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# EFFECT OF HARDNESS OF WATER ON TEXTILE WET PROCESSING

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## ABSTRACT

Water is used significantly in the textile industry's various processing operations. The success of textile wet processing strongly depends on a consistent and clean supply of good-quality water. Hence, it is imperative to bestow the greatest attention towards the quality of water. Any problem in textile processing is usually associated with the water used. It is therefore essential to first test the sample of water to obviate any difficulties that the textile processing unit may face. Usually, water is considered to be unsuitable for textile processing if it contains more than 250ppm parts of hardness. Hardness in water causes wastage of dyes, chemicals and soaps, dullness of shades, uneven and patchy shades in dyeing and printing, poor fastness in shade in processed fabric, corrosion of the boiler and vessels. Keeping this in mind, the present work was carried in textile chemistry laboratory of Banasthali Vidyapith. The main objective was to see the effect of hardness of water on wet textile processing. The procedure adopted was divided into three phases. In first phase, fabric and raw materials were collected and water was prepared in textile chemistry laboratory by the researcher herself. The second phase included procedure adopted for carrying out wet textile processing (desizing, scouring, bleaching, and dyeing) with three different water samples (hard, moderately hard and soft). In the last phase, the treated samples were analyzed on the basis of percentage weight loss, whiteness index and color fastness test, percentage dye absorption and wettability test etc. It was observed that weight loss after desizing process (enzymatic desizing) was found to be more with soft water as compared to the hard and moderately hard water. In the scouring process, it was found that with moderately hard water, weight loss percentage was more as compared to soft and hard water. In the bleaching process, it was found that sample was more white when treated with moderately hard water compared to hard and soft water. In dyeing process, it was found that intensity of shades in sample treated with moderately hard water was more as compared to hard and soft water. It can also be said that some degree of hardness is required for textile wet processing.

**Keywords:** Water Hardness, Wet processing, Dye absorption, Whiteness Index

## 1. INTRODUCTION

Water is the most important constituent of life. A person can live for a few weeks without food but only a few days without water. It is an integral part of animal and vegetable tissue. All life on earth uses water as a basic medium of metabolic functioning. Water is required for agriculture, hygienic home and human waste disposal, drinking, cooking, bathing, and washing (cleaning). It helps in removing the dirt and is an excellent solvent. It is needed for the production of such a wide variety of materials as steel and other metals, paper, textiles, beverages, daily products, petroleum and coal, rubber and plastics (Kaur, 1997).

In the wet processing industry, water is an essential necessity for the treatment of textile materials. The usage of textile materials has expanded significantly as a result of rising living standards, which in turn has raised demand for water and the need for textile production (Gopalkrishan, 2019). The textile industry uses a lot of water, which strains the world's water supply. The textile wet processing industry's enormous water consumption, huge waste water output, and significant pollution potential are causes for increasing concern (Gomes *et al*., 2000). Water is used extensively in the textile industry for a variety of wet processing procedures, including desizing, washing, scouring, bleaching, and dyeing. A clean, reliable supply of high-quality water is essential for the successful wet processing of textiles, and the quality of the processing water varies considerably between places and factories based on the water source and water treatment facilities. Use of untreated water in the process has hidden cost. The quality of water consumed depends to its source and season (Manezes, 2004).

Three types of water are used in textile wet processing factories: wastewater produced during the treatment process, raw water taken from subterranean sources, and processed water that has had its hardness removed. Soft water is utilised in treatment processes like dyeing and finishing as well as in the boiler to generate steam. Part of this soft water is also utilised for lab work, pilot processing, dyehouse cleaning, and other purposes. A loss of resources and economic results when factories use all of the water for soft water. Since the remainder is typically used for other household needs, the ratio of groundwater to soft water is typically greater than 70% (N.C., 2009).

Because water quality affects soils, crops, and the environment, it is crucial for human health as well as the amount and quality of grain crops (Kimbrough,1996; Hoek *et al*., 2001). A few uses of water include domestic use, mining, forestry operations, industrial, agricultural, and power generating (Khatri *et al*., 2014). One of the essential raw materials for all wet textile processes is water. The majority of textile processors pay little attention to the quality of the water, despite their best efforts to inspect the quality of every other raw material. Since water is used in processing units in far larger quantities than any other chemical, any deterioration in water quality will inevitably have an impact on processing. As such, it is essential that the water's quality should be given careful consideration. In the textile processing industry, the water's pre-processing treatment and conditioning are crucial. Richer the fabric's finish, the better the water quality (Smith, 1987).

The presence of contaminants in the water supply affects different textile wet processes in different ways. Consideration should be given to a number of primary types of water consumption, such as processing, potable, utility, and laboratory applications. In many cases, laboratory water must meet specific standards, which are typically satisfied by additional water purification within the laboratory. Chlorinating potable water can change the colour of dyes or have other negative impacts on processing. Poor lab-to-dye house coloration for dye formulations or other coloration issues might occasionally be caused by this. Hardness is one type of impurity that can lead to issues with boiler water or water used for humidification in production areas, which includes knitting, spinning, weaving, and inspecting regions. water hardness in systems that use direct atomization humidification (Smith, 1987).

The biological, chemical, and physical properties of the water were compared to a set of standards to determine the quality of the water. This makes it possible to assess if the water is suitable for consumption or use in the environment. When water comes into contact with dirt, rocks, or the earth, it gathers pollutants from these surfaces. When sewage or industrial wastes come into contact with water, the water gets contaminated. Remains of plants and animals decompose and introduce organic pollutants into water. Rainwater draws gases from the atmosphere, such as carbon dioxide, oxygen, and others (Krishnamurthy, 2001).

Hard water is defined as having a high concentration of ions such as calcium and magnesium. However, other dissolved metals can also create hardness in the form of divalent or multivalent cations, including manganese, iron, zinc, barium and aluminium (Sengupta, 2013). Since the removal method varies, the two types of hardness must usually be distinguished from one another. Water is classified as soft, hard, or very hard based on the amount of calcium and magnesium present, which can induce both temporary and permanent hardness. Technically speaking, several distinct water hardness scales (such as very soft, moderate, medium hard, hard, and very hard) were suggested (Kumari et al., 2016).

