Effect of water quality on Reactive dyeing of cellulose Textiles

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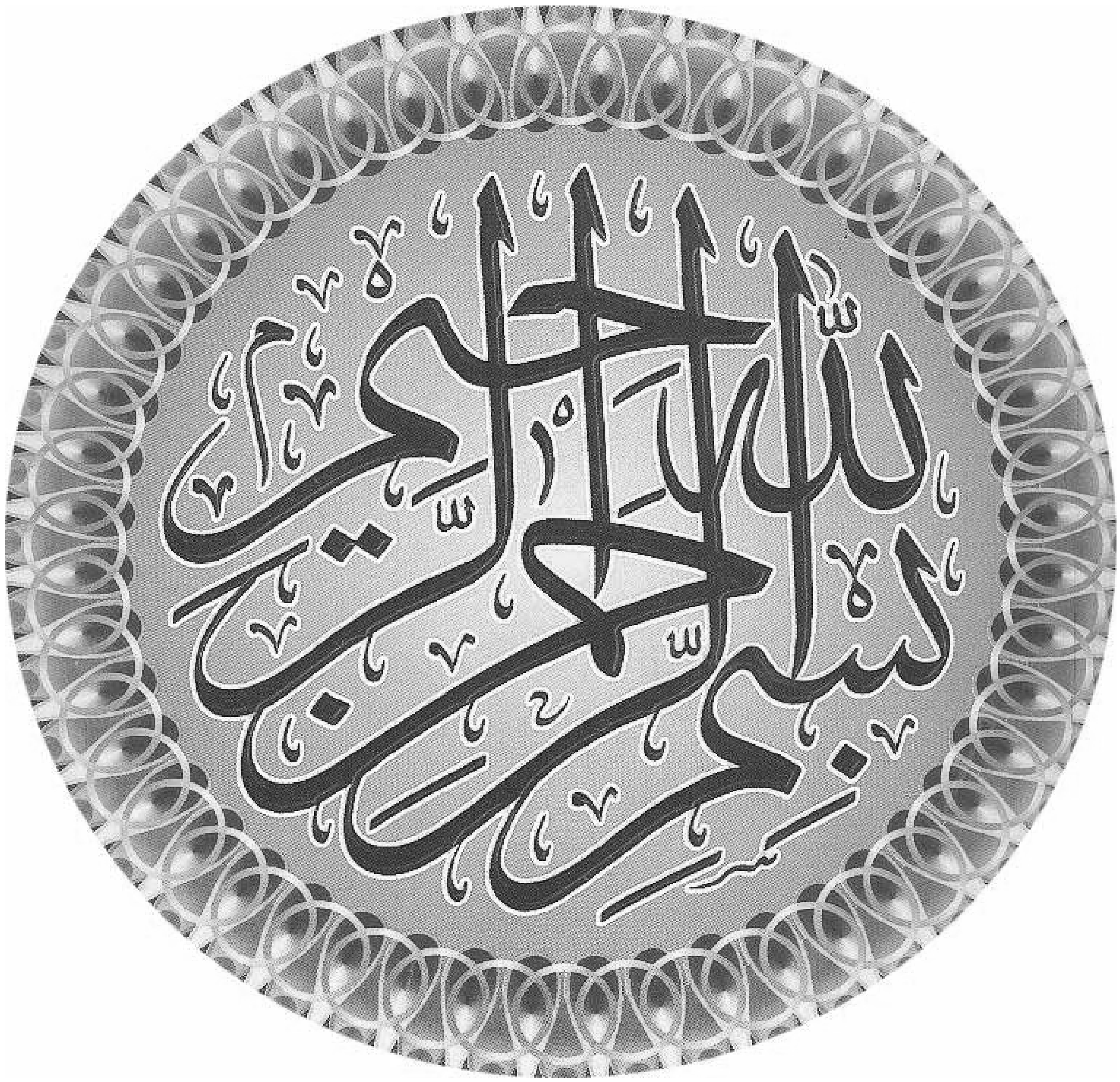
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Abstract

