | | |
| *PSe2* | *D65* | -3.30 | 1.20 | 3.65 | 1.72 | 3.44 | 5.07 | | 2.56 | 141.59% |
| | *msTL84* | -3.14 | 0.73 | 3.98 | 1.60 | 3.72 | 5.12 | 0.59 | | |
| | *F02* | -3.62 | 0.90 | 3.18 | 1.42 | 2.98 | 4.90 | 0.65 | | |
| *PSe3* | *D65* | -1.95 | -0.12 | 2.04 | 0.31 | 2.02 | 2.82 | | 1.51 | 121.00% |
| | *msTL84* | -1.92 | -0.26 | 2.10 | 0.37 | 2.09 | 2.86 | 0.16 | | |
| | *F02* | -2.14 | -0.03 | 1.68 | 0.36 | 1.64 | 2.72 | 0.42 | | |

**PRa1, PRa2, and PRa3-0.63%, 1.25%, and 1.83% shade with rain water; PRiK1, PRiK2, and PRiK3-0.625%%, 1.25%, and 1.83% shade with Karnaphuli River water, PRiP1, PRiP2, and PRiP3-0.625%%, 1.25%, and 1.83% shade with Padma river water, PSe1, PSe2, and PSe3-0.625%%, 1.25%, and 1.83% shade with sea water with recipe salt; and PSeW1, PSeW2, and PSeW3-0.625%%, 1.25%, and 1.83% shade with sea water without recipe salt respectively for polyester fabrics. Again, color co-ordinates L-lightness, a, b-parameters for color difference, C-Saturation, H-Tone and ΔE-color difference.*

The color strength of polyester fabrics dyed with rainwater at 0.63% shade (Table 3) was 111.78% with CMC DE value 0.95 and Metamarism 0.34 for msTL84 light source and 0.48 for F02 light source, respectively. Polyester fabrics dyed with rainwater at 1.25% shade had a color strength of 108.81% with a CMC DE value of 0.55 and a Metamarism of 0.20 for the msTL84 light source and 0.31 for the F02 light source, respectively. Furthermore, polyester fabrics dyed with rainwater at 1.825% shade showed 109.21% color strength with a CMC DE value of 0.66 and Metamerism 0.18 for the msTL84 light source and 0.33 for the F02 light source, respectively.

The color strength of polyester fabrics dyed with Karnaphuli River water at 0.63% shade (Table 3) was 144.77% with a CMC DE value of 2.46 and Metamarism 0.74 for the msTL84 light source and 0.76 for F02 light source, respectively. Polyester fabrics dyed with Karnaphuli River water at 1.25% shade have a color strength of 60.0%, a CMC DE value of 3.42, and a Metamerism of 1.04 for the msTL84 light source and 0.86 for the F02 light source, respectively. Polyester fabrics dyed with Karnaphuli River water at 1.825% shade have a color strength of 102.87% with a CMC DE value of 0.37 and a Metamerism of 0.11 for the msTL84 light source and 0.18 for the F02 light source, respectively.

The color strength of polyester fabrics dyed with Padma River water at 0.63% shade (Table 3) was 134.28% with a CMC DE value of 2.08 and Metamerism 0.69 for the msTL84 light source and 0.81 for the F02 light source, respectively. Polyester fabrics dyed with Padma River water at 1.25% shade had a color strength of 110.08% with a CMC DE value of 0.72 and a Metamerism of 0.23 for the msTL84 light source and 0.30 for the F02 light source, respectively. Furthermore, polyester fabrics dyed with Padma River water at 1.825% shade exhibited 111.55% color strength with CMC DE value 0.76 and Metamerism 0.20 for msTL84 and 0.34 for F02 light sources, respectively.

The color strength of polyester fabrics dyed with seawater at 0.63% shade (Table 3) was 247.96% with a CMC DE value of 5.99 and a Metamerism of 1.85 for the msTL84 light source and 1.70 for the F02 light source, respectively. Polyester fabrics dyed with seawater at 1.25% had a color strength of 141.59%, a CMC DE value of 2.56, and a Metamerism of 0.59 for the msTL84 light source and 0.65 for the F02 light source, respectively. Furthermore, polyester fabrics dyed with seawater at 1.825% shade showed a color strength of 121.00%, CMC DE value of 1.51, and Metamerism 0.16 for msTL84 light source and 0.42 for the F02 light source, respectively.