The presence of salt of calcium and magnesium ions in water are responsible for hardness of water and lead to the formation of insoluble precipitates with soap. Other metal solution such as iron may also contribute to hardness but they are present in small amounts as compared to calcium and magnesium. Calcium and magnesium compounds are commonly present as sulphates and chlorides are the cause of permanent hardness. Hard water is harmful both in the manufacturing and finishing processing of textile fiber, yarn, fabric and garment (Krishnamurthy, 2001).

The conventional method used to determine hardness is chemical titration. The hardness of a water sample is measured in parts per million, or ppm, and is represented in milligrammes per litre of calcium carbonate, or mg/l CaCO3. (Wurts *et al*., 1993).

Parts per million (ppm) is the common unit used for hardness of water. It is defined as the number of parts by weight of $CaCO_3$, present in million parts by weight of water. Hard water is not good for cleaning, bathing, drinking, or other household uses. Soluble soaps become insoluble precipitates when they come into contact with the ions responsible for hardness. As a result, soap is wasted during bathing and washing.

Hard water is harmful for a lot of businesses, including paper, sugar, and textiles. The following characteristics are impacted by dissolved salts such as Ca, Mg, Fe, and Mn: giving paper in the paper industry a glossy, smooth surface producing a rich lather in the laundry. Because hard water leads scales to form on inner plates, it is also unsuitable for creating steam in boilers. Hard water can also lead to other issues such as corrosion, foaming, and priming. Due to the hardness-producing ions interaction with different reactions, hard water is unsuitable for laboratory analysis **(Krishnamurthy, 2001).** Medium and large-scale processing houses can very well get installed a water treatment plant for softening the water by the ion-exchange process.

The present study has been taken to study the effect of hard, moderately hard and soft water on different textile processing (desizing, scouring, bleaching and dyeing). The work will be useful academically and industrially also. In textile industry, water consumption is far greater than amounts of fibres processed specially in wet processing treatments. Rinsing, washing operations consume enormous amount of water. Hard water creates many problems from desizing to finishing in textile industry. Hardness in wet processing leads to numerous other unfavourable consequences. Every fibre has a specific textile colour that is intended to be less soluble in hard water. Inadequate solubility causes the dye to become weaker and may even result in dyeing defects. The most important parameter to determine before dyeing for the presence of metal content is the hardness of the dye house water. It has more of an effect on human health as well. The work's outcomes will help future projections on the deterioration of water quality in the years to come, as well as how it will affect dyeing behaviours and the sustainability of the present dyeing method in light of the water's continuous deterioration.

Keeping above points in mind the present work has been under taken with the following objectives:

## 2. OBJECTIVES

1. To determine hardness of collected water sample.
2. To prepare different water samples of hard, moderately hard and soft water.
3. To carry out wet processing (desizing, scouring, bleaching and dyeing) on grey cotton fabric with different water samples.
4. To study the effect of hardness of water on textile processing.

## DELIMITATIONS

1. The study was de-limited to cotton fabric only.
2. The study was de-limited to water samples that is soft, moderately hard and soft.
3. The study was de-limited to desizing, scouring, bleaching and dyeing.

## RELATED STUDIES:

(i) Gupta (1998) The study was done with the objective to bleach the grey cotton fabric with $H_2O$, and NaOCI bleach on different pH, temperature, time and study on effect of dye evenness and physical properties of bleached fabric. They concluded that $H_20$, gave better white. Also, after bleaching stiffness, thickness were decreased and there was increase in crease recovery and wettability of fabric.

(ii) Kaur (1997) studied on "Effect of water hardness on dyeing and laundering of cotton fabric". The objective was comparison of percentage soil removal of washed soil samples and eveness of dye with hard and soft water. They concluded soil cleaning and eveness of dye efficiency was more when treated with soft water samples compared to hard water.

(iii) Bajpai (2001) The study was done to see the effect of different desizing methods on comfort and physical properties of Khadi with the objective to find a efficient method. Efficiency of desizing method was assessed by the weight loss percentage and amount of size removed. They concluded crease recovery and bending length and softness of fabric was decreased and tensile strength was increased.

(iv) Chaptwala et al. (1994) Study of "Effect of water hardness and total dissolved solids on dyeing of polyester and cationic dyeable polyester". Water sample with hardness range from 780 pm to 7200 ppm were collected from different units and for water softening using metaclaw -CL. They concluded the adverse effect of hardness of water on the results of dyeing, there is no need to soften the hard water by adding large quantity of metaclaw-CL.

(v) Shinde *et al*, (2015) did a study on the impact of water hardness, specifically the presence of calcium, magnesium, and iron, on the dyeing process of cotton with reactive dyes. The work experimented with various water hardness levels ranging from 20ppm to 2000ppm. The findings suggest that increasing water hardness negatively affects dyeing, leading to decreased fabric strength across all studied shades. It was found that the impact of water hardness varies with the type of reactive dye used, indicating the need for soft water or the addition of sequestering agents to optimize dyeing results. Overall, the study underscores the significance of water quality management in textile dyeing processes and emphasizes the necessity of tailored approaches to mitigate adverse effects of water hardness.

(iv) Chougule, (2020) did a study on "An experimental study of effect of water quality on cotton". The work highlights the critical importance of water quality in textile processing, emphasizing how these requirements must be met to ensure smooth operations. It discusses the significant variations in water usage among textile mills due to factors such as fabric types, processes, and water sources, with high water costs being a concern for many operations. The study focuses on experimental investigations into the effects of different water types on textile wet processing, aiming to understand and optimize water usage in the industry. After the dyeing process, processed cotton fabric was tested for K/s value using 2% reactive dye (Procion blue MG MR dye was used), washing fastness (AATCC), washing fastness (ISO-105), rubbing fastness (AATCC Wet), rubbing fastness (ISO-105 Dry), and rubbing fastness (ISO-105 Wet) was assessed. These tap water values were found to be more acceptable. These values were not at all satisfactory for bore-well water. Blended water performs at its best, making the usage of the blend system cost-effective.

