Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **15(2),** 88-93, June **(2025)** *Res. J. Chem. Sci.*

Quantifiable assessment of Iron content in Dyeing and Colouring industrial seepages: Implications for Environmental impact and Treatment strategies

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Available online at: www.isca.in, www.isca.me
Received 20th August 2024, revised 27th February 2025, accepted 4th April 2025

Abstract

The amount of iron (Fe) in dyeing industrial effluents can vary significantly depending on several factors such as the type of dyes used, the dyeing process, and the efficiency of wastewater treatment systems in place. In general, iron may be present in these effluents due to the use of iron-based mordants in dyeing processes or as impurities in the dyes themselves. Additionally, iron can also enter the effluents from equipments corrosion or from water sources used in the dyeing process. To determine the exact amount of iron in a specific dyeing industrial effluent, it is required to conduct a comprehensive analysis through different chemical and instrumental methods or other suitable analytical techniques. These analyses would provide precise measurements of the concentration of iron in the effluent.

Keywords: Iron, Dyeing Effluent Water, Chemical Method, Environmental Impact, Treatment Strategies.

Introduction

The dying process is one of the most crucial elements of the successful trading of textile products. In addition to the design and lovely colour, consumers usually look for certain basic product attributes, such as excellent fixation with regard to light, perspiration, and washing, both initially and after prolonged wear. To ensure these characteristics, the color-giving chemicals used in fibres must have high affinity, uniform colour, fading resistance, and economic viability. Based on the properties of the fibre and the dyes and pigments to be used in textiles, a number of steps are selected for use in contemporary dyeing technology. These procedures include fixing properties compatible with the material to be coloured, commercial availability, classification, chemical structure, economic considerations, and many more[1-4].

Water is mostly used to clean, dye, and add auxiliary chemicals to the materials as well as to rinse the treated fibres or fabrics. The dyeing process consists of three steps: preparation, dying, and finishing.

The materials must be prepared by eliminating any unwanted pollutants prior to dying. Aqueous alkaline solutions and detergents can be used for cleaning, or enzymes can be used. Many fabrics are bleached with hydrogen peroxide or chlorine-containing chemicals to remove their original colour. Optical brightening agents are used if the cloth is to be marketed white without being coloured.

Applying colour to textile surfaces using aqueous methods is known as dyeing. Usually, synthetic organic dyes are employed, and some processes could require high pressures and temperatures. It's important to remember that neither dye can colour every fibre in the world nor that all known dyes can colour any fibre. This step involves applying dyes and chemical aids, such as surfactants, acids, alkali/bases, electrolytes, carriers, levelling agents, promoting agents, chelating agents, emulsifying oils, softening agents, etc., to the textile in order to achieve a uniform depth of colour with colour fastness qualities suitable for the fabric's intended use. This process includes diffusion of the dye into the liquid phase, adsorption onto the outer surface of the fibres, and finally diffusion and adsorption on the inner surface of the fibres. Depending on the textiles' expected final use, different fastness properties may be required.

Additionally, binders, polymers that hold the pigment to the fibers can be used to pigments and to colour them. Pigments do not have a chemical or physical affinity for the fibres, which sets them apart from dyes. The process of giving fabric chemical treatments to improve its quality is called finishing. Permanent press treatments, water proofing, softening, antistatic protection, soil resistance, stain removal, and microbial/fungal protection are some of the fabric treatments used in the finishing process[1-4].

The specific concentration of iron in textile dyeing effluent can be determined through laboratory testing or analysis of wastewater samples taken from the dyeing facility. Regulatory authorities often impose limits on the concentration of iron and other contaminants in industrial effluent to protect the environment and public health.

There is a comprehensive overview of the significant environmental challenges posed by the textile industry, particularly concerning water consumption and wastewater pollution. The textile industry is a heavy consumer of water, utilizing large amounts for various processes such as dyeing and washing. On an average the textile and dyeing industry can take around 200 liters of water per kilogram of yard goods treated per diurnal. Weave processes like dyeing and finishing contribute significantly to industrial wastewater generation, accounting for approximately 17-20% of industrial wastewater globally. In India alone, textile industries reportedly utilize millions of gallons of water daily.

