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Application of Different Inorganic Salts as Exhausting Agent for Dyeing of Cotton Knitted Fabric with Reactive Dye

By Kamrunnahar
Northern University

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Strictly as per the compliance and regulations of:

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Abstract: Aplenty of textile substrate especially cotton fabric dyed with reactive dyes because they produce a extensive gamut of bright colors with excellent colorfastness. As the reactive dye requires considerable quantities of salt and alkali for efficient application of colorants, this study is providing an assortment of knowledge about dyeing fabric with reactive dye and using some of the inorganic salts such as glauber salt, sodium chloride, zinc sulfate, aluminum sulfate, ammonium chloride and copper sulfate as an exhausting agent. Color strength measurements and colorfastness properties investigated here. In addition to, visage variation of dyed fabric also included in this study. In this experiment, 5 gm weights of samples dyed with 2% shade of a reactive dye at 60^{0}c within 60 minutes where salts applied in three different concentrations like 50 gm/l, 20 gm/l and lastly 10 gm/l. It has observed that colorfastness of the reactive dyed sample with sodium chloride and zinc sulfate is slightly higher though the color strength of fabric dyed with glauber salt and sodium chloride are better than rest other salts.

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I. Introduction

After the completion of three process that is adsorption, sorption and desorption then dye molecules saturated into the fabric and the overall procedure is known as exhaustion. The presence of dye alone in the dye bath does not fully dissipate in the fibers. For this reason, salt used as an exhausting agent with different colorants (direct dye, reactive dye) in textile dyeing process [1].

During the dyeing process of cellulosic fabric like as cotton, viscose or linen, after soaking into dye liquor the surface of the textile substrate get covered in negative ions and on the other hand some dyestuff such as direct dye or reactive dye also developed a negative charge which acts as a zeta potential[2]. As a result, the dye molecules are incapable to show a chemical reaction to the textile substrate and roll off the fabric surface that hinders the color changing capacity of the substrate. Salts play the role of glue that holds the dye molecules into the fabric and with the addition of alkali, certain percentage of dyestuff fixed with textiles.

Author: Lecturer, Department of Textile Engineering, Northern University Bangladesh, Bangladesh. e-mail: kns2221978@gmail.com

Based on using salts as electrolyte various studies carried out. M.A Salam, P.K Sheik, F.I Faruoique observed the effects of salt on jute fabric dyeing with reactive, direct and mordant dyes[3] as well as Awais Khatri experimented to improve the process substantivity of cotton with reactive dyes in the presence of biodegradable organic salts[4].

Reactive dyes are the leading class of dyestuff in the textile industries, and 50% of cellulosic materials dyed with it. They are also increasingly gaining importance for wool and polyamide fibers. Worldwide consumption of reactive dyes for cellulosic materials in the mid-1980s was about 10-12% [5]. As reactive dye reached the acme among various dyestuff so, now it is renowned for cotton dyeing with its superior fastness properties and a wide range of applications [6]. The reason of the excellent washing fastness is due to the covalent bonding between the fiber polymers and the dye molecules under alkaline pH conditions [7], and reactive dye is the only class of dyes amongst all the dyestuffs that makes covalent bond with the fiber and becomes a part of it. Nevertheless, it has some drawbacks for example; large amounts of salt are required to force its deposition on the fabric due to its low affinity of substrate. In addition to that, to fix up the dye with the textiles materials, fixing agent is needed and dye hydrolysis (20-70%) is another demerit of reactive dye [8,9]. To overcome the shortcomings of reactive dyes one experiment carried out by adopting lower liquor ratio [10]. Divyesh R. Patel, Jigna A. Patel, Keshav C. Patel had worked in another article on Synthesis and evaluation of a series of symmetrical hot brand bis azo reactive dyes [11]. Therefore, to minimize the drawbacks of reactive dye, the motive of this experiment is observing that within six inorganic salts that which one gives the best results at optimum salt concentration.