The quality of water is very important in the dyeing of textile materials. Dyeing industry uses a huge quantity of water. The quality of ground water is different at different locations. The major objective of this project is to check the quality parameters (PH, TDS, alkalinity and hardness etc) of ground water collected from different industrial areas and their effect on the quality of dyeing regarding to quality of dyed specimen surface (evenness and whiteness), hue, and chroma, lightness and total difference. The effect of quality of water is also studied for washing fastness and crocking of dyed specimen. The water is tested at PCSIR labs. The Faisalabad water has lot of contaminations but the water samples from Multan Road, Kotlkhpat and Raiwind Manga Road has contaminations with in accepted limits. The Knitted fabric samples are dyed with Red, Yellow and Navy colors in different water samples. Fabric samples dyed with different dyes in different depth are compared with relevant samples dyed in Multan road water, selecting as standard. The comparison is done both visually and with spectrophotometer. The washing fastness and crocking of the dyed samples is also measured. All the information are arranged in tables and studied for final evaluation. It is evaluated that water quality has definable effect on the surface properties, Hue, chroma, lightness and total difference of the dyed specimens. It is also evaluated that water quality has no effect on the washing fastness and crocking. The area has bright chances for future research. The effect of water on dyeing can be studied further by varying the parameters of quality of water artificially by the addition of chemicals and by the results prediction of most suitable water, quality parameters for dyeing.

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(Signed)

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1 CHAPTER

INTRODUCTION

The textile industry is characterized as a dynamic industry with constantly changing manufacturing processes. This is to a great deal dependent on the customers demand but also on new fibers, process chemicals or technology introduced. Processing of textile materials involves fibers from vegetable and animal origin and man-made polymers, together with process chemicals of different nature. These ingredients are processed along a variety of process schemes, which are dependent on the fiber, or fiber blends used and the desired product quality. A lot of water and energy is consumed during these operations. With the steadily increasing cost of energy, chemicals, fibers and treatment of water and waste water, technologies have been introduced and are under development aimed to save as much as possible of the resources.

The textile industry is comprised of a diverse, fragmented group of establishments that produce and/or process textile-related products (fiber, yarn, fabric) for further processing into apparel, home furnishings, and industrial goods. The four production stages are:

- Yarn formation
- Fabric formation
- Wet processing
- Fabrication

Wet processing is the most significant textile operation. Methods used vary greatly depending on end products and applications, site-specific manufacturing practices, and fiber type. Natural fibers typically require more processing steps than manmade fibers. Processing methods may also differ based on the final properties desired, such as tensile strength, flexibility, uniformity, and luster.

The important requirements for wet processing industry are:

- Electricity
- Heat
- Air pressure
- Water

Water quality has a direct effect on the reactive dyeing of cotton goods. Water quality effect the depth of shade, hue, chroma, surface properties of dyed textile material, fastness properties of dyed textile material and cost of the wet processing. The project includes the testing of water quality from different industrial areas, dyeing of cellulosic fabric with reactive dyes from these water samples. The evaluation consists of comparison of dyed samples for depth, comparison of fastness properties (washing fastness, rubbing fastness and light fastness) and visual results like hue, evenness, whiteness, etc. on the basis of theses evaluations we will try to conclude that what area is most suitable for reactive dyeing of cellulosic goods.

1.1 Problem Statement

The water acts as a media in the dyeing of textile goods for the transfer of dye molecules to the textile material. A lot of problems are faced by the dyers in the dyed textile goods. Some problems are given below.

- Uneven dyeing.
- Whiteness on the surface of dyed specimen.
- Less color yield
- Poor fastness properties.
- Lab to bulk difference.
- Lack of reproducibility.
- Cost for the treatment of contaminated water.

One of the major causes for these problems is the quality of water. Dyers desperately trying their best to make their results up to the mark. It is required to conduct research work to get the following information.

- Effect of water quality on dyeing.
- Effect of water quality on fastness properties.
- Effect of different parameters of water on quality of dyed textile material.
- Effect of water quality on surface properties of dyed textile material.
- Selection of most suitable water for dyeing.