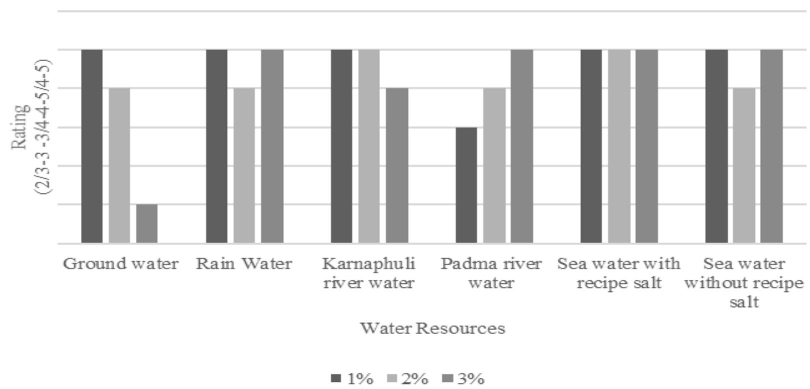
Thus, rain and Karnaphuli River water are excellent coloring materials for polyester. Compared to groundwater, the Padma River requires greater purification, and sea water does not assist at all in achieving the desired shade depth. It showed that the shadow depth was attained close to the groundwater usage in over half of the instances. Thus, there is the potential to directly reduce at least 50% of groundwater usage if necessary; industrial authorities make efforts with sufficient attention and desire. The fastness qualities of these fabrics are now examined in the following procedures.

According to the preceding findings from Tables 1 and 2, 6-7 instances out of 15 may be directly matched with the result of groundwater for cotton fabrics and 6-7 cases for polyester fabrics without changing the recipe quantity. Thus, 40-60% of groundwater consumption may be avoided by employing different water sources for the coloration of cotton fabric and 40-47% for polyester fabric. In bulk production, the possibilities are limited with the assistance of suitable recipe modification in sample preparation stages. Thus, the dropping groundwater level in this region may be reduced to approximately 40-50% less, and the sustainable aim would be partly accomplished. Environmental effects due to excessive extraction of groundwater by the textile industry may be mitigated; therefore, the supply of fresh drinking water will be available for much longer than forecasted by the World Bank and Dhaka WASA. The sector may be concerned about the fastness attributes owing to these applications. The next part explored the color fastness properties to understand this topic.

**Color fastness to rubbing**

**In the case of cotton fabrics**

Figure 1: Color fastness to dry rubbing for cotton fabrics at different shade %.




From graph in (Figure 1), cotton fabrics colored with the rain, Karnaphuli river and sea water (with and without recipe salt) water showed very good dry rubbing fastness in comparison to ground water and Padma River water-colored samples. Thus, the fastness properties for cotton fabric in dry condition exhibits good for light, medium and dark shades except ground water and Padma River water.

Figure 2: Color fastness to wet rubbing for cotton fabrics at different shade %.

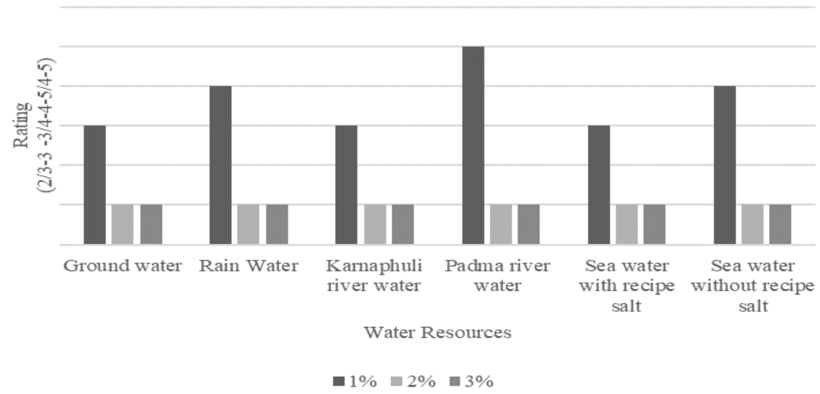
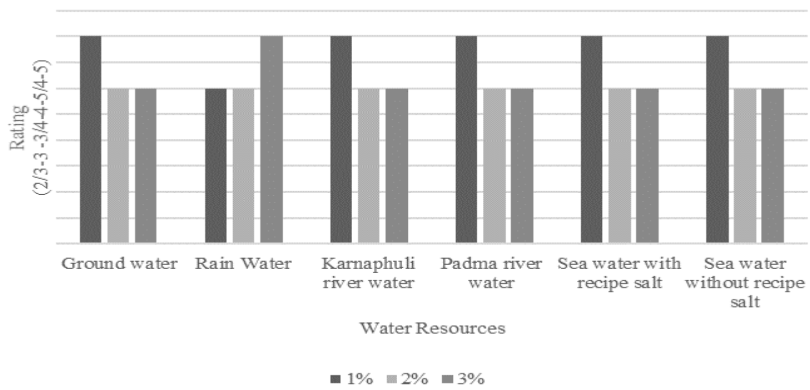