(vii) Burkner *et al*., (1970) found no significant differences between water samples collected in the fall, winter, and spring seasons. However, water analyses revealed that softening equipment in several cases did not achieve the expected level of water softness. Additionally, the water supplies in the area were found to contain elevated levels of iron and manganese, exceeding thresholds known to cause staining during laundering. Consequently, the study recommended avoiding the use of chlorine bleach when iron and manganese are present in the water. White fabrics laundered in hard water with high iron and manganese content showed initial discoloration, which worsened with repeated washings. Moreover, for fabrics laundered in very hard water, tensile strength tended to decrease in the lengthwise direction. These findings underscore the importance of water quality management in textile processing, highlighting the need for effective softening methods and caution when dealing with water containing iron and manganese.

## 3. METHODOLOGY

The methodological approach followed was as follows:

3.1 Material Used
3.1.1 Fabric
3.1.2 Chemical
3.1.3 Water
3.1.4 Instruments
3.2 Determination of Preliminary Data of the Fabric
3.2.1 Thread Count
3.2.2 Thickness of the fabric
3.2.3 Weight per unit area
3.3 Determination of Water Hardness
3.3.1 Determination of Total hardness
3.3.2 Determination of Calcium hardness
3.3.3 Determination of Magnesium hardness
3.3.4 Estimation of Permanent hardness
3.3.5 Estimation of Temporary hardness
3.4 Wet Processing of Fabric
3.4.1 Desizing (Enzymatic)
3.4.2 Scouring
3.4.3 Bleaching
3.4.4 Dyeing Direct dye, Cold reactive dye)
3.5 Analysis of the Treated Samples
3.5.1 Weight loss percentage
3.5.2 Whiteness index
3.5.3 Wettability Test
3.5.4 Intensity of shade of the samples
3.5.5 Optical Densiy

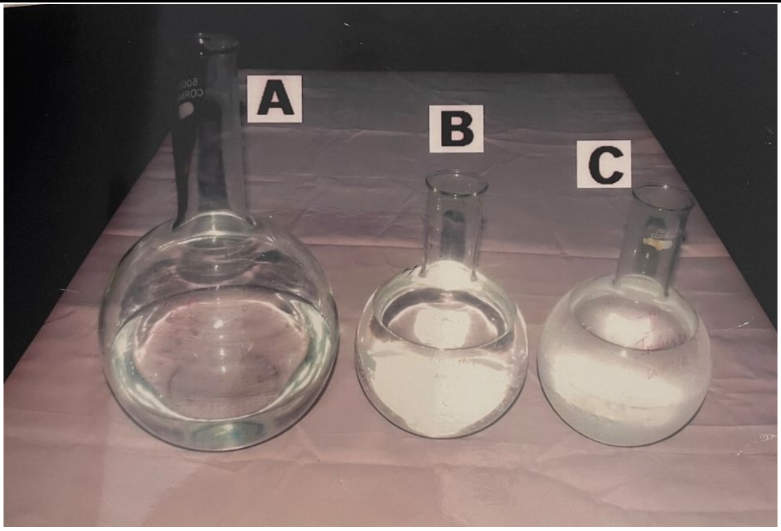



Fig.1 Water Samples (A: Soft Water, B: Moderately Hard Water, C: Hard Water)

## 3.1 MATERIAL USED -

**3.1.1 Fabric -** Pure 100 % grey cotton fabric was purchased from Jaipur.

3.1.2 Chemicals Used - EDTA, Erichrome Black-T, Murexide indicator, malt disatase, $HSO_4$, $H_2O_2$, NaOCI, Caustic Soda, direct dye, reactive dye.

3.1.3 Water - Tap water taken from "Textile Chemical Laboratory of Banasthali Vidyapith ".

3.1.4 Instruments – Pick glass, Thickness gauge, Spectrophotometer

## 3.2 DETERMINATION OF PRELIMINARY DATA OF THE FABRIC

3.2.1 Thread Count – Thread Count was determined by pick glass. The grey cotton fabric was spread on the table. Five square samples of size I" x I" were marked. The count of threads warp wise and weft wise with in these squares was determined. The average of these five readings were calculated.

3.2.2 Thickness of the Fabric - Thickness of the fabric was determined by using prolific Shirley thickness gauge.

3.2.3 Weight per Unit Area- Five specimen of 5 cm x 5cm were cut randomly from the fabric. Every sample was weighed on analytical balance.

## 3.3 DETERMINATION OF WATER HARDNESS

(a) Preparation of Buffer Solution (pH=10)- Dilute 142 ml of concentrated ammonia solution (sp. gr. 0.88-0.99) and 17.5 gm of A.R. quality ammonia chloride to approximately 250 ml with distilled water.

(b) Ericrome Black -T indicator – Mix 0.5 gm dye with 100 gm NaCl to prepare dry powder dissolve 0.2g of the solid indicator in a solution containing 15 ml of tri ethanolamine and 5 ml of absolute ethyl alcohol.

(c) Murexide Indicator – Prepare a ground mixture of 200 gm murexide with 100gm of solid NaCl.

(d) Sodium hydroxide buffer solution – Dissolve 80 gm NaOH and dilute it to 1000 ml.

(e) Standard EDTA solution 0.01 M (M/100)- For preparing M/100 solution of EDTA dissolve 3.723 gm EDTA Sodium Salt in distilled water and dilute it 1000 ml. Standardize against standard Calcium solution. (1 ml=1mg $CaCO_3$).

**3.3.1 Estimation of Total Hardness –**

Take 210 ml of water sample in conical flask before shaking it properly. Add 1-2 ml of Ammonium buffer solution. Add 1 drop of Ericrome black-T and titrate with standard EDTA (0.01M) till wine red colour change to blue. Note down the burette reading. Total hardness was calculated.

