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Analytical Chemistry for Study of Sulphate Levels in Dyeing Effluent: A Quantitative Approach

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Abstract

This research work explains the analytical aspects and possible environmental ramifications of measuring and detecting sulphate in particular in the water discharged from dyeing processes. Sulphate levels in dyeing wastewater must be estimated and managed in order to protect the environment, comply with regulations, run businesses efficiently, and uphold public confidence. Sustainable industrial practices depend on reducing sulphate levels through enhanced process controls and treatment technology. Analytical methods are used to determine the amount of sulphate in dyeing effluents, and the results are compared to the recommended level provided by standard bodies.

Keywords: *Sulphate Concentration, Dyeing Effluents, Analytical Technique.*

1. Introduction

In Textile dyeing industry some of the inorganic salts used to effectively apply colorant as an exhausting agent are Glauber Salt ($Na_2SO_4.10\ H_2O$), Sodium Chloride (NaCl), Zinc Sulphate ($ZnSO_4$), Aluminum Sulphate [$Al_2(SO_4)_3$] and Ammonium Chloride (NH_4Cl). Suitable electrolyte are used in cotton good for the reactive dyeing process. The various electrolytes of Glauber salt, common salt and vacuum salt for the dyeing of cotton fibers in a dyeing process are used. [1] It is not necessary for the dye molecule and textile substrate to have uniform properties in order to mix. Under such circumstances, a catalyst is needed to speed up the fabric's dyeing process. This vital catalytic function is fulfilled by salt. Water and salt have a very strong attraction for one another. In general, salt is required in three ways. Firstly, it is needed to force dye into the fabric during the dying process. Second, while dyeing fabrics, the use of salt causes the maximum number of dye molecules to be exhausted. Furthermore, it functions as an electrolyte to facilitate the migration, adsorption, and fixing of the dye to the cellulose substrate. Salts are essential to reactive dyeing because they increase the dye's affinity for the fibre, speed up the dye's association with the fibre, and lowering its solubility. Typically, common salt or Glauber's salt are used for this. The equipment may corrode due to the chlorine ions found in regular salt. Thus, Glauber's salt is always recommended in place of regular salt. Sodium sulphate decahydrate, or $Na_2SO_4.10H_2O$, is also known as "glauber's salt" and is typically found as colourless or white monoclinic crystals. It effloresces when exposed to relatively dry air, generating powdered anhydrous sodium sulphate. The salt was first made (from Hungarian spring waters) by Johann Glauber. Water soluble and bitter in flavour, Glauber's salt is also frequently used in dyeing and occasionally employed as a mild laxative in medicine. Sodium chloride is also known as vacuum salt (NaCl). [2] Due to its widespread affordability, absorbency and softness, cotton is the most often used natural fibre in the textile industry. To enhance its wettability, dyeability, chemical affinity, crease recovery, hydrophilicity, and functional qualities, various chemical changes have been researched. Anionic dyes are an easy way to colour cotton fibres, however most typical cotton dyeing methods call for significant amounts of salt and alkali (preferably Glauber's salt (Na_2SO_4) or common salt NaCl) to promote increased dye-uptake, which mostly stay in the dye bath after the dyeing process and can be harmful to the environment. Cotton fabric is frequently dyed using reactive dyes because they generate vibrant colours in a variety of shade ranges, have good colour fastness, and work well with a variety of application techniques.[3] Many textile substrates are available, particularly cotton cloth coloured with reactive dyes, which yield a wide range of vibrant colours with superior colorfastness. Dyeing fabric with reactive dye and some inorganic salts as an exhausting agent, such as glauber salt, sodium chloride, zinc sulphate, aluminium sulphate, ammonium chloride, and copper sulphate are used. This is because the reactive dye requires significant amounts of salt and alkali for the effective application of colourants. [4] Dye that reacts are highly fashionable in clothing since they are safe for the environment and have reasonable general fastness characteristics. Nevertheless, applying such pigments requires an extremely high salt concentration. The increased salinity in the drain water stream caused by the salt released from clothing colouring has a detrimental effect on the ecology of the surrounding area.[5] There are different chemical process takes place in dyeing industries and Sulfur can enter in dyeing effluent through various stages of the dyeing process, depending on the specific dyes and chemicals used such as Sulfur Dyes. These dyes contain sulfur as a key component in their chemical structure. During the dyeing process, sulfur dyes react with the textile substrate to form strong covalent bonds, resulting in durable coloration. However, unreacted or excess sulfur dyes can end up in wastewater if not properly fixed or rinsed off after dyeing. Sulfuric acid is commonly used in the pretreatment and dyeing processes to adjust pH levels, particularly in dye baths where acidity is crucial for dye absorption onto the textile fibers. Residual sulfuric acid can be carried over into wastewater if not neutralized or treated before discharge. Various auxiliary chemicals used in dyeing, such as reducing agents, leveling agents, and carriers, may contain sulfur compounds as part of their formulation. These compounds can leach into the dye bath and subsequently into wastewater during the dyeing process. Sulphate salts may also be present in dye formulations or as impurities in raw materials used in the dyeing process. These salts can dissolve in water and contribute to sulphate levels in dyeing effluent. Cleaning processes and rinsing of dyeing equipment and textiles after dyeing can also contribute to sulfur-containing residues entering wastewater. This can include residual dyes, chemicals, and detergents that may contain sulfur compounds. When the concentration of Sulphate get increased in the water bodies due to directly or indirectly discharge of dyeing effluent water in water reservoir then it affect aquatic ecosystems by altering pH levels and creating conditions that are unfavorable for many aquatic organisms. This disruption can lead to reduction in biodiversity and ecosystem health. Sulphates can infiltrate into groundwater sources if not properly managed. Elevated sulphate levels in drinking water can have adverse health effects on humans, such as gastrointestinal issues like diarrhea and dehydration, especially in vulnerable populations like infants and the elderly. Sulphates in wastewater can contribute to the corrosion of pipes and infrastructure if they accumulate and react with metals. This can lead to increased maintenance costs and potential failures in water distribution systems. In aquatic environments, sulphates can contribute to eutrophication when they promote excessive growth of algae and aquatic plants. This can lead to oxygen depletion in water bodies, which in turn harms fish and other aquatic life. While sulphates themselves are not typically emitted directly into the air from dyeing processes, they can contribute to particulate matter (PM) formation indirectly. Fine sulphate particles can become airborne through processes such as aerosolization of contaminated water, contributing to respiratory problems and reducing air quality. Sulphur discharge leads to environmental pollution and can contribute to the formation of fine particulate matter , which poses risks to human health and contributes to climate change. Exposure to sulphur compounds can cause respiratory issues, aggravate existing respiratory conditions, and