Figure 2 shows that the wet rubbing fastness properties for light shade with all sources of colored samples showed average quality but were very poor for medium and dark shade. In comparison with groundwater, the quality was almost similar.

Figure 3: Color staining for cotton fabrics at different shade %.

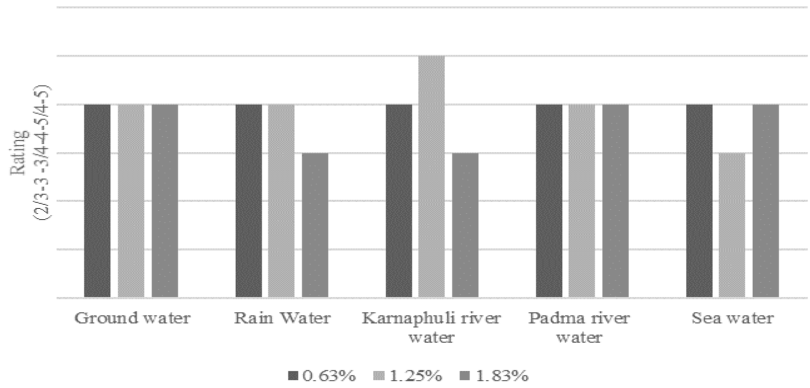



From Figure 3, the color staining from the fabric dyed with different water sources showed good properties for light shade except with rainwater. But, for dark shades, rainwater showed the best quality regarding color staining.

However, color staining and dry rubbing fastness properties show better results than wet rubbing fastness, as previously found for seawater by Ferreira et al. and Karim et al. (Ferreira et al. 2020; Karim et al. 2021). Hence, with seawater, river water is also a very good alternative for the coloration of cotton fabrics due to the presence of metallic salt that can cause corrosive effects in coloring baths. As it is mandatory to remove the metallic salt from the water before coloration, the other water sources can be utilized for the responsible consumption of groundwater to prevent the lowering of water level and dissertation (Ercin and Hoekstra 2013; Islam 2021). Dyeing with seawater may also create a scope in the requirement of additional salt as the dye promoter in fixation.

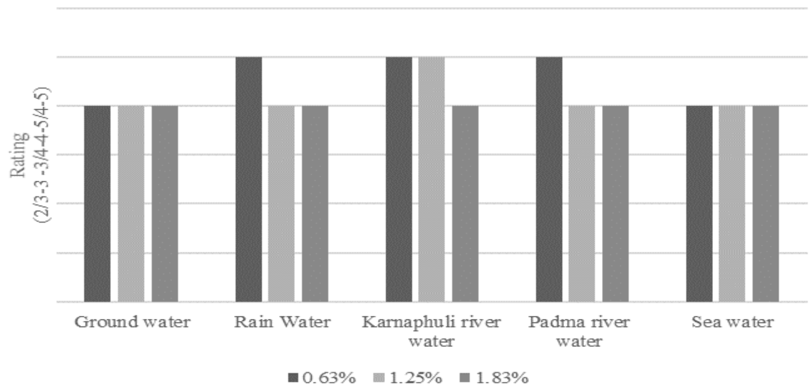
**In the case of polyester fabrics**

Figure 4: Color fastness to dry rubbing for polyester fabrics at different shade %.