II. Materials And Methodology

a) Materials

i. *Fabric*

100% cotton knitted single jersey (160 GSM) scoured, and the bleached fabric collected from

Impress Newtex composite mills Limited and used without any further treatment.

ii. *Dye Stuff and Chemicals*

The chemicals and dyestuff collected from Impress Newtex composite mills Limited.
Dye: Reactive dye- Solazol red SP2B:2%

Electrolyte:

1. Glauber salt ($Na_2SO_4.10\ H_2O$): 50, 20,10 gm/l
2. Sodium Chloride (NaCl): 50, 20. 10 gm/l
3. Zinc sulfate($ZnSO_4$) : 50, 20,10 gm/l
4. Aluminum sulfate[$Al_2(SO_4)_3$] : 50, 20, 10 gm/l
5. Ammonium Chloride(NH_4Cl) : 50, 20,10 gm/l
6. Copper sulfate($CuSO_4.5H_2O$) : 50, 20,10 gm/l

Alkali:

1. Soda ash (Na_2CO_3): 5 gm/l
2. Sodium hydroxide (NaOH): 0.2 gm/l

Soaping agent (A340ND): 2 gm/l
Acetic acid (CH_3COOH):1 gm/l
Temperature: 60^0 c
Time: 60 min
M: L-1:8

b) *Methodology*

i. *Dyeing with Reactive dyes*

The dyeing of cotton fabric carried out by alkali controllable reactive dye (Solazol red Sp-2B) on Fong's sample dyeing machine. Keeping the material to liquor ratio 1: 8 for the shade percentage 2%.

The process sequence of cotton fabric with reactive dye (Solazol red Sp-2B):

Dyeing started in the neutral condition and at the ambient or room temperature (30^0c).

↓

Required water pureed in the dye pot as M: L ratio.

↓

Add salt to the dye pot and check the p^H

↓

Linear dosing of dye at 10-20 minutes and raise the temperature at 3^0c/min.

↓

Add soda ash and sodium hydroxide.

↓

After temperature reached, 60^0 c run the machine for 60 minutes at this temperature.

↓

Then drain the machine, and rinse the sample at 30^0c for 10 minutes.

↓

At last, a hot wash done using a soaping agent at 90^0c for 10 minutes.

ii. *Measurement of color strength*

The reflectance value of the dyed samples measured in the wavelength of 400-700 nm with 10 nm intervals using Data color 650® Spectrophotometer. This reflectance value is putting into the Kubelka Munk's theory to find out the color strength (K/S) of each specimen.

$$\text{Color Strength, } K/S = (1\text{-}R)^2 \div 2R.$$

iii. *Measurement of colorfastness*

To measure colorfastness properties of the dyed sample. Following fastness test done:

1. Colorfastness to wash: According to ISO Test Method, ISO 105-C10-2006.
2. Colorfastness to rubbing (Dry and Wet): According to ISO Test Method, ISO 105×12
3. Colorfastness to perspiration (Acid, Alkali): According to ISO Test Method, ISO 105×E04

Each sample tested for colorfastness to washing, rubbing, and perspiration that were prepared using Society of Dyers and Colourists (SDC) standard. As well as for assessing color change (ISO 105 A02) and color staining (ISO105 A03) standard grey scales utilized to obtain ratings of fastness test.

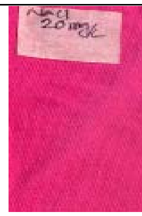
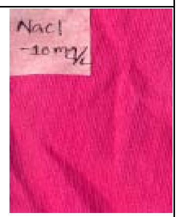
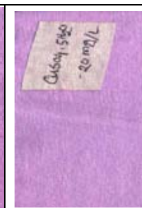
III. Results and Discussion

The experimental results represented in a series of tables and charts. Which provides information about the activity of salts acts as exhausting agent with respect to their various concentration. Color strength assessed instrumentally, and colorfastness considered on visual experience regarding grey scale rating.

a) *Visual appearance*

Although all the samples dyed with 2% shade of reactive dye, and higher variation observed in their look in the presence of different inorganic salt.