Synthetic dyes used in textile processes pose a major threat to water bodies due to their inadequate binding to fabric, .These dyes, particularly aromatic and heterocyclic ones, are stable and challenging to degrade, impacting the environment and aquatic life. Textile effluents are characterized by their intense color, high pH, biochemical oxygen demand (BOD), suspended solids, chemical oxygen demand (COD), salts, and elevated temperatures. Furthermore, the usage of hazardous chemicals in different textile processes may also result in the presence of heavy metals as lead, chromium, and mercury[5].

Methodology

Textile and Dyeing industrial effluent water composed from the three dissimilar dyeing trades were taken and analysed for Iron content volumetrically by potassium dichromate using diphenylamine indicator. Dyeing effluents are reacted with stannous chloride and mercury chloride then after titrated with potassium dichromate to give the estimation of amount of iron present in the effluent water with respect to change in the colour of the solution in the presence of an indicator.

Statistical Analysis: Evaluating differences across sampling sites in terms of error is a robust approach since it helps pinpoint any significant deviations and trends. Excel's functions and formulas were used to handle such quantitative analyses. Mean ± Standard Deviation shows data's central tendency and variability, while Standard Error indicates mean reliability. Standard Deviation and Variance measure data dispersion, aiding in reporting, publication, and regulatory compliance.

By monitoring and regulating iron levels, statistical analysis helps to protect aquatic life and lessen water pollution. Strategies for sustainable wastewater management that minimise environmental harm are informed by data analysis. Statistical analysis guarantees that iron discharge regulations are followed, preventing financial and legal consequences. Too much iron in water can have negative health effects. Waterborne disease prevention and risk identification are aided by statistical analysis. Risk assessment and mitigation strategies are informed by data analysis that establishes the toxicity of iron-containing effluents. Statistical analysis finds ways to optimise resource allocation and reduce wastewater treatment costs.

By increasing dyeing efficiency, data-driven insights, lower production costs and improve product quality. Treatment plant performance is assessed using statistical analysis, which improves operations and lowers maintenance expenses.

Results and Discussion

Statistical analysis offers trustworthy data for well-informed choices about environmental management, wastewater treatment, and process optimisation. By identifying patterns and trends in iron content, data analysis makes proactive management and predictive modelling possible. Consistent effluent quality that satisfies industry standards and customer expectations is guaranteed by statistical analysis. Data analysis guides studies on cutting-edge dyeing and wastewater treatment technologies. Industries can enhance process efficiency, minimise environmental effects, and optimise wastewater treatment by using statistical analysis on iron content data.

Using Microsoft Excel to analyse the heavy metal data gathered for present study requires a systematic strategy to calculate different statistical measures and evaluate sampling site differences. The procedures for computing and assessing the measured values—such as mean, middle point, most common/frequent value, highest value/peak, lowest value, dispersion, variability, and dispersion measure—as well as clearly presenting the findings are mentioned below.

Following are the statistical analysis of iron content determined in dyeing effluent water of different sampling area.

Table-1: Statistical Analysis for Fe metal.

Dyeing Effluent-I										
No.	Amount of Fe in gram/1000ml	Mean	Median	Mode	Max	Min	Error	SD	Avg. Deviation	Variance
1	0.5585	0.5585	0.5864	0.5585	0.5864	0.5585	0.0093	0.01610	0.0124	0.000259
2	0.5864									
3	0.5585									

Table-2: Statistical Analysis for Fe metal.

Dyeing Effluent-II										
No.	Amount of Fe in gm/1000ml	Mean	Median	Mode	Max	Min	Error	SD	Avg. Deviation	Variance
1	2.7925	2.7925	2.8204	2.7925	2.8204	2.7925	0.0093	0.01610	0.0124	0.000259
2	2.8204									
3	2.7925									

Table-3: Statistical Analysis for Fe metal.

Dyeing Effluent-III										
Sr.No.	Amount of Fe in gm/1000ml	Mean	Median	Mode	Max	Min	Error	SD	Avg. Deviation	Variance
1	2.234	2.234	2.289	2.234	2.289	2.234	0.018333	0.0317542	0.024444	0.0010083
2	2.289									
3	2.234									

Table-4: Quantity of Iron in Textile Effluent.