1.2 Objectives

The objective of the project is to test the quality of water sample collected from the different industrial areas. The effect of water quality on the reactive dyeing of cellulosic textile materials w.r.t Hue, Chroma, Lightness and surface properties. The effect of water quality is also studied for the fastness properties of dyed samples. Hence the selection of industrial area most suitable for the reactive dyeing of cellulosic textile materials.

1.3 Applications

- This project will help in improving work procedure in the industry. It will help in better understanding of faults and problems during dyeing related to water usage.
- Suitable industrial areas for reactive dyeing of cellulosic textile materials
- Requirement of water treatment for contaminated water.
- Helpful for future research in this area.

CHAPTER 2

LITERATURE SURVEY

The relevant literature studied in this content consists of study of different water properties like pH, hardness, color etc and their effect on water quality the testing procedure for these properties of water different types of reactive dyes, their functional groups, and literature of reactive dyes prepared from different dyes manufacturing multinational companies. Reactive dyeing procedure for the cotton goods. Fastness testing methods, for washing and rubbing were also studied from manuals of ISO and AATCC. But unfortunately no remarkable information is available about effect of water quality on reactive dyeing of cellulosic goods on internet, books and research journals.

2.1 Water

Water is the most abundant and also the most important compound that exists on the planet Earth. No life whether vegetable or animal can exist without water. The human body for example contains water up to 60% of its weight and cucumber is 97% water. Nature has provided our planet with abundant water and about 70% of the surface of earth is covered with it. However, in spite of this apparent abundance potable water is becoming increasingly scarce. This scarcity is due to the tact that 97.2% of the total water is in the oceans and this has a high concentration of dissolved salts that makes it unfit for bio-consumption. Out of the remaining 2.8%, about 2% is perpetually frozen and 90% of it is in Antarctica [1].

It has been estimated that with rising population consumption of water is increasing by 2-3% annually. It is thus easy to anticipate that water for industry will keep on becoming more expensive because the first charge on the fresh water is for human consumption and for growing crops. Agriculture uses about 70% of the total available water and its utilization may be judged from the figures that one-kilo of rice, potatoes and beef require 1,900, 500 and 100,000 liters of water respectively. An individual person consumes, on the average, about 100 m3 (100,000 liters) of water annually. Fortunately some of the consumed water can be reclaimed but it is not enough to check the increase in cost of water [1].

2.1.1 Sources of Water

The only source of fresh water on earth is evaporation from the seas and lakes and it has been estimated to be about 230 cubic miles every day. (One cubic mile is about 5,000 bill ion liters) Unfortunately, out of this total evaporation, 210 cubic miles rain back on the seas and only 20 cubic miles are blown over to land to support life on earth. The main sources of water for drinking, irrigation and industry such as rivers, lakes, sub-soil water, canals etc are all fed by the rainwater.

2.1.2 Special Properties of Water

Water (H_2O) is a very simple compound but has very unique physical and chemical properties. Its density for example, increases with lowering of temperature but unlike other substances, it starts decreasing after reaching a temperature of 4°C. This unusual property is perhaps responsible for existence of any Iife on our planet today. The fall in density below 4°C creates an insulating layer of ice on the surface of oceans and lakes. In the absence of this layer, all the water sources would have frozen from bottom to top during the ice ages and the entire marine life would have perished.

Water has a highly surface tension and a high dielectric constant. The latter property is responsible for the great capacity of water to dissolve ionic and polar compounds thus making water an excellent solvent. Water has a low relative molecular mass (18) but still it has a very high boiling point of 100°C. This phenomenon indicates presence of an inter-molecular bonding force that is termed as "hydrogen bonding. This bonding is also responsible for a high specific heat or heat capacity of water and steam, the latent heat of vaporization of steam is 537 calories per gram of steam at 100°C and this property makes it a very economical and efficient medium for heat transfer in industry. Interestingly, water is corrosive to metals and minerals and yet it is essential for the living organisms.

2.1.3 Impurities Associated with Water

Dew and rain, as condensed from water vapors, are in a very pure state but on coming in contact with air, water dissolves gases like carbon dioxide and oxides of nitrogen and Sulphur that are usually present in the atmosphere of the urban areas. The following water while passing over land normally consists of calcium and magnesium carbonate rock strata, converts these minerals into soluble bicarbonates by reaction with carbon dioxide that is already dissolved in it [1].