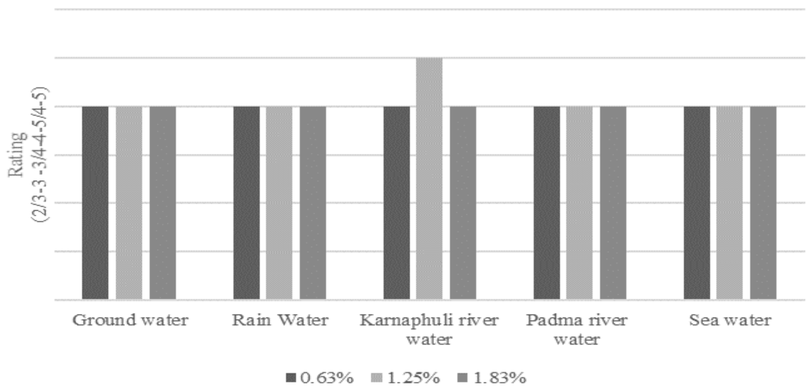

From Figure 4, color fastness to rubbing was good for polyester fabrics colored with all water sources, whereas, for a medium shade, Karnaphuli River water showed excellent fastness properties. On the contrary, seawater showed moderate fastness properties for medium shade and the same with Karnaphuli River water for dark shade.

Figure 5: Color fastness to wet rubbing for polyester fabrics at different shade %.




However, the wet rubbing fastness of polyester fabric dyed with rainwater, Karnaphuli River water, and Padma River water at light shade showed excellent results in Figure 5. However, for medium and dark shade, the fastness properties were just above average for all water sources.

Figure 6: Color staining for polyester fabrics at different shade %.




Excellent color staining properties were seen only for Karnaphuli River water dyeing at medium shade, as shown in Figure 6. For light, medium, and dark shades for all other water sources showed good results.

From the above discussion, the fastness properties of polyester fabrics for all water sources are good and much better than the result found in the case of cotton fabrics. It is due to the good fixation of dye molecules inside the fiber at high temperatures, and there is almost no possibility of color staining from the fabric surface during rubbing. Though a few cases show average fastness, it can be improved to the desired level after treatment. Though there are possibilities for color fading, as mentioned earlier, industries and consumers should be aware of the matter of responsible consumption for the sustainable development of Bangladesh (Sandin and Peters 2018).

**Color fastness to wash**

**In the case of cotton fabrics**

Figure 7: Color fastness to wash for cotton fabrics at 1% shade.

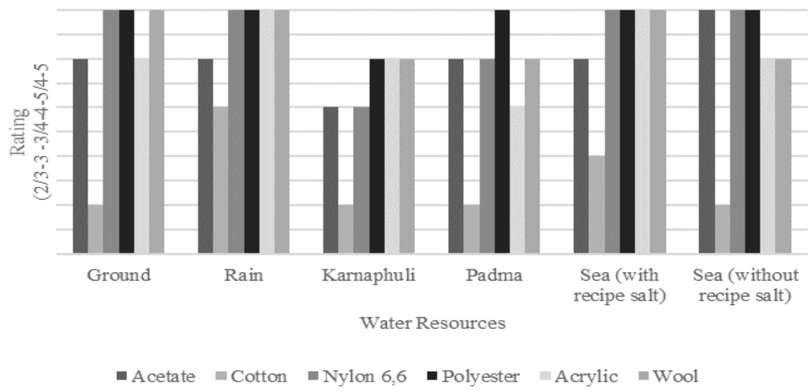
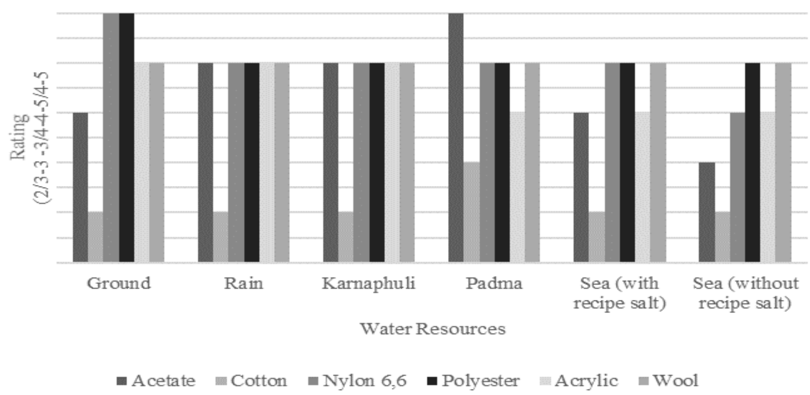