**Estimation of Total Hardness**

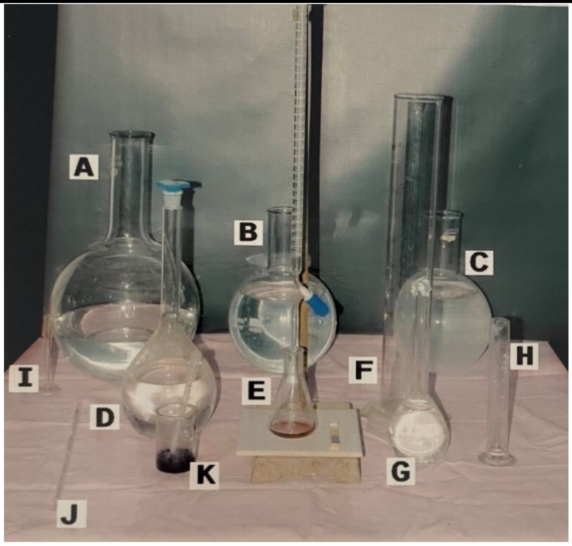


Fig.2 Estimation of Total Hardness

**Starting Point**

(Wine Red)

A: Soft Water B: Moderately Hard Water

C: Hard Water D: Ammonia Buffer Solution

E: Conical flask F: Measuring Cylinder (H, I)

G: NaOH Buffer Solution J: Pipette

K: Ericrome Black- T

**Estimation of Total Hardness**

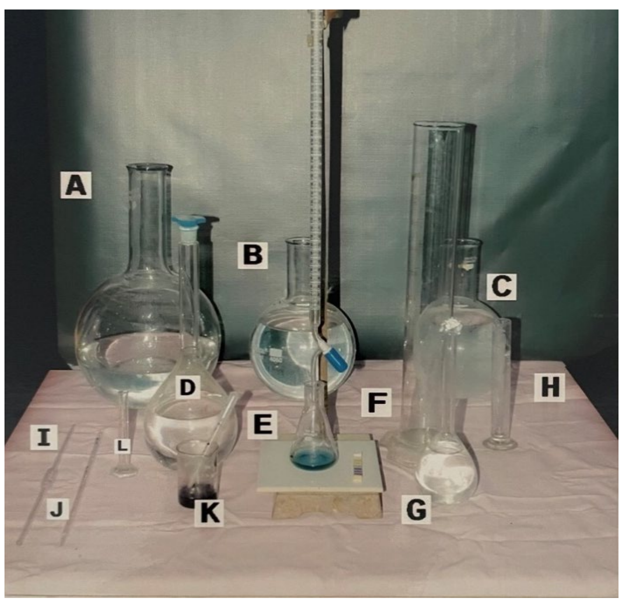


Fig.3 Estimation of Total Hardness

**Ending Point**

(Blue)

A: Soft Water B: Moderately Hard Water

C: Hard Water D: Ammonia Buffer Solution

E: Conical flask F: Measuring Cylinder (H, I)

G: NaOH Buffer Solution J: Pipette(J)

K: Ericrome Black- T

### 3.3.2 Estimation of Calcium hardness

Take 10 ml water sample in a conical flask. Add 1 ml NaOH buffer solution to raise pH to 12.0. Add a pinch of murexide indicator**.** Titrate immediately with EDTA till pink colour change to purple. Note down the volume of burette reading. Calcium hardness was calculated.

### 3.3.3 Estimation of Magnesium hardness

Magnesium hardness is calculated.

### 3.3.4 Estimation of Permanent hardness

Permanent hardness was estimated by evaporating 100 ml of sample to dryness on water bath. The residue was extracted with freshly boiled hot distilled water and was separated from the insoluble residue of calcium carbonate by filteration.

Filterate added in 10 ml water sample in conical flask. Add 1-2 ml ammonium buffer solution. Add a drop of Erocrome black- T solution and titrate with standard EDTA till wine red colour changes to blue. Note down the burette reading.Permanent hardness was calculated.

**Estimation of Calcium hardness**

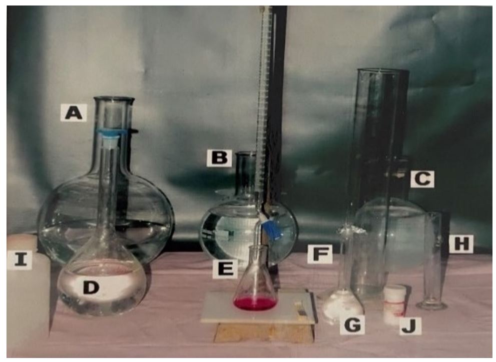



Fig.4 Estimation of Total Hardness

**Starting Point**
**(Pink)**

A: Soft Water B: Moderately Hard Water
C: Hard Water D: Ammonia Buffer Solution
E: Conical flask F: Measuring Cylinder (H)
I: Distilled Water G: NaOH Buffer Solution J: Murexide Indictor K :Pipette

**Estimation of Calcium hardness**

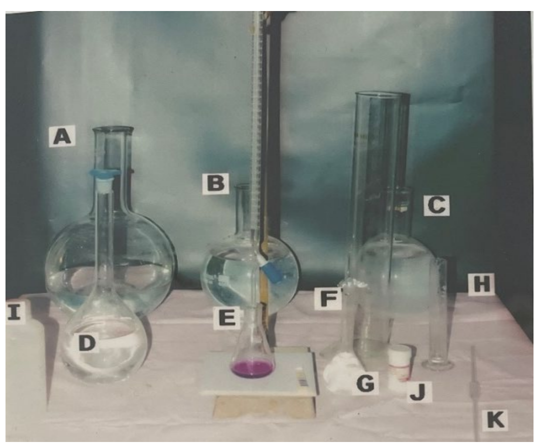



Fig.5 Estimation of Total Hardness

**Ending Point**
**(Violet)**

A: Soft Water B: Moderately Hard Water
C: Hard Water D: Ammonia Buffer Solution
E: Conical flask F: Measuring Cylinder (H)
I: Distilled Water G: NaOH Buffer Solution
J: Murexide Indicator K: Pipette

**3.3.5 Estimation of Temporary Hardness –** Temporary hardness was calculated.

## 3.4 WET PROCESSING FOR GREY COTTON FABRIC –

Desizing was done to remove sizing material. Then it was followed by scouring to remove impurities such as fats, waxes, pectin etc. Oxidative treatment for scouring was used to destroy natural colouring matter.

**3.4.1 Desizing –** For selecting best desizing process different process of desizing process were carried out to obtain best result. For desizing various process were done -Rot seeping, Acid desizing, Enzymatic (malt diastase desizing), Hydrogen peroxide desizing, Sodium per sulphate desizing

**(i) Rot Steeping** – This procedure involves steeping grey cotton cloth in water in an appropriate box for 12 hours at a temperature of about 40 °C. Microorganisms grow during storage and release enzymes that break down starch. This partially transforms the swollen and hydrolyzed starch into soluble form, which is subsequently extracted from the cloth by a standard water wash. The main problems with this approach are low efficiency brought on by extended treatment times and cellulose breakdown from mildew cross-infections if the fermentation process is not properly controlled.