As the rivers flow towards sea, concentration of both the dissolved and suspended impurities keeps on increasing. In addition to leaching of salts of the soil on which river flows, the municipal sewerage and industrial effluents from downstream cities are also added. The river water, therefore, contains both the suspended and dissolved mineral and organic matter in addition to dissolved gases and bacteria. The main dissolved mineral matter consists of cations of calcium, magnesium and sodium and anions of bicarbonate, carbonate, chloride and sulphate. The calcium and magnesium ions create a special difficulty in use of water for household and industrial purposes that is known as hardness. Hardness wastes soaps because the calcium and magnesium ions replace the sodium ions soaps and convert these into insoluble soaps destroying there by their detergent quality. Reaction of soap with the metal salts may be represented as under.

$$2\ C_{17}\ H_{35}\ COONa + CaC_2 \rightarrow (C_{17}\ H_{35}\ C\ OO)_2\ Ca + 2\ NaCl \qquad (2:1)$$

a. Hardness of Water

Hardness is due to presence of any metal ions in water that will react with soap and make it insoluble but these ions are normally of calcium and magnesium metals. In most of the science textbooks hardness is classified as temporary and permanent; the former is produced by anions of bicarbonate and the latter by chloride and sulphate of calcium and magnesium. Temporary hardness is so termed because it is supposed to be removed on boiling t hard water when the bicarbonates are converted into insoluble carbonates that are precipitated.

The white particles and scale formed on the water-boiling vessels are mainly calcium and magnesium carbonates. However, it is worth noting that the temporary hardness is never completely removed even on prolonged boiling. In modern literature the terminology of temporary and permanent hardness has been replaced with alkaline and non-alkaline hardness respectively.

Determination of hardness: Hardness was estimated in the past with a standard soap solution the end point being formation of foam that is stable for a definite time. The foam is formed after the hardness causing salts have been precipitated by soap. This method is time consuming and is also not very accurate. Presently alkaline hardness is measured with a standard hydrochloric acid solution using methyl orange and phenolphthalein as indicators.

The non-alkaline hardness is determined by titration with a metal chelating compound, such as disodium salt of ethylene diamine tetra acetic acid, commonly termed as E.D.T.A. or Versene. EDTA forms complexes with calcium, magnesium or other metal cations and removes these from the solution. The indicator is an acid dye (Eriochrome Black T) that changes color from bluish red to brilliant blue. To find calcium arid magnesium hardness separately, caustic potash is added to the hard water which suppresses ionization of magnesium ions and only calcium ions react with EDTA The magnesium hardness is determined as the difference in total and the calcium hardness.

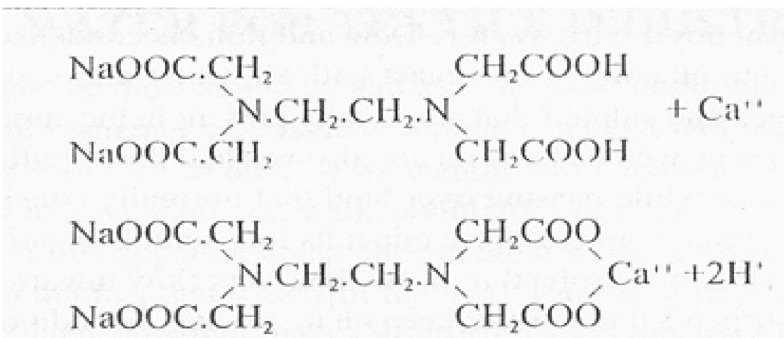

Figure 2.1

Hardness is usually indicated as parts of calcium carbonate per million parts of water (PPM) irrespective of the nature of the ions present.

b. Total Dissolved Solids

Quantity of total dissolved solids (TDS) is an important parameter in assessment of quality of water. Evaporating water and weighing, dried residue can directly measure it. However, a more convenient and rapid method is to determine the electrical conductivity of water and calculate the TDS from calibrated tables. Currently pre-calibrated digital meters are available that directly read the TDS in PPM.