Figure 7 shows that color fastness to washing cotton fabric at 1% shade by rainwater showed excellent results for man-made fibers, moderate for cotton, and good for acetate fiber. Dyeing with Karnaphuli River water showed moderate results for acetate and nylon, good for polyester, acrylic, and wool. However, more results were needed for cotton fiber. Again, seawater-dyed fabrics showed excellent results with the addition of salt for all man-made fibers and moderate to excellent without additional recipe salt. For both cases of sea water fastness for cotton fiber was very poor. Dyed with groundwater showed very good to excellent results for man-made fibers and very poor for cotton fiber. It was also seen that coloration with Padma River water showed very good results for acetate, nylon, and wool, moderate for acrylic, very poor for cotton, and excellent for polyester.

Figure 8: Color fastness to wash for cotton fabrics at 2% shade.




Colorfastness to washing cotton fabric at 2% shade by rainwater and Karnaphuli River water in Figure 8 was a good result for man-made fibers. Fastness by sea water was moderate for acetate and acrylic fibers. Again, fastness by Padma River water showed good for nylon, polyester, and wool but moderate with acrylic and excellent with acetate. On the contrary, fastness for seawater without additional salt was poor for acetate, moderate for nylon and acrylic, and good for polyester and wool fiber. Here, fastness with groundwater showed excellent fastness results for nylon and polyester, as well as good results like other waters for acrylic and wool fibers. Here, the fastness for all sources of water was very poor with cotton fibers.

Figure 9: Color fastness to wash for cotton fabrics at 3% shade.

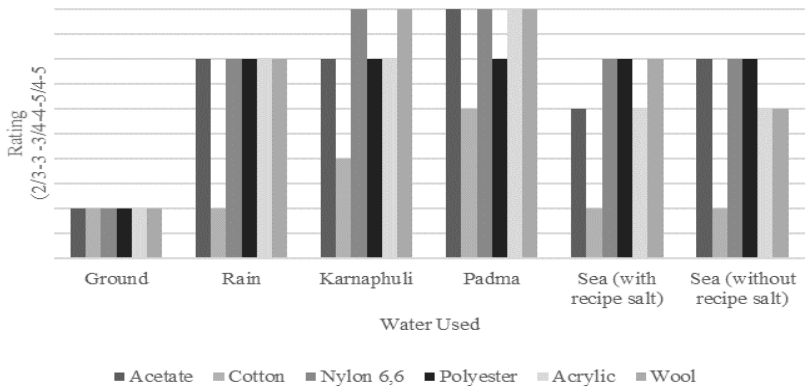



Figure 9 shows that color fastness to wash of cotton fabric at 3% shade good result with nylon and polyester fiber dyed by rain, sea (with and without additional salt) water. However, an excellent result was found for Karnaphuli River water and Padma River water for nylon and wool fibers. With acrylic fibers, excellent results for Padma River water, moderate for seawater (with and without additional salt), and good for others except groundwater were observed. Here, fastness by groundwater was found to be very poor with all fibers. Finally, with cotton fibers, only moderate results were found in Padma River water. As no fastness improvement was made before these tests, the fastness of the cotton fabric will certainly show good to excellent results for all these cases after treatment (Ferreira et al., 2020; Karim et al., 2021).

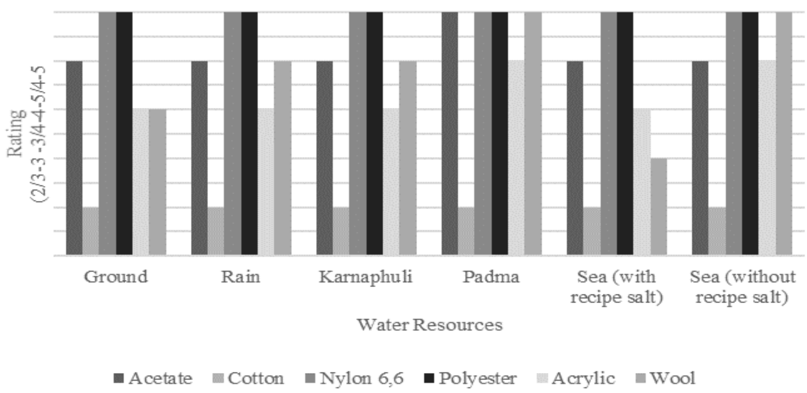
**In the case of polyester fabrics**

After examining all the samples, the fastness properties were good to excellent for all types of fibers for dyeing with all water sources for polyester fabrics (the rating scale showed 4-5 for all samples). So, for the dyeing of man-made fibers, the water sources do not have that much difference in the fastness properties to wash. Due to the fixation of dye particles at high temperatures, this might happen, and the different salts present in the waters can create fading of the color in a few cases (Solaiman et al., 2019; Karim et al., 2021).