**(ii) Acid desizing-** In this method grey cotton sample was treated with dilute 5% sulphuric acid at 40 °C for 3 hours.

**(iii) Enzymatic desizing –** (Malt diastase) 5 gm/ liter malt diastase enzyme was used for desizing at 60°C for 2 hours pH at 7.5 pH., 7gm/liter wetting agent at 98°C for 2 minutes.

**Summary of desizing process-**

**Table 1**

Rot Steeping –

| | | |
|---|---|---|
| 1. | M: L: R | 1:40 |
| 2. | Time | 12 Hrs. |
| 3. | Temperature | 40 |

**Table 2**

Acid desizing

| | | |
|---|---|---|
| 1. | M: L: R | 1:40 |
| 2. | Time | 3 Hrs. |
| 3. | Temperature | 40°C |
| 4. | Acid concentration | 5% $H_2SO_4$ O.W.F. |

**Table 3**

Enzymatic desizing-

| | | |
|---|---|---|
| 1. | M: L: R | 1.40 |
| 2. | Time | 2 Hrs. |
| 3. | Temperature | 50 °C |
| 4. | pH | 7.5 |
| 5. | Malt diastase | 5 gm/ liter |

**Table 4**

Sodium Persulphate desizing –

| | | |
|---|---|---|
| 1. | M: L: R | 1: 40 |
| 2. | Time | 2 Minutes |
| 3. | Temperature | 95 °C |
| 4. | pH | 10-10.5 |
| 5. | Sodium persulphate | 5 gm/ liter |
| 6. | Caustic Soda | 8 gm/ liter |
| 7. | Wetting agent (detergent) | 7 gm/ liter |

**Enzymatic desizing-** In actual grey cloth was padded wirh desizing mixture containing 5 gm/litre for 3 hrs. pH was adjusting 7.5. Enzymatic desizing was done on grey cotton at 50°C for 2 hrs with hard (500 ppm) moderately hard (230) and soft (less than 50 ppm) water.

**3.4.2 Scouring-** Scouring was done on desized sample. Scouring of cotton was done with alkaline agents. In this process the desized cotton sample was boiled in 6% sodium hydroxide (o.w.f) solution for 6 hours.

**Table 5**

Scouring-

| | | |
|---|---|---|
| 1. | NaOH | 6 % o. w.f. |
| 2. | Time | 6 Hrs. |
| 3. | Temperature | 100°C |
| 4. | M. L. R. | 1: 30 |

Sodium hydroxide scouring is done on enzymatic desized cotton fabric with hard, moderately hard and soft water.

**Table 6**

**3.4.3 Bleaching –**

| | | |
|---|---|---|
| 1. | H2O2 | 2.5 -4 % o. w. f |
| 2. | Soda Ash | 8 % o. w. f |
| 3. | Caustic Soda | 5 % o. w. f |
| 4. | Sodium Silicate | 3 % o. w. f |

All the quantities are expressed in percentage of the weight of fabric (o. w.f.). The scoured fabric was impregnated with bleaching liquor which contains $H_2O_2$ (50%), take 4% o. w. f., soda ash was 8% o. w. f. and caustic soda 5% o. w. f. and sodium silicate 3% o. w. f. used as a stabilizer for 2 hrs at the 100 °C. The pH of bleaching liquor was kept between 9-10. After bleaching, the fabric was rinsed thoroughly.

**3.4.4 Dyeing-**

**(i) Direct Dye –** 1% dye shade was done on bleached fabric with hard (500 ppm) and moderately hard and soft water.

**Table 7**

Recipe of Direct dye

| | | |
|---|---|---|
| 1. | Dye | 1 % shade |
| 2. | M. L. R. | 1 :40 |
| 3. | $Na_2CO_3$ | 5 % o. w. f. |
| 4. | NaCl | 5% o. w. f. |
| 5. | Wetting agent | As required |

Take calculated amount of dye in a bowl. Add lissapol and Soda ash. Stir it to make a dye paste. Take required amount of water according to M : L: R. When water was at 40°C added first lot of dye paste into water and dip the fabric and maintain for 10 minutes, then replace the fabric. Second lot of dye paste into dye bath and raise the temperature up to 60 °C. After addition of the dye, maintain the temperature at 60°C for 10 minutes. Then take out fabric from the dye bath. Add remaining part of the dye paste into water and raise the temperature up to 80 °C. Maintain temperature at 80°C and maintain for 10 minutes. Again, take out fabric from the dye bath. Remove the fabric from dye bath and required amount of salt was added and put the fabric back in the dye bath. Drain, rinse and dry the fabric.

(ii) Cold reactive dye – It is done on bleached fabric with hard and moderately hard and soft water.

**Table 8**

Recipe of Cold Reactive dye

| | | |
|---|---|---|
| 1. | Dye | 1% |
| 2. | M. L. R. | 1: 30 |
| 3. | Glauber's Salt | 30% |
| 4. | Soda Ash | 20% |

Take calculated amount of dye and water, continuously stir for 10 minutes. First installment of Glauber's salt and soda ash were added and continuously stirred for 5 minutes. Then, second installment of Glauber's salt and soda ash is added and stirred for 5 minutes. After this, last installment of Glauber's salt and soda ash is added and continuously stirred for 50 minutes. Then, fabric was added into it and continuously stirred for 50 minutes.Drain, rinse and dry fabric.

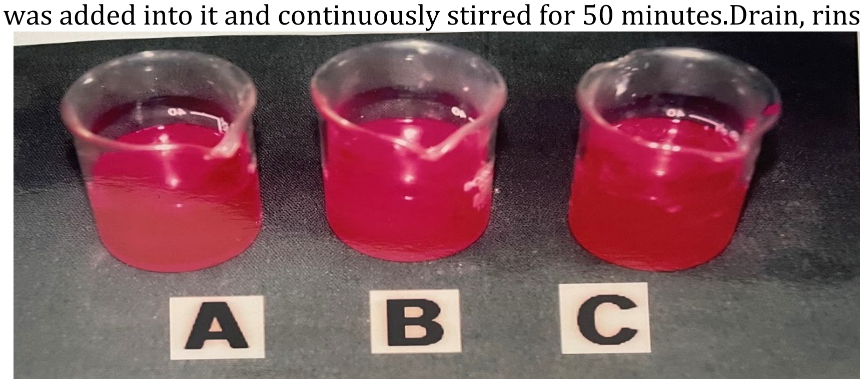



Fig.6. Dye liquor after dyeing (A: Soft Water, B: Moderately Hard Water, C: Hard Water)

## 3.5 ANALYSIS OF THE TREATED SAMPLES -

**3.5.1 Weight loss percentage-** The desized and scoured samples were evaluated on the basis analysis of weight loss percentage was measured by the following formula

$$\text{Weight loss }\% = \frac{\text{Initial weight} - \text{after weight} \times 100}{\text{Initial weight}}$$

**3.5.2 Whiteness index -** The bleached sample was evaluated by post graduate students of Clothing and Textiles. The samples were evaluated visually on the basis of whiteness index. The views were collected separately. Percentage was calculated from the collected data.