2.1.4 Water Quality For The Dyehouse

During the Industrial Revolution, the textile industry invariably grew in regions having an abundant supply of soft water such as in West Yorkshire. Such water is relatively free from calcium and magnesium salts. It does not precipitate soap or other chemicals during washing, or form a scale on the boiler walls when generating steam.

Water for a textile plant may come from various sources. These include surface water from rivers and lakes, and subterranean water from wells. The water may be obtained directly from the source or from the local municipality. Natural and pretreated water may contain a variety of chemical species that can influence textile wet processing in general, and dyeing in particular.

The various salts present in water depend on the geological formations through which the water has flowed. These salts are mainly the carbonates (CO_3^{2-}), hydrogencarbonates (HCO_3^-, more commonly named bicarbonates), sulphates (SO_4^{2-}) and chlorides (Cl^-) of calcium (Ca^{2+}), magnesium (Mg^{2+}) and sodium (Na^+). Although calcium and magnesium carbonates in limestone are relatively insoluble, the action of dissolved carbon dioxide in rain water can leach them out in the form of the more soluble bicarbonates (Equation 2:2). Hard water contains Calcium and magnesium ions and gives an immediate precipitate with soap. Soap is a water-soluble sodium salt of a high molecular weight carboxylic acid, such as stearic acid. Its calcium and magnesium salts are much less soluble and give a gummy precipitate with a soap solution in hard water (Equation 2:3). When this happens, the cleaning efficiency of the soap decreases dramatically. The dirt in suspension, as well as the precipitated calcium and magnesium soaps, can deposit back onto the material being washed. This gives a dingy fabric with a poor handle that will be difficult to dye in a level shade.

$$CaCO3(s) + CO2(aq) + H2O(l) \rightarrow Ca(HCO3)2(aq) \tag{2:2}$$

$$2CH3(CH2)16CO2Na+ (aq) + Ca^{2+} (aq) \rightarrow CH3(CH2)16CO2\ Ca^{2+} (s) + 2Na^+ (aq) \tag{2:3}$$

Besides dissolved salts of natural origin, water may contain a variety of other salts from human or industrial activity. These include nitrates (NO_3^-), phosphates (HPO_4^{2-} and $H_2PO_4^-$) and various metal ions. The ions of certain transition metals, such as those of iron, copper and manganese, can precipitate dyes, or form complexes with them, dulling or even changing their shade. In addition, many of these ions catalyse the decomposition of hydrogen peroxide in bleaching baths. It is not uncommon for a particle of iron rust on the surface of a cotton fabric to generate such rapid peroxide decomposition that the cellulose is totally oxidised and a hole results. These transition metal ions may be present in the natural or municipal water, or, in the case of iron, come from corrosion within pipelines. Both dissolved and colloidal silica in boiler feed water can lead to the formation of a hard resistant scale on the boiler's internal surfaces, considerably decreasing heat transfer efficiency. Organic compounds from the decomposition of vegetable matter in the water, or from sources of pollution, can be very varied. They can have such high concentrations that the water is coloured. Table 2.1 illustrates the quality of water usually considered acceptable for textile processing and steam generation.

Water entering a textile dyeing or finishing plant usually passes through a grill to eliminate floating debris. Small particles in suspension must also be removed.

Component	Permissible concentrations mg l–1
Hardness	0–25 $CaCO_3$
Iron	0.02–0.1
Manganese	0.02
Silica	0.5–3.0
Alkalinity to pH 4	35–65 $CaCO_3$
Dissolved solids	65–1 50

Table 2.1: Typical dyehouse water quality

The water may pass from the primary source into a settling pond, from which water can be drawn after any small particles have settled to the bottom, or it may be filtered by passage through a bed of fine sand. For particles smaller than about 0.02 mm, a coagulant aids sedimentation and clarification of the water. Addition of small quantities of sodium aluminate ($NaAlO_2$) or aluminium sulphate, and adjustment to around pH 7, give a gelatinous precipitate of aluminium hydroxide that imprisons the small particles and accelerates sedimentation or filtration. Addition of a flocculant, such as a polyacrylic acid–polyacrylamide copolymer, gives better particle adhesion and a higher rate of sedimentation. This type of treatment also improves the colour of the water. Soluble impurities in the water, such as iron, pollutants, and organic matter, are a real problem. Good aeration of the water will usually convert iron into Fe^{3+}, which precipitates as ferric hydroxide unless the water is quite acidic.