**Color fastness to perspiration**

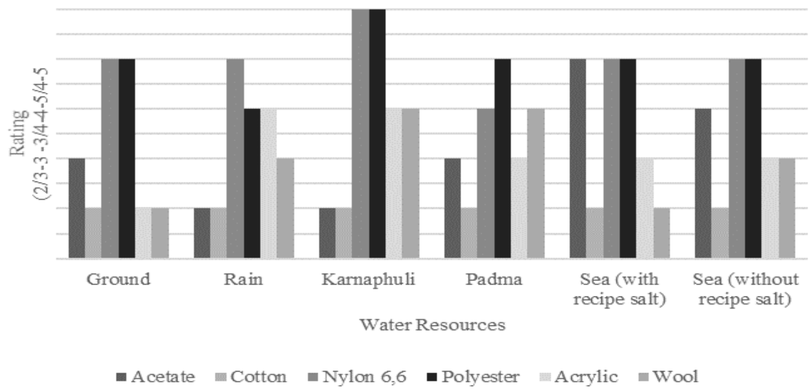
**In the case of cotton fabrics**

Figure 10: Color fastness to perspiration in alkaline solution (cotton 1% shade).



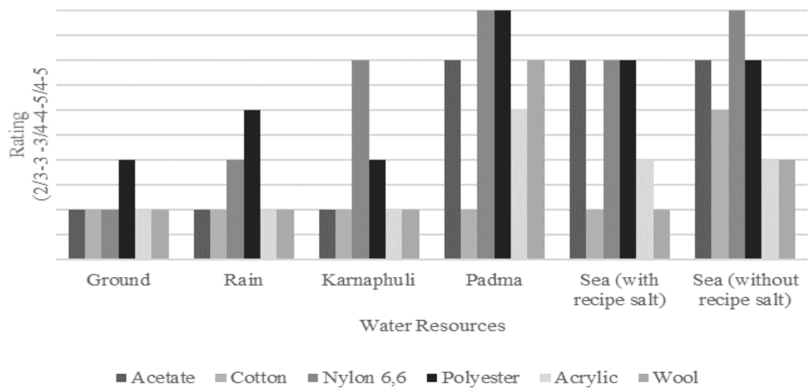

From Figure 10, it demonstrates that color fastness to perspiration in alkaline solution of cotton fabric at 1% shade was excellent with nylon 6,6 and polyester for all water sources. Acetate for Padma River water and wool for Padma River water and sea water without additional salt also showed excellent results. For other sources of water with acetate fiber, the result was good. However, the result for acrylic fiber is moderate except good for seawater without additional salt. Here, with cotton fiber, the result is very poor.

Figure 11: Color fastness to perspiration in alkaline solution (cotton 2% shade).




Color fastness to perspiration in an alkaline solution of cotton fabric at 2% shade was excellent with nylon 6,6 and polyester for Karnaphuli River water but, from moderate to good for other sources (Figure 11). The result for other fibers was below average quality, which means poor fastness for cotton fabrics for 2% shade depth of color.

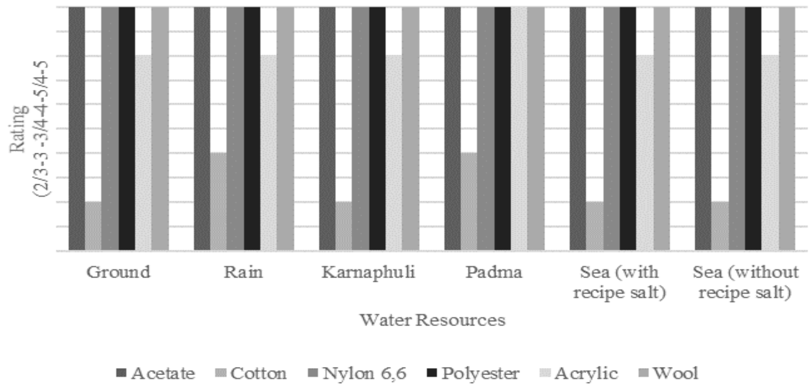
Figure 12: Color fastness to perspiration in alkaline solution (cotton 3% shade).