Table 3.1: Visual changes of dyed fabric using different salts with respective concentrations

Name	50gm/l salt	20 gm/l salt	10 gm/l salt
Sodium Chloride	 **Raspberry**	 **Deep pink**	 **Cerise**
Glauber salt	 **Ruby**	 **Rose**	 **Cerise**
Zinc sulfate	 **Lavender pink**	 **Light hot pink**	 **Deep hot pink**
Aluminum sulfate	 **Thulian pink**	 **Amarnath pink**	 **Carnation pink**
Ammonium Chloride	 **Hot pink**	 **Thulian pink**	 **Amarnath pink**
Copper sulfate	 **Wisteria**	 **Mauve**	 **Thistle**

It mentioned earlier that all the samples are dyed in the shade %, so their hue should be the same at equal salt concentration. Nevertheless, their look is far different to each other. In addition to, it observed that zinc sulfate and ammonium chloride give bright shade at lower salt concentration while rest of the salts yield vivid color with higher salt concentration. The main reason for this fact is –

The dye Solazol red SP-2B belongs to the vinyl sulphone functional group. Moreover, it works well in the alkaline media. It noticed from the following tabulated data prior dyeing only glauber salt exhibits basic media of salt solution then the sodium chloride is in slightly high pH condition, and other salt solutions are in the state of acid condition.

Table 3.2: Before adding dye in water liquor the P^H of the salt solution mentioned in the following table

Name of the salt	P^H at different salt Concentration after adding salt		
	50 gm/l	20 gm/l	10 gm/l
Glauber salt	8.86	8.40	7.88
Sodium Chloride	7.18	7.46	7.61
Zinc sulphate	4.63	6.14	6.81
Aluminum sulphate	3.05	3.44	3.61
Ammonium Chloride	6.3	6.6	6.8
Copper sulphate	4.21	4.84	5.11

b) Color Strength (K/S) Analysis

The color strength of sample dyed with sodium chloride and glauber salt are nearly same for 50 gm/l salt that is 9.1 and 9.2 respectably. However, the k/s value of sample using 20 gm/l salt is 5.2, and 10 gm/l salt is 4.7 for sodium chloride; whereas the k/s value of sample dyes with 20 gm/l is 6.5 and 10 gm/l is 5 in respect of glauber salt.

The color strength of dyed sample using ammonium chloride is not so high; nevertheless, it is higher than copper sulfate and zinc sulfate.

So the series of salt regarding color strength-

Glauber salt > Sodium chloride > Ammonium Chloride > Zinc sulfate > Aluminum Sulfate > Copper sulfate.

Table 3.3: Maximum k/s value with respective wavelength for different salt concentration

Name of the salt	50gm/l salt concentration		20gm/l salt concentration		10gm/l salt concentration	
	Wavelength	k/s value	Wavelength	k/s value	Wavelength	k/s value
Glauber salt	540	9.2	540	6.5	540	5
Sodium chloride	540	9.1	540	5.2	540	4.7
Zinc sulfate	550	0.45	550	1.8	540	2.3
Aluminum sulfate	554	1.15	550	1	550	0.48
Ammonium chloride	550	3	550	4.8	550	2
Copper sulfate	540	0.75	540	0.7	540	0.65

c) *Evaluation of Colorfastness Properties*

i. *Colorfastness to Wash*

Wash fastness of sample dyed with sodium chloride, zinc sulfate and glauber salt are comparatively higher than sample dyed with other salts.

Figure 3.1 shows that color fastness to washing (regarding color change) of dyed sample with six inorganic salts at different concentration. It observed that for 50 gm/l salt glauber salt and sodium chloride have higher (5) rating than another salt while zinc sulfate and aluminium sulfate show high rating (4.5) for 20 gm/l and 10 gm/l salt conc.

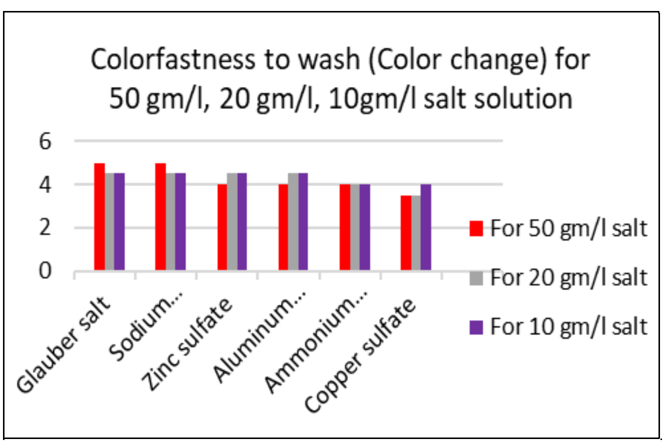


Figure 3.1: Bar chart of colorfastness to wash for color change

Color staining of wash colorfastness of dyed sample using different inorganic salts according to their salts concentration shown in figure 3.2. For 50gm/l, 20gm/l, 10 gm/l salt solution, zinc sulfate shows outstanding color staining wash fastness and copper sulfate exhibit lower color staining fastness grading. On the other hand, moderate fastness observed for sodium chloride and glauber salts.