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contribute to cardiovascular problems. Prolonged exposure may lead to chronic health problems and reduced quality of life. Sulphates can act as osmotic laxatives, drawing water into the intestines and potentially causing discomfort and increased bowel movements. High sulphate concentrations in drinking water can impart a bitter taste and unpleasant odor, which may reduce consumer acceptance and satisfaction with the water quality. Sulphates themselves are generally not considered toxic at typical environmental concentrations. However, they can contribute to the formation of other contaminants such as hydrogen sulphide (H_2S) under anaerobic conditions, which is toxic and can pose additional health risks. Sulphates are not typically as harmful as some other contaminants, their presence in high concentrations can lead to a range of environmental and health concerns. It is important for industries and municipalities to monitor and manage sulphate levels in water sources through appropriate treatment and regulatory compliance to minimize potential risks to both human and environmental health. [6,8-10]

2. Methodology

Dyeing industrial effluents water were collected from three different dyeing industry of Bhiwandi city, District Thane, state Maharashtra, India. The sample were brought to the laboratory immediately and analysis of sulphate ions were done by Turbidimetric measurements. Series of standard solution of sulphate were prepared and for each solution turbidance were measured on the instrument, the samples were also given the same treatment for finding the turbidance and then from turbidance value the concentration of sulphate ions present in the dyeing effluents were evaluated. Light scattering intensity by the sulphate ions present in the solution were measured at 200 NTU and 2000NTU and amount of sulphate present in the effluent water were determined.

3. Result and Discussion

Calibration graph of turbidance in NTU plotted against concentration of sulphate ions in ppm to find the level of unknown amount of sulphate in effluent water, as shown in Figure 1 & Table 1.