**3.5.3 Wettability Test -** The fabric was placed on embroidery frame. A drop of distilled water dropped by the burette. Time was taken with stop watch when drop sinks and time was again taken when the brightness of drop disappeared. Mean values ware calculated from the reading and with the help of readings and wettability of fabric was determined.

**3.5.4 Dye absorbency of the hard, moderately hard and soft water -**

Dye absorbency percentage was determined by spectrometer 20. Readings were taken in percentage. The instrument was set at 540 wave length with the help of knob. A blank solution (distilled water) was placed inside the instrument set monitor at zero. After that the dye solution which was tested placed inside the instrument and reading was directly read from the monitor. Two readings were taken before the dyeing and after the dyeing. Dye solution was diluted 10 times. The percentage dye absorption was calculated by the given formula-

$$\% \text{ Dye absorption} = \frac{\text{Before reading} - \text{after reading} \times 100}{\text{Before reading}}$$

Percentage dye absorption was calculated for hard, moderately hard and soft water treated sample.

**3.5.5. Intensity of Shade-** The dyed samples evaluated by intensity of shade of the samples was evaluated by panel of judges visually on the basis of two criteria that is dull shade and bright shade. The views were collected separately, percentage was calculated from the collected data.

## 4. RESULTS & DISCUSSION

The results of the study were divided under following sections -

4.1 Preliminary data of fabric
4.2 Analysis of water
12.1 Hardness of industrial area water
42.2 Hardness of moderately hard water
42.3 Hardness of distilled water
4.3 Analysis of desized samples
4.4 Analysis of scoured samples
4.5 Analysis of bleached samples
4.6 Analysis of dyed samples
4.7 Comparative analysis of all the samples

**4.1: Preliminary data of the fabric**

**Table 9**

Fabric details

| Fabric | Thread count | Thickness (mm) | Weight (gm/cm$^2$) |
|---|---|---|---|
| Grey cotton | 46× 45 | 0.33 | 1.99 |

The above data depicts that weight of the fabric was found to be 1.99 gm/m$^2$. The fabric was of 0.33 mm thickness and thread count of the fabric was 46 × 45.

## 4.2 ANALYSIS OF WATER

12.1 Hardness of Sample water

**Table 10**

Total Hardness

| S. No. | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.001 | 5.0 | 5.0 |
| 2. | 5.1 | 10.1 | 5.0 |
| 3. | 10.1 | 15.2 | 5.1 |
| 4. | 15.2 | 20.2 | 5.0 |

Total Hardness = 500

It was inferred from the above data that sample of water taken for the study was hard water as hardness was found to be 500 ppm.

**Table 11**

Permanent Hardness

| S. No. | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.00 | 0.9 | 0.9 |
| 2. | 0.09 | 1.8 | 0.9 |
| 3. | 1.8 | 2.7 | 0.9 |
| 4. | 2.7 | 3.6 | 0.9 |

The above table shows that the permanent hardness of water sample taken for the study was 90 ppm, when measured.

Temporary Hardness

Temporary Hardness= 410 PPM

It depicts that the temporary hardness of water sample taken for study was 410 ppm when calculated.

**Table 12**

Calcium Hardness

| S. No. | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.00 | 3.1 | 3.1 |
| 2. | 3.1 | 6.3 | 3.2 |
| 3. | 6.3 | 9.4 | 3.1 |
| 4. | 9.4 | 12.3 | 3.1 |

Calcium Hardness= 310 PPM

The table shows that the calcium hardness of water sample taken for study was 310 ppm when estimated.

Magnesium Hardness

Magnesium Hardness = 190 PPM

It depicts that the magnesium hardness of water sample taken for study was 190 ppm when estimated.

**Different type of hardness of water sample collected from Textile Chemistry Lab.**

**Table 13**

Type of Hardness

| Types of Hardness | Hardness in ppm |
|---|---|
| Total Hardness | 500 ppm |
| Permanent Hardness | 90 ppm |
| Temporary Hardness | 410 ppm |
| Calcium Hardness | 310 ppm |
| Magnesium Hardness | 190 ppm |

The above data depicts that water sample taken for the study had total hardness of 500 ppm. The permanent hardness was 90 pm, and temporary hardness was found to be 410 pm. Calcium and magnesium hardness was found to be 310 pm and 90 ppm respectively.

### 4.2.2 Hardness of moderately hard water

Table 14
**Total Hardness**

| S. No. | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.00 | 2.1 | 2.1 |
| 2. | 2.1 | 4.2 | 2.1 |
| 3. | 4.2 | 6.2 | 2.0 |
| 4. | 6.2 | 8.3 | 2.1 |
| 5. | 8.3 | 10.4 | 2.1 |

Total Hardness= 210 PPM

The above table shows that the total hardness of water sample was found to be 210 ppm, when calculated.

**Table 15**
Permanent Hardness

| S. No. | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.00 | 0.5 | 0.5 |
| 2. | 0.5 | 1.0 | 0.5 |
| 3. | 1.0 | 1.5 | 0.5 |
| 4. | 1.5 | 2.0 | 0.5 |

**Permanent Hardness = 50 PPM**

Temporary Hardness

**Temporary Hardness = 160 PPM**

It depicts that the temporary hardness of water was found to be 160 ppm when calculated.