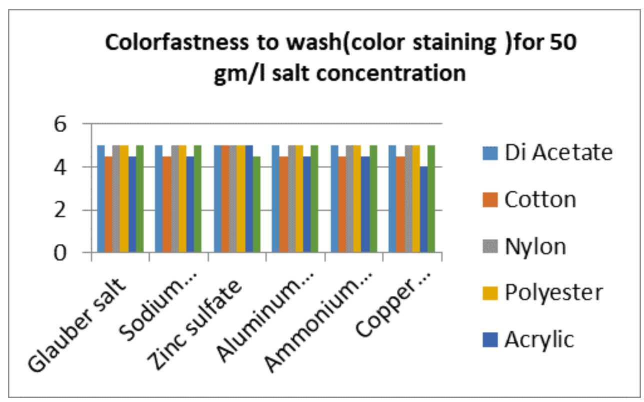


Figure 3.2: Color fastness to wash for color staining at 50 gm/l salt concentration

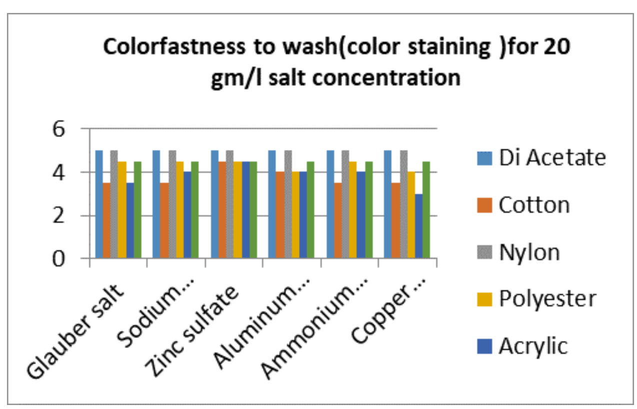


Figure 3.3: Colorfastness to wash for color staining at 20 gm/l salt concentration

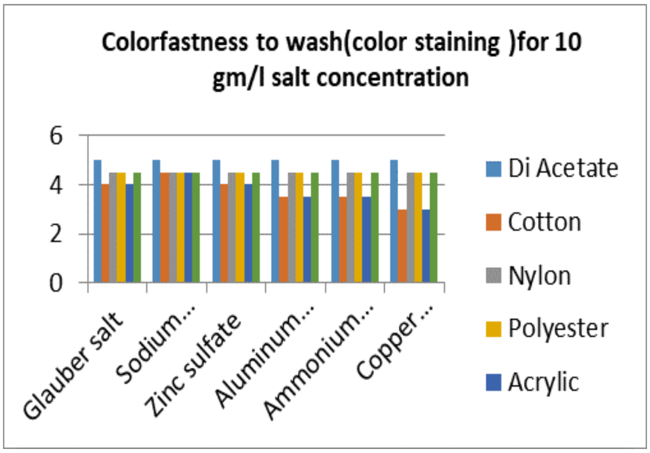


Figure 3.4: Colorfastness to wash for color staining at 10 gm/l salt concentration

ii. *Colorfastness to rubbing*

Dry rubbing fastness of the entire sample dyed with various salt is same. That is for 50 gm/l, 20 gm/l and 10 gm/l salt concentration in the fastness grading of dry rubbing is 5.