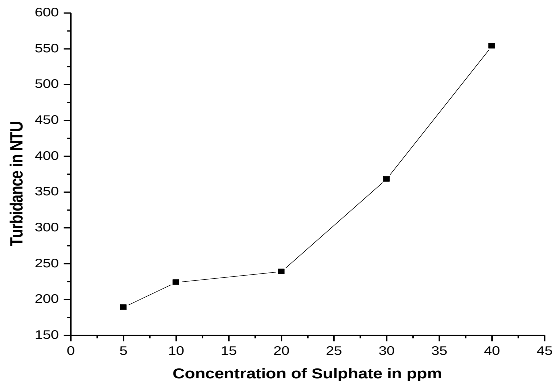

Figure 1 Graph of Turbidance in NTU against Concentration of Sulphate in ppm

Table 1 Amount of Sulphate in Dyeing Textile Effluent Water

Sr.No.	Sample	Amount of Sulphate in ppm
1	Effluent-I	7.5
2	Effluent-II	2.7
3	Effluent-III	7.6

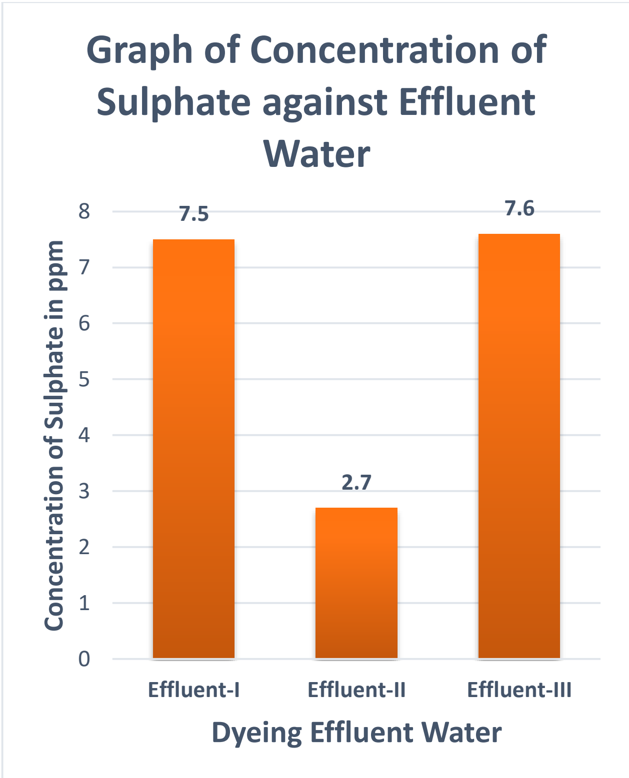

Figure 2 Amount of Sulphate in Effluent Water

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Amount of Sulphate present in dyeing effluent I is 7.5 ppm, in effluent II 2.7 ppm, in effluent III 7.6 ppm, this all values of Sulphate found in dyeing textile industrial water are lower than the standard bodies value of discharge of dyeing effluent in to water system. Concentration of Sulphate shall not exceed 300 ppm as per Jordanian Standard (JS: 893/2002) for discharge to streams, wadis and water storage areas and for ground water discharge as shown in Figure 2. The amount of sulphate should not go above 500 ppm as per Jordanian Standard (JS: 893/2002) for effluent reuse for agricultural irrigation. Amount of Sulphate determined in industrial effluents are all lesser than the standard values given in Table 2 & 3.

Table 2 Standard Value of Sulphate Concentration [7]

Jordanian Standard (JS: 893/2002) for discharge to streams, storage		
	Discharge to streams, wadis and water storage areas	Ground water discharge
Sulphate	300 ppm	300 ppm

Table 3 Standard Value of Sulphate Level [7]

Jordanian Standard (JS: 893/2002) for effluent reuse for agricultural irrigation	
Parameter	(mg/L) Guideline values (maximum permissible)
Sulphate	500 ppm

Conclusion

As per result and discussion the concentration of Sulphate in the dyeing effluent water samples are less than the prescribed values by the standard bodies so with respect to sulphate ions the discharge of these under study dyeing effluents in environment are safe and does not leads to much environmental damage but then also it should be tried to make its concentration near to nil in effluent water as high level of sulphate in the environment has numerous detrimental effect and damage to ecosystem.Therefore implementing wastewater treatment technologies such as chemical precipitation, coagulation-flocculation, biological treatment, and advanced oxidation processes can effectively remove or reduce sulfur compounds from wastewater before discharge. Optimizing dyeing processes to ensure efficient dye fixation can minimize the amount of unreacted dyes and chemicals entering wastewater. Exploring alternative dyeing techniques and chemicals that are less sulfur-intensive or using low-sulfur or sulfur-free dyes can help reduce sulfur in effluent. Implementing water recycling and reuse systems within the dyeing process can minimize overall water usage and reduce the volume of wastewater requiring treatment. Regulatory measures and adherence to environmental standards are essential to ensure that sulphate discharges are kept within safe limits to protect both human health and the environment.

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