Sr.No.	Sample	Concentration of Iron in g/litre	Amount of Iron in mg/litre
1	Effluent-I	0.5585 ±0.01610	558.5 ±0.01610
2	Effluent-II	2.7925± 0.01610	2792.5± 0.01610
3	Effluent-III	2.234± 0.0317542	2234.0± 0.0317542

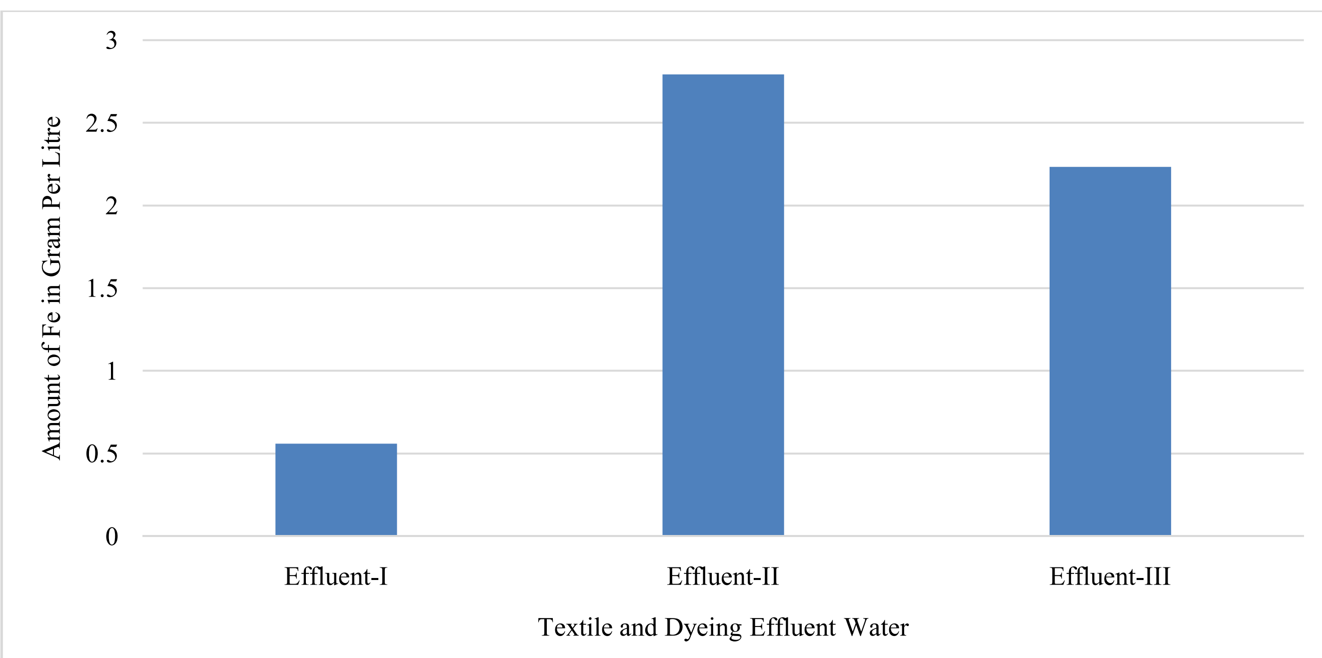

Figure-1: Amount of Fe Metals in Effluent Water.

Amount of Fe present in dyeing effluent I is 0.5585 gram with standard deviation of 0.01610, in effluent II 2.7925 gram with standard deviation of 0.01610, in effluent III 2.234gram with standard deviation of 0.0317542, this all values of Iron metal found in dyeing textile industrial water are very higher than the standard bodies value of discharge of dyeing effluent in to water system. Concentration of Iron shall not exceed 5.0ppm according to FAO guidelines. Acclaimed determined concentration (ppm is 5.0) as per the prescribed value of (JS: 893/2002) for discharge to watercourses, stowage, recommended by (JS: 893/2002) for seepage reprocess for agronomic irrigation. Amount of Iron determined in industrial effluents are all greater than the standard value and values given in the following tables[4].

Table-5: Standard Values of Iron Metal suggested by FAO.

FAO guidelines for trace metals in irrigation water: Recommended maximum concentration (mg/L)		
Factor	Commende-dextreme concentration (mg/L)	Remark
Fe	5.0ppm	Although it can cause soil acidity and reduce the availability of vital phosphorus and molybdenum, it is not harmful to plants in aerated soils. Sprinkling from above can leave ugly deposits on buildings, machinery, and plants.