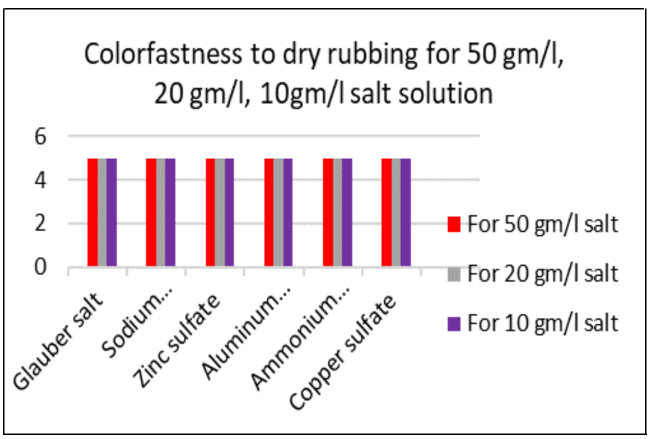


Figure 3.5: Colorfastness to dry rubbing at 50gm/l,20 gm/l and 10 gm/l concentration

Figure 3.4 shows that wet rubbing fastness of the sample dyed with zinc sulfate is relatively better (grade 5) than fabric colored with other salt and which is same for all three concentration. Though wet rubbing fastness of 20 gm/l and 10 gm/l glauber salt and sodium chloride shows equal grading like as zinc sulfate and both have lower fastness rating at 50 gm/l than zinc sulfate.

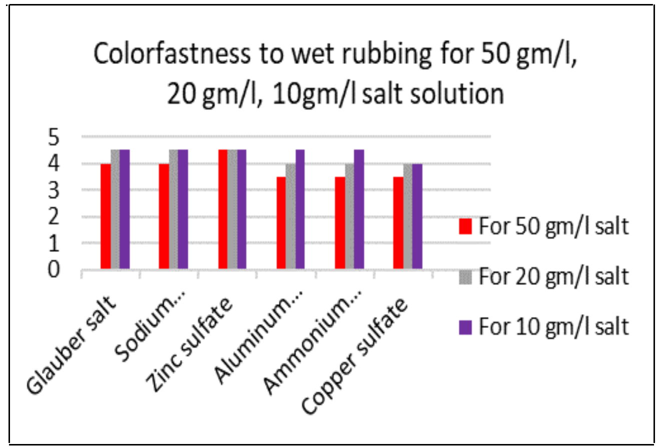


Figure 3.6: Colorfastness to wet rubbing at 50gm/l,20 gm/l and 10 gm/l salt concentration

iii. *Colorfastness to acid perspiration*

For 50 gm/l salt solution, color change to acid Perspiration of sample dyed with zinc sulfate is higher (grade 5), but in case of 20 gm/l and 10 gm/l, both glauber salt and sodium chloride expose grade 5 in rating scale for color change.

Regarding color staining, acid perspiration, fastness of colored fabric is better for zinc sulfate at 50 gm/l however; at 20 gm/l and 10 gm /l salt concentration, acid perspiration fastness is good for sodium chloride and glauber salt respectively.

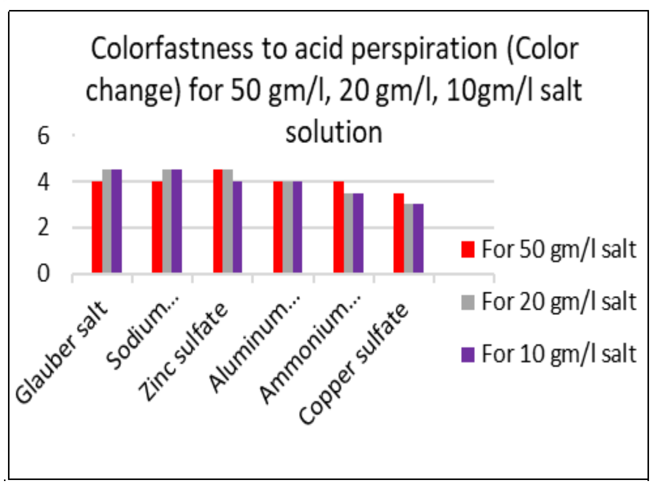


Figure 3.7: Colorfastness to acid perspiration for color change at various salts concentration