**Table 16**
Calcium Hardness

| S. No. | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.00 | 1.5 | 1.5 |
| 2. | 1.5 | 3.0 | 1.5 |
| 3. | 3.0 | 4.4 | 1.4 |
| 4. | 4.4 | 5.9 | 1.5 |
| 5. | 5.9 | 7.5 | 1.5 |

**Calcium Hardness= 210 PPM**

It shows that the calcium hardness of water sample was found to be 50 ppm when measured.

**Magnesium Hardness**

**Magnesium Hardness= 60 PPM**

It depicts that the magnesium hardness of the water sample was found to be 60 ppm when calculated.

**Different types of hardness of moderately hard water –**

**Table 17**
**Type of Hardness**

| Type of Hardness | Hardness in ppm |
|---|---|
| Total Hardness | 210 ppm |
| Permanent Hardness | 50 ppm |
| Temporary Hardness | 160 ppm |
| Calcium Hardness | 150 ppm |

| | |
|---|---|
| Magnesium Hardness | 60 ppm |

The above data depicts that the moderately hard water had total hardness 210 ppm. The permanent hardness was 50 pm and temporary hardness was found to be 160 ppm. Calcium and magnesium hardness was found to be 150 and 60 ppm respectively.

### 4.2.3 Hardness of distilled water

**Table 18**

Soft Water (Water hardness)

| S. No | Starting Point (ml) | Ending Point (ml) | Burette reading (ml) |
|---|---|---|---|
| 1. | 0.01 | 0.1 | 0.1 |
| 2. | 0.1 | 0.2 | 0.2 |
| 3. | 0.2 | 0.3 | 0.3 |
| 4. | 0.3 | 0.4 | 0.4 |

**Total Hardness = 10 PPM**

It was inferred from the above table that the sample of water came in the range of soft water as hardness estimated was 10 ppm.

**Table 19**

Distilled Water

| Name of Hardness | Hardness in ppm |
|---|---|
| Total Hardness | 10 ppm |
| Permanent Hardness | ----- |
| Temporary Hardness | 10 ppm |

The above data depicts that the distilled water sample had total hardness 10 ppm and permanent hardness was nill. Temporary hardnes s was found to be 10 ppm.

**Comparison of different hardness of water samples**

**Table 20**

Comparison of Hardness of water

| Water Sample | Total Hardness (ppm) | Permanent Hardness (ppm) | Temporary Hardness (ppm) | Calcium Hardness (ppm) | Magnesium Hardness (ppm) |
|---|---|---|---|---|---|
| Hard Water | 500 | 90 | 410 | 310 | 190 |
| Moderately Hard Water | 210 | 50 | 160 | 150 | 60 |
| Soft Water | 10 | --- | 10 | 10 | ---- |

The above data depicts the comparison of hardness of different samples of hard water. It was found that total hardness of hard water was maximum (500 pm), for moderately hard water. It was 210 ppm and for soft it was 10 ppm. The permanent hardness of hard water and moderately hard water was found to be 90 ppm and 50 ppm respectively. The temporary hardness of hard water was maximum (410 ppm). For moderately hard water, it was160 ppm and for soft, it was 10ppm. And calcium hardness of hard water, was maximum (310 ppm), for moderately hard water, it was 150 ppm and for soft it was 10 ppm. The magnesium hardness of hard water and moderately hard was found to be 190 ppm and 60 ppm respectively.

## 4.3 COMPARATIVE ANALYSIS OF DIFFERENT DESIZING METHODS –

**Table 21**

Comparison of different desizing methods

| Desizing Methods | Percentage weight loss |
|---|---|
| Rot Steeping | 6.8 % |
| Acid Steeping | 6.7 % |
| Hydrogen Peroxide | 6.3 % |
| Sodium Persulphate | 11 % |
| Enzymatic | 21.5*% |

The above data depicts that the comparison between different desizing methods. It was observed that enzymatic (malt diastase) desizing method gave good results. The percentage weight loss was found to be maximum (21.5 %) with enzymatic (malt diastase) desizing.

Desizing Samples


1. Rot Steeping


2. Acid Steeping


3. Hydrogen peroxide


4. Sodium Persulphate


5.Enzymatic (malt diastase)

**Enzymatic desizing with different samples of water (hard, moderately hard and soft)**

**Table 22**

Fabric weight loss after Desizing

| Water Samples | Weight loss% |
|---|---|
| Hard Water | 19.2 % |
| Moderately Hard Water | 18.3% |
| Soft Water | 21.5% |

It was observed from the above data that the weight loss % of the grey fabric after desizing was found to be maximum (21.5%) when treated with soft water as compared to hard water and moderately hard water. It was observed that there was less difference in percentage weight loss of grey fabric after desizing when treated with hard and moderately hard water.

## DESIZED SAMPLES


**Hard Water**


**Moderately Hard Water**


**Soft Water**

**Sodium hydroxide scouring with different samples of water (hard, moderately hard and soft)**

**Table 23**

Weight loss during scouring process

| Water Samples | Weight loss % |
|---|---|
| Hard Water | 4.6 % |
| Moderately Hard Water | 5.6% |
| Soft Water | 5.3% |

It was inferred from the above data that weight loss percentage during scouring process was found to be maximum (5.6 %) when treated with moderately hard water, weight loss percentage after scouring was found to be 5.3 % when treated with soft water. It was observed that weight loss after scouring was maximum (4.6%) when treated with hard water.

**Desized and scoured Samples**

**Hard Water**

**Moderately Hard Water**

**Soft Water**

**Desized, scoured and Bleached Samples**

**Hard Water**

**Moderately Hard Water**

**Soft Water**

## 4.5 ANALYSIS OF THE BLEACHED SAMPLES

**Table 24**

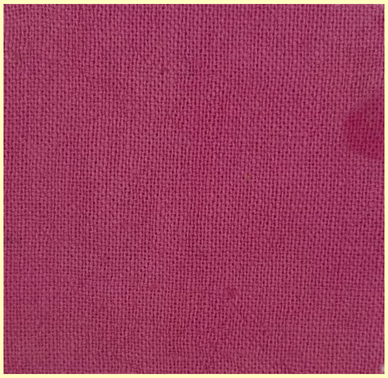
Whiteness of the bleached samples treated with different water samples (hard, moderately hard, and soft water)

| Water Samples | Whiteness |
|---|---|
| Hard Water | 4 |
| Moderately Hard Water | 3 |
| Soft Water | $^3/_4$ |

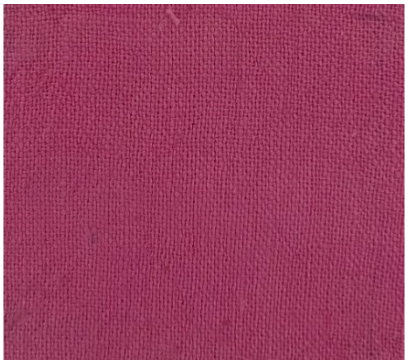
It was observed from the above data the whiteness of bleached sample was found to be maximum when treated with moderately hard water but there was not much difference found between bleached samples of moderately hard and soft water.