Table-6: Jordanian Standard Values for Iron Metal

(JS: 893/2002) for absolution to brooks, stowing		
	Absolution to brooks, stowing, wadis and water storing areas	Earth water discharge
Fe	5.0	5.0

Table-7: Jordanian Permissible Values for Iron Metal

(JS: 893/2002) for seepage re-claim for agrarian irrigation	
Parameter	(mg/L) Guideline values (maximum permissible)
Fe	5.0

The concentration of Fe gained by current investigational work is greater than the normal approved values. This information received from experimental work of this paper highlights the significant environmental challenges posed by the textile industry, particularly in terms of wastewater treatment. Given the complex composition of textile industry effluents, effective treatment methods are crucial to mitigate their environmental impact.

Following treatment strategies should be adopted for reducing the level of Fe metal discharged as contaminant or as wastes.

Adsorption process involves the attachment of pollutants to a solid surface, typically activated carbon or other adsorbents. Adsorption is effective for removing dyes and organic compounds from wastewater.

Coalescence includes the adding of chemicals like aluminum sulfate (alum) or ferric chloride to dislocate suspended units and assist their removal by sedimentation or filtration.

The Fenton process involves the addition of hydrogen peroxide and ferrous ions to wastewater under acidic conditions, leading to the generation of hydroxyl radicals. Because of their high reactivity, these radicals have the ability to oxidise organic contaminants, such as dyes, into smaller, less dangerous molecules.

Photo-Fenton Process, similar to the Fenton process, but with the addition of UV or visible light to enhance the generation of hydroxyl radicals and accelerate the oxidation of organic pollutants.

Ozonation comprises the usage of ozone gas to oxidize organic combinations in wastewater. Ozone is a powerful oxidant that can effectively degrade dyes and other organic pollutants.

Electro-coagulation encompasses the usage of electrical current to weaken suspended particles and facilitate their removal through coagulation and flocculation processes.

These treatment methods can be applied individually or in combination depending on the specific characteristics of the textile effluent and the desired treatment outcomes. Additionally, advancements in treatment technologies, such as membrane filtration and biological treatment, may also be considered to achieve more comprehensive and sustainable wastewater treatment in the textile industry.

Aquatic environments are heavily contaminated by environmental pollutants such as organic pollutants, dyes, and heavy metals. However, because of their high cost and disadvantageous economic effects, these above mentioned technologies are not frequently adopted. The most adaptable and often used method for purifying water is adsorption. Activated carbon, metal hydroxides, and alumina-silica are the most widely used adsorbent materials. Numerous studies have demonstrated that using activated carbon to remove colours is both more easily accomplished technically and economically. Because of its high degree of surface, microporous structure, high surface area, and high adsorption capacity, activated carbon is a commonly utilised adsorbent. Photocatalytic degradation by semiconducting nanomaterials is another method of eliminating dye molecules. Because of their special characteristics, like small size, these nanoscale particles show promise in this field.

Thus, removing dangerous and harmful materials from water is a significant environmental issue. To detect, monitor, evaluate, and treat the aquatic environment, scientists have created a number of instruments and methods throughout the last few decades. These methods include oxidation, ion exchange, ozonation, chlorination, membrane separation, coagulation, flocculation, adsorption, bioremediation, electrochemical precipitation, and chemical precipitation. Numerous companies, industries produce and discharge a significant amount of coloured wastewater, many of which contain dyes that pose major risks to human health and other living things. As a result, the aforementioned polluted wastewater must be treated before it is released into any bodies of water[9].

Conclusion

Implications for Environmental Impact and Treatment Strategies: The waste from the textile industry, along with that of several other industries, has drawn a lot of attention recently since, as was already said, it may produce huge volumes of effluents that, if improperly handled before being disposed of into water resources, can be problematic. The textile industry generates a vast array of dyes, chemicals, and derivatives that vary with the seasons, resulting in highly complex wastewaters that make it more challenging to find practical, feasible solutions. The methods now employed by these companies to handle textile effluents are limited since they generate various kinds of waste.These businesses thus generate wastewater that is highly organically loaded and coloured, which can significantly worsen surface water pollution and other environmental problems[6,7].

The presence of untreated dye in textile effluents can hinder sunlight penetration into water bodies, adversely affecting aquatic organisms and disrupting the photosynthetic process in plants.