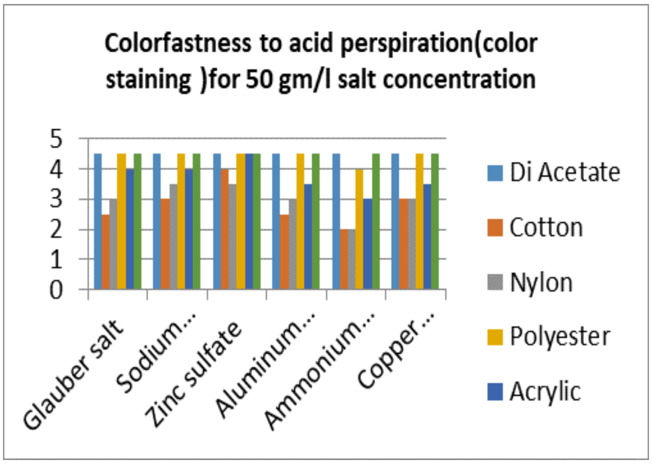


Figure 3.8: Colorfastness to acid perspiration for color staining at 50 gm/l salt

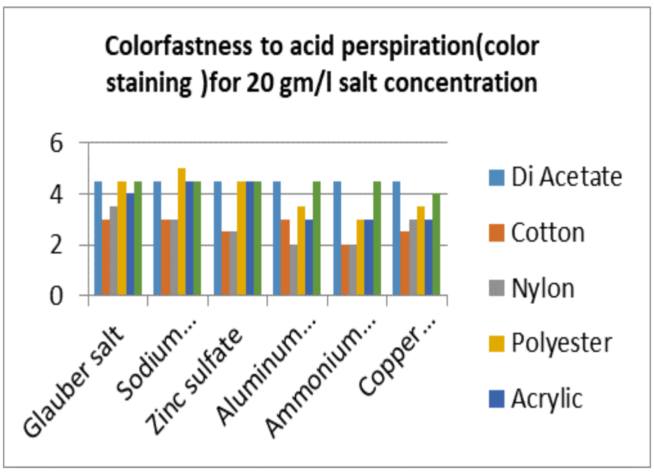


Figure 3.9: Colorfastness to acid perspiration for color staining at 20 gm/l salt

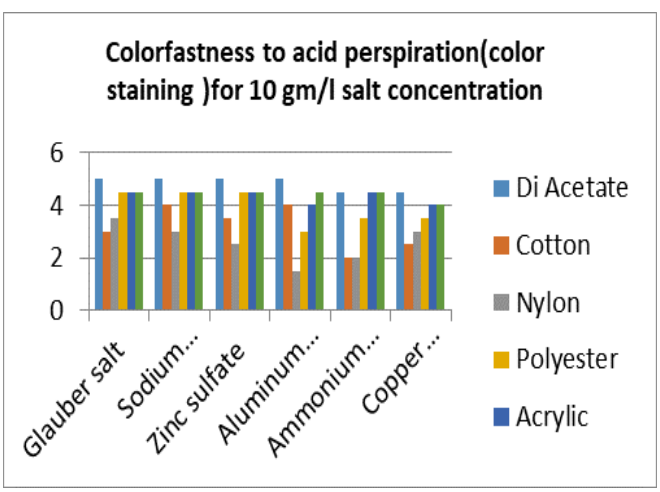


Figure 3.10: Colorfastness to acid perspiration for color staining at 10 gm/l salt

iv. *Color fastness to alkali perspiration*

For colorchange of alkali perspiration fastness, sample dyed with both zinc sulfate and aluminum sulfate is good(4.5) at 50 gm/l concentration but at 20 gm/l and 10 gm/l salt concentration fabric dyed with zinc sulfate, sodium chloride show equal color grading.

On the other side of the coin, alkali perspiration of color staining grading is good for dyed fabric with zinc sulfate at 50 gm/l and 20 gm/l, but sample dyed with sodium chloride has moderate color staining grade at those salt concentration, and at 10 gm/l, it shows good fastness properties for color staining.

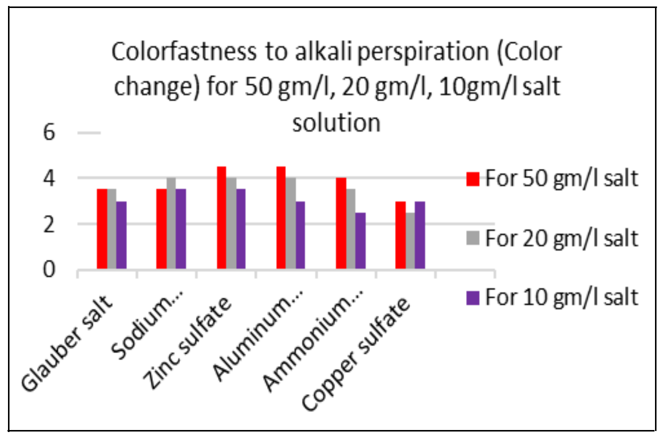


Figure 3.11: Colorfastness to alkali perspiration for the color change at various salts concentration