**Desized, Scoured, Bleached and Direct Dyed Samples**

Hard Water



Moderately Hard Water



Soft Water

## 4.6 ANALYSIS OF DYED SAMPLE

Exhaustion of dye (direct dye) on different samples treated with different water samples (Hard, moderately hard and soft)

**Table 25**

Intensity of Shade

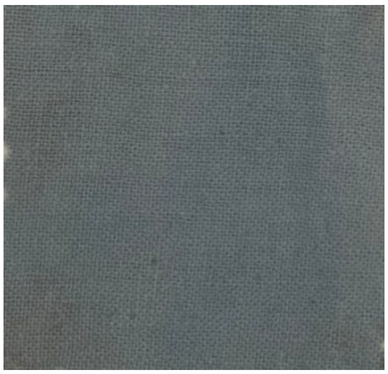
| Water Samples | Intensity of Shade |
|---|---|
| Hard Water | Fair |
| Moderately Hard Water | Very Good |
| Soft Water | Good |

It was inferred from the above data that the intensity of the shade of the dyed sample (direct dye) was found to be maximum when treated with moderately hard water compared to soft and hard water.

**Desized Scoured, Bleached and reactive Dyed Samples**

**Hard Water**

**Moderately Hard Water**



**Soft Water**

**Exhaustion of dye (cold reactive) on different samples treated with different water samples (hard, moderately hard and soft).**

**Table 26**
**Intensity of the shade (Cold Reactive)**

| Water Samples | Intensity of Shade |
|---|---|
| Hard Water | Fair |
| Moderately Hard Water | Very Good |
| Soft Water | Good |

It was observed from the above data that the intensity of the shade of the dyed sample (cold reactive dye) was found to be maximum when treated with moderately hard water as compared to soft and hard water.

**2.. Percentage dye absorption of dyed samples treated with different water samples (hard, moderately hard and soft)**

**Table 27**
Dye Absorption

| Water Samples | Percentage of absorption |
|---|---|
| Hard Water | 68% |
| Moderately Hard Water | 78.6% |
| Soft Water | 70.6% |

It was inferred from the above data that the percentage dye absorption of dyed sample was more when treated with moderately hard water as compared to soft and hard water.

**Wettability of Sample**

**Table 28**
Wettability of desized samples –

| S. No. | Desized Sample | Time Taken for absorption of water Droplet |
|---|---|---|
| 1. | Controlled | 2 Hours |
| 2. | Hard Water | 25 Minutes |

| | | |
|---|---|---|
| 3. | Moderately Hard Water | 65 Seconds |
| 4. | Soft Water | 50 Seconds |

It was observed that wettability of soft water was found to be good as compared to hard water. There was not much difference between moderately hard and soft water. And poor wettability was observed when treated with hard water.

**Table 29**

Wettability of scoured samples

| S. No | Scoured Samples | Time Taken for absorption of water droplet |
|---|---|---|
| 1. | Controlled | 50 Seconds |
| 2. | Hard Water | 30 Seconds |
| 3. | Moderately Hard Water | 13 Seconds |
| 4. | Soft Water | 10 Seconds |

It was inferred from the above data that wettability of moderately hard water was found to be good as compared to soft and hard water. There was not much difference between, moderately hard and soft water. And poor wettability was observed when treated with hard water.

**Table 30**

Wettability of the bleached samples

| S. No | Bleached Samples | Time Taken |
|---|---|---|
| 1. | Controlled | 50 Seconds |
| 2. | Hard Water | 5 Seconds |
| 3. | Moderately Hard Water | 3 Seconds |
| 4. | Soft Water | 4 Seconds |

It was observed from the above data good wettability of bleached samples when treated with moderately hard water was good as compared to soft and hard water. There was not much difference in wettability of bleached samples treated with different samples of water (hard, moderately hard and soft).

**Comparison of wettability of samples**

**Table 31**

Comparison of wettability of samples

| S. No. | | Hard Water | Moderately Hard water | Soft Water |
|---|---|---|---|---|
| | Control | 2 Hrs. | 2 Hrs. | 2 Hrs. |
| 1. | Desized Samples | 25 Minutes | 63 Seconds | 50 Seconds |
| | Control | 50 Seconds | 50 Seconds | 50 Seconds |
| 2. | Scoured samples | 30 Seconds | 13 Seconds | 15 Seconds |
| | Control | 15 Seconds | 15 Seconds | 15 Seconds |
| 3. | Bleached samples | 5 Seconds | 3 Seconds | 4 Seconds |

It was observed from the above table that bleached samples had good wettability as compared to desized and scoured sample when treated with different samples of water.

## 5. SUMMARY AND CONCLUSION

In desizing process, the percentage weight loss was found to be more with soft water as compared to hard and moderately hard water. In scouring process, it was found that weight loss percentage was found to be more with moderately hard water as compared to soft and hard water. In bleaching process, it was assessed by whiteness index that sample treated with moderately hard water was found white as compared to soft and hard water. In direct and cold reactive dyed samples when treated with moderately hard water was found to have darker shade as compared to when treated with soft and hard water. For dyed samples when treated with moderately hard water, it was found to have more percentage dye absorption as compared to when treated with soft and hard water.

The results of the study proved that extreme hardness of water has profound effect on textile processing as presence of calcium and magnesium salts decrease the efficiency of enzymes, sodium hydroxide, soaps, dyes and bleaching agents. Thus, it was concluded that moderately hard water taken for the study gave good results when taken for textile wet processing. Thus, it means some degree of hardness is required for different textile wet processing.

## CONFLICT OF INTERESTS

None

## ACKNOWLEDGMENTS

None

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