Various treatment techniques such as physical, chemical, biological treatment, and advanced oxidation processes (AOPs) are employed to mitigate the environmental impact of textile wastewater. These methods aim to remove color, solids, organic load, and toxic metals from the effluents, thereby reducing their harmful effects on the environment.

Addressing the challenges associated with textile wastewater requires a comprehensive approach involving efficient water management practices, adoption of sustainable technologies, and stringent regulatory measures to ensure environmental protection and sustainability within the textile industry[5].

Even at very low environmental concentrations (1 mg/L), dyes are hazardous due to their complex, stable chemical structure that prevents degradation. Because most colours are not biodegradable, there is a serious environmental issue.

Significant health problems brought on by dye pollution include skin rashes, headaches, lack of focus, nausea, diarrhoea, exhaustion, soreness in the muscles and joints, wooziness, troubleinhalation, uneven heartbeats, annexations, and, tumour.

There are two classes of toxicity related to textile dyes: genotoxicity (chronic toxicity) and acute toxicity. Acute toxicity includes oral consumption and breath; genotoxicity is the major lasting potential health risk associated with certain textile dyes. Deoxyribonucleic acid (DNA) is usually damaged by genotoxic substances through a chemical reaction.

The three main ways that heavy metal exposure in humans, found are by oral intake, inhalation, and skin exposure.

Because heavy metals are widely distributed in the environment and have both acute and long-term effects on plant growth, heavy metal contamination in farming soil is another major ecological issue.

When heavy metal concentrations are excessive, they can cause main health problems. The brain, central nervous system, lungs, liver, kidneys, blood components, and other important organs can all be harmed or have their functioning compromised by heavy metal toxicity. Prolonged exposure to hazardous heavy metals can result in multiple sclerosis, Alzheimer's disease, muscular dystrophy, and other malignancies.

Eating is thought to be one of the primary ways that these heavy metal exposures occur.

Because harmful heavy metals can pose serious health risks to humans and other living things, removing them from textile wastewater is an important concern. From this angle, it makes sense to create treatment plans to eliminate dangerous metallic ions from fabric waste in order to lessen the amount of pollution that enters the environment[9].

Efforts to minimize the amount of iron in textile dyeing effluent may include using alternative dyeing processes or chemicals that generate less iron-containing waste, implementing more efficient wastewater treatment technologies, and recycling or reusing water within the manufacturing process to reduce overall water consumption and the introduction of contaminants like iron into the effluent.

References

1. Moore S. B., & Ausley, L. W. (2004). Systems thinking and green chemistry in the textile industry: concepts, technologies and benefits. *Journal of cleaner production*, 12(6), 585-601.

2. Reddy S.S., Kotaiah B. and Reddy N.S.P. (2012). Color pollution control in textile dyeing industry effluents using tannery sludge derived activated carbon. *Bulletin of the Chemical Society of Ethiopia*, 22(3), 369-378.

3. Vassileva V., Valcheva E. and Zheleva Z. (2012). The kinetic model of reactive dye fixation on cotton fibers. *Journal of the University of Chemical Technology and Metallurgy*, 43(3), 323-326.

4. World Health Organization. (2006). A compendium of standards for wastewater reuse in the Eastern Mediterranean Region. In *A compendium of standards for wastewater reuse in the Eastern Mediterranean Region*.

5. Christian, D., Gaekwad, A., Dani, H., MA, S., & Kandya, A. (2023). Recent techniques of textile industrial wastewater treatment: A review. *Materials Today: Proceedings*, 77, 277-285.

6. Zollinger, H. (1987). Azo dyes and pigments. *Colour chemistry-synthesis, properties and applications of organic dyes and pigments*, 92-100.

7. Dos Santos, A. B., Cervantes, F. J., & Van Lier, J. B. (2007). Review paper on current technologies for decolourisation of textile wastewaters: perspectives for anaerobic biotechnology. *Bioresource technology*, 98(12), 2369-2385.

8. Velusamy, S., Roy, A., Sundaram, S., & Kumar Mallick, T. (2021). A review on heavy metal ions and containing dyes removal through graphene oxide□based adsorption strategies for textile wastewater treatment. *The Chemical Record*, 21(7), 1570-1610.]

9. Zollinger, H. (2003). Color chemistry: syntheses, properties, and applications of organic dyes and pigments. John Wiley & Sons.