In Figure 12, the color fastness to perspiration in an alkaline solution of cotton fabric at 3% shade was found to be moderate to excellent with acetate, nylon 6,6, and polyester for seawater (with and without additional salt condition), and Padma River water. But, for other fibers and water sources, the result was below-average quality.

As the agencies used in perspiration tests are responsible for destroying the color particles, the fastness is poor for dark shades, largely for groundwater, rain, and Karnaphuli water. However, the fastness properties can be considered average to good for light and medium shade. This result could be better in the case of cotton fabrics concerning the result found by Karim et al. (Karim et al. 2021). This might be due to the after-treatment process.

Figure 13: Color fastness to perspiration in acidic solution (cotton 1% shade).




From Figure 13, it was found that color fastness to perspiration in an acidic solution of cotton fabric at 1% shade was excellent with acetate, nylon 6,6, polyester, and wool for all sources of water in the study and good with acrylic fiber. On the contrary, poor to very poor fastness to perspiration in acidic solution with cotton fibers was found. It was a little bit good compared to groundwater for Rain and Padma River water, which is a scope in dyeing.

Figure 14: Color fastness to perspiration in acidic solution (cotton 2% shade).

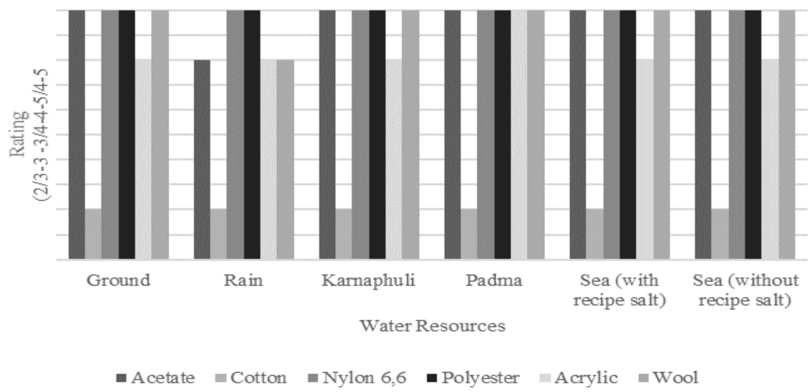
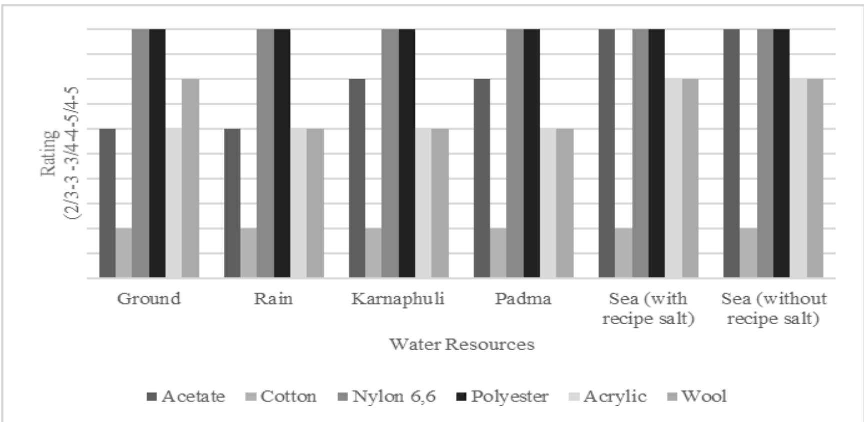



Figure 14 shows that color fastness to perspiration in an acidic solution of cotton fabric at 2% shade was excellent with acetate, nylon 6,6, polyester, and wool for Karnaphuli River water, sea water (with and without additional salt), groundwater, Padma River water. It was good with rainwater for acetate and wool fiber. The result was good with acrylic fiber but could have been better with cotton fiber.

Figure 14: Color fastness to perspiration in acidic solution (cotton 3% shade).