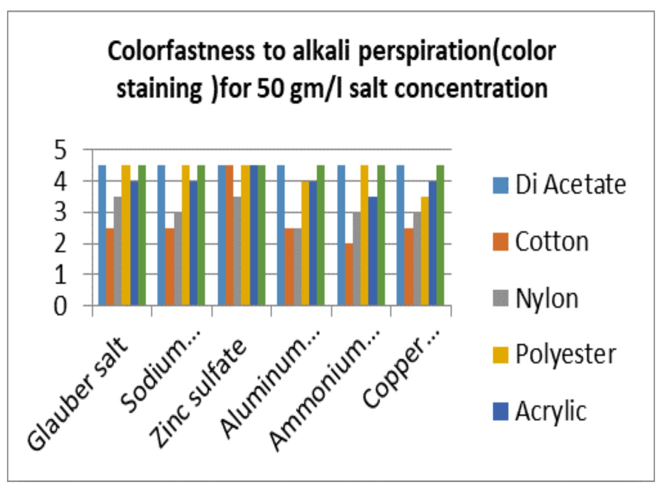


Figure 3.12: Colorfastness to alkali perspiration for color staining at 50 gm/l salt

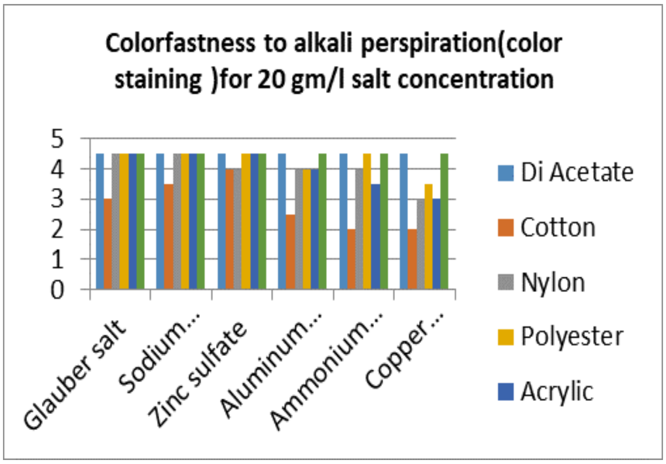


Figure 3.13: Colorfastness to alkali perspiration for color staining at 20 gm/l salt

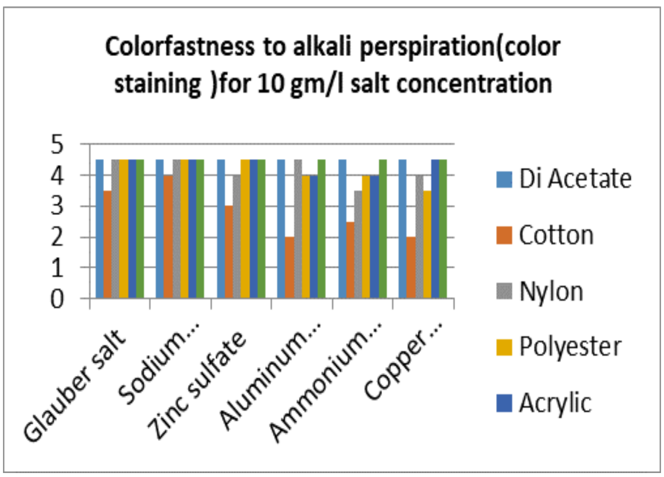


Figure 3.14: Colorfastness to alkali perspiration for color staining at 10 gm/l salt

IV. Conclusion

This study has demonstrated that appropriate salt is an essential factor in the reactive dyeing process. After completing all experimental tests, it revealed that all color fastness properties of zinc sulfate is higher than sodium chloride and glauber salt but the color strength is incredibly lower. So concerning to the color strength and fastness properties, sodium chloride is the best electrolyte as an exhausting agent for reactive dye and then glauber salt come to the next among all salts.

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