a. WATER HARDNESS [2]

i. Consequences of using hard water

The use of hard water in a textile dyeing or finishing mill can have some serious consequences. These include:

(1) precipitation of soaps;
(2) redeposition of dirt and insoluble soaps on the fabric being washed – this can cause yellowing and lead to unlevel dyeing and a poor handle;
(3) precipitation of some dyes as calcium or magnesium salts;
(4) scale formation on equipment and in boilers and pipelines;
(5) reduction of the activity of the enzymes used in desizing;
(6) decreased solubility of sizing agents;
(7) coagulation of some types of print pastes;
(8) incompatibility with chemicals in finishing recipes.

ii. Definitions

Soft water is relatively free of calcium and magnesium ions. It produces a rich foamy lather with soap. This is essential for the soap to be an effective emulsifying agent for oils and dirt. With hard water, the soluble sodium salt of soap reacts with the alkaline earth metal ions and precipitates as the useless and undesirable calcium or magnesium soap (Equation 2.3). The cleaning ability is lost.

Hardness is defined as the presence of soluble calcium and magnesium salts in the water. If these are present in the form of bicarbonates, the hardness is temporary. Heating hard water containing bicarbonates eliminates dissolved carbon dioxide and the reverse of (Equation 2.1) causes precipitation of calcium carbonate. Magnesium carbonate is slightly soluble in water but heating will cause its hydrolysis into the much less soluble magnesium hydroxide (Equation 2.4 &2.5). Simply boiling and filtering the water therefore eliminates temporary hardness. In regions where water has high temporary hardness, and is used directly without treatment, it is not uncommon to see hot water rinsing and washing baths with a generous crust of chalk ($CaCO_3$) on the inner surfaces. This type of precipitation inside a boiler is also undesirable because the scale reduces the efficiency of heat transfer.

$$Mg(HCO3)2(aq) \rightarrow MgCO3(s) + CO2(g) + H2O \tag{2:4}$$

$$MgCO3(aq) + H2O \rightarrow Mg(OH)2(s) + CO2(g) \tag{2:5}$$

Permanent hardness arises when water contains soluble salts of calcium and magnesium such as chlorides and sulphates. It is unaffected by boiling the water. The total hardness of water is determined by the amount of dissolved calcium and magnesium, but expressed in the form of $CaCO_3$. This is possible because calcium and magnesium carbonates have identical stoichiometry. Therefore, water that contains 1.0 mM calcium and 0.5 mM magnesium ions, has a total concentration of 1.5 mM. Since the molecular weight of $CaCO_3$ is 100 g mol^{-1}, 1.5 mM corresponds to 150 mg l–1 of $CaCO_3$, or 150 ppm (parts per million), assuming that 1.0 l of the water has a mass of 1.0 kg. The permanent hardness is that remaining after the water has been boiled and filtered to remove the precipitated calcium and magnesium carbonates and magnesium hydroxide. The temporary hardness is the difference between the total and permanent hardness. Occasionally, hardness due to magnesium alone is of interest, again expressed as the equivalent amount of $CaCO_3$. For the water mentioned above, 0.5 mM of magnesium ions is equivalent to 50 mg l–1 or 50 ppm $CaCO_3$.

Understanding water hardness values is often a tedious exercise in manipulation of units. In the past, the hardness of water was given in units called degrees. The definition of one degree of hardness, however, varied from one country to the next (Table 2.2). It is much simpler to express hardness in mg l–1 or ppm of $CaCO_3$.

Unit of water hardness	ppm $CaCO_3$
1 British degree	14.3
1 American degree	17.2
1 French degree	10.0
1 German degree	17.9
1 mmol l–1 $CaCO_3$	100

Table 2.2 Various units used for water hardness