Here, in Figure 15, it finds that color fastness to perspiration in an acidic solution of cotton fabric at 3% shade is excellent with nylon 6,6, polyester fibers. Good to moderate results for acrylic and wool fibers, except for excellent results for seawater (with and without additional salt). But it was also very poor result like other fastness properties with cotton fiber.

The result is much better than the perspiration fastness properties in alkaline medium except for cotton fabrics, also found in the previous section.

**In the case of polyester fabrics**

The study found that the color fastness to perspiration of polyester fabrics in alkaline solution is excellent for all shade % and all sources of water (in the rating scale 5 for all samples). So, different water sources did not make any difference in the fastness properties of dyeing polyester. Which is found for sea water by (Karim et al. 2021). Thus, the fastness of the fabric is not affected by water sources, such as solvents or dyes (Ferreira et al., 2020).

Similar excellent fastness properties were found with all fibers for all different water sources (on a rating scale of 5 for all samples). Thus, the differences in the fastness properties of perspiration in an acidic solution for polyester fabric water sources did not deteriorate the quality of fastness properties.

The results found in this experiment were slightly different results from the experiments done by others in the case of cotton fabrics, but the fastness properties of polyester are excellent for all cases that are like the previous study. As the types of dyes and chemicals used for the coloration of the fabrics are not the same and the depth of shade% varies with reference, it can be established that the proper acceptance of the buyer helps the local industry to export in the foreign countries need to come forward to accept the little variation or let the industry a helping hand to adjust with the requirement (Karim, et al. 2021; Solaiman et al. 2019; Ferreira et al. 2020).

Though the other chemicals present in the seawater and river water that may produce the scale formation in the coloration bath need to be taken care of, the utilization of these in fixation of dyes and the fastness properties of polyester and cotton fabrics are very amazing (Ahmed 2017; Reddy 2001; Radaideh et al. 2008; Wiesenburg 1988). The fading of colors due to metallic salt and color staining in the cotton fabric are a few disadvantages, but dye fixation treatment might be a little costly alternative considering these huge resources in the production stages (Sharif, Ahmad, and Siddiqui 2008).

## Conclusion

Five distinct water sources were employed in this investigation. The shade depth of cotton fabric colored with Karnaphuli River (all shade %), Rain (3% shade), and Sea (1% shade with and without extra salt) water nearly matched the shade depth of the ground water-dyed fabric. Cotton fabrics colored with Padma River water, rainwater (1% shade), and seawater (3% shade with and without extra salt) yielded a much lighter color. The shade depth of polyester fabrics dyed with rain (all shade percentage), Karnaphuli River (3% shade), and Padma River (2% and 3% shade) water, on the other hand, was nearly matched with the depth of shade colored with groundwater. Cotton fabrics created a lighter depth of shade than polyester fabrics. Rain, the Karnaphuli River, and sea water were discovered to be acceptable alternatives for dying cotton fabrics using reactive colors in this experiment. Rain and Padma River water were discovered to be an excellent option for coloring polyester fabrics. However, dyeing cotton with Padma River water created a very pale hue, and dyeing polyester with sea water produced a dark shade. All things considered, polyester fabrics had good wash and perspiration resistance. Cotton fabric, on the other hand, produced excellent results as compared to groundwater dyeing in certain circumstances (about 50%). The present research is limited in scope, concentrating solely on reaching the requisite color depth by altering the quantity of dyes and compounds about production costs. This method may limit the number of color possibilities and ignore possible variances. Furthermore, the study's exclusivity to certain natural and man-made fibers raises questions about the derived recipes' wider application to alternative materials. Due to the short length of dyeing procedures and the limited research of prolonged durations, an imperfect grasp of color outputs and resource efficiency may ensue. Environmental concerns are recognized, but a more thorough examination of the ecological effect of the dyeing process is required. Future researchers are invited to broaden the color palette, experiment with other fiber kinds, and examine prolonged dyeing. It is time for various organizations to come up and limit groundwater use by 50% to avert the effects of the water level dropping. This kind of industrial practice will guarantee the realization of sustainable objectives such as responsible consumption and production (SDG 12), climate change prevention (SDG 13), and life below water SDG (14) and on land (SDG 15).

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**Conflict of Interest**
The author declares that there is no conflict of interest.

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