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Unraveling the Decontamination Potential of Synozol Yellow Dye from Wastewater by Cobalt Ferrite Nanoparticles and their Composite with Bark of *Ficus religiosa*

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ABSTRACT

One of the greatest sources of industrial wastewater is the textile industry which produces effluents that are rich in persistent dyes, high chemical oxygen demand, and complex salts and organic compounds mixtures. The reactive dyes, including Synozol Yellow, are some of these pollutants that are hazardous to the environment and health in that they are not biodegradable and they may produce intermediates which are toxic. Cobalt ferrite (CoFe2O4) nanoparticles and their complex with Ficus religiosa bark-based biochar were produced and tested in this study with regard to their capacity to decontaminate dye-contaminated waste water.

The production of cobalt ferrite nanoparticles was done through a co-precipitation technique and the composite material was produced through a hydrothermal technique with the addition of biochar as a support media. Fourier transform infrared spectroscopy (FTIR) was used to describe the characteristics of the materials, scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) were used to confirm the existence of the functional groups, the porous morphology, and the elemental composition that would be favorable to adsorption process. Experiments of batch adsorption were performed to examine the operational parameters such as pH, dosage of adsorbent, initial dye concentration and contact time.

The findings revealed that the performance of dye removal was extremely affected by pH with the most favorable performance at around pH 6. A higher dosage of adsorbent increased the dye removal because of the availability of more active sites but a change in the dye concentration and contact time affected the adsorption behavior. It was shown that the composite material showed better adsorption ability than that of the isolated components due to the synergistic actions between magnetic nanoparticles and biomass-derived functional groups. Also, cobalt ferrite magnetic nature allowed easy separation and reuse of the adsorbent.

In general, it can be concluded that CoFe2O4 nanoparticles and Ficus religiosa biocomposite of nanoparticles are a promising, inexpensive, and green method of removing reactive dyes in wastewater, and may have implications in multifaceted textile effluent treatment procedure.

Keywords: Cobalt Ferrite Nanoparticles, Ficus Religiosa Biochar, Synozol Yellow Dye, Wastewater Treatment

Introduction

One of the most water intensive industries in the world is the textile manufacturing industry(Catarino et al., 2025). The wet-processing processes (scouring, bleaching, dyeing, printing, rinsing and finishing) involve very large amounts of process water, and have very contaminated effluents; it has been estimated that the fashion/textile value chain contributes a very large portion of industrial wastewater (the fashion industry itself has been estimated as contributing around 20 percent of all industrial wastewater), and the water consumption in the sector is measured in billions to trillions of liters each year(Al Montasir et al., 2025). The textile industry achieves this massive water footprint which makes it a target of water-quality management and reuse plans(Aykaç Özen et al., 2025).

Textile effluents are heterogeneous and fluctuating mixtures, the distinguishing pollutants of which are a high colour loading (dyes), a high chemical oxygen demand (COD), suspended solids and salts (high TDS), surfactants, sizing agent and occasionally heavy metals (mordants)(El Ouadrhiri et al., 2025). Even synthetic dyes are produced and consumed at very high scale, and it is not uncommon in the dyeing process to lose to effluent a non-negligible portion of dyes(Abd El-Fattah et al., 2025). Moreover, numerous reactive dyes are developed to be wash-fast and not biodegradable that enhances their persistence in a water body(Rani et al., 2025).

Ecological and social impacts of colour pollution have been much more significant than their own since even slight residues of the dyes decrease the penetration of light through surface waters, inhibited photosynthesis in aquatic plants and phytoplankton, changed regimes of dissolved-oxygen, and thereby destabilised food webs(Apau et al., 2025). The effects on primary productivity, benthic community structure and downstream oxygen dynamics are recorded in lab and field studies of the textile discharges and are the impacts that have a cascading effect on ecosystem-wide impacts(Guild et al., 2025). To these ecological effects pre-dating the occurrence of acute chemical toxicity limits, colour and light-attenuation are themselves causes of ecological damage(Barnard et al., 2023).

In addition to dyes, major operating issues also include salts and process auxiliaries (surfactants, complexing agents, finishing chemicals): dye baths cause high salinity (TDS) that degrades the performance of many adsorption and membrane treatments and makes desalting or the management of brine even more expensive and challenging(Yadav et al., 2025). Organics (e.g. softeners, binders, dispersants) are frequently radical scavengers in advanced oxidation reactions that boost the oxidant demand and thereby the costs of treatment(Delfino et al., 2025). This is the reason pilot and scale-up experiments focus more on the matrix effects - success with pure dye solutions in the bench fails to translate to real textile effluent(Ferri & Bolelli, 2025).

The toxicological issues are centered on dye molecules of parent dyes as well as on the degradation products of the dyes(de Souza et al., 2025). Thousands of azo dyes can be reduced (e.g. in anaerobic conditions or in the gut or in the interior of cells) to aromatic amines, some of which are mutagenic or carcinogenic(Rajendran et al., 2025). Therefore, strategies to be used in removal should not only take into consideration the decolorization process but also mineralization (TOC removal) and screening of the existence of hazardous intermediates (LC-MS, aromatic-amine assays, genotoxicity tests)(Chmelová et al., 2024). This trade-off in treatment is criticized in many reviews: biological treatments can quickly decolorize through the conversion of dye to amines, whereas AOPs can degrade dyes but may need large amounts of oxidants, and can be highly sensitive to control to prevent the production of oxidized side products(Yabalak et al., 2025).

Regional in dependence but real, human-health and socio-economic impacts may include contaminated sources of irrigation or drinking, with research associating the chronic effects of contaminated with organics caused by the textile effluents, which may lead to the increased ecological risks and the possible human health problems(Nurullah et al., 2025). Occupational (dust/skin contact with powdered dyes, splashes during processing) is also a known risk factor and regulatory systems are progressively demanding effluent monitoring on a case-by-case basis, besides colour and COD, individual toxicants and genotoxicity endpoint(Leppanen et al., 2024).

Due to the scale and complexity and persistence of textile wastes, multi-barrier treatment and water-management is the best practice currently: increased process efficiency to minimise water/dye losses, recovery and recycling (including Zero Liquid Discharge concepts), primary-secondary treatment of solids and biodegradable loads, and specific tailored tertiary steps (coagulation/flocculation, adsorption, AOPs, membrane filtration) to the effluent matrix(Ferri & Bolelli, 2025).

Although there are various treatment options, effective extraction of textile dyes in composite wastewater matrices has been a major scientific and technological challenge. The drawbacks that conventional methods are usually faced with include high operation cost, incomplete mineralization, susceptibility to matrix interferences and producing secondary pollutants. In this regard nanotechnology based adsorbents, more so the magnetic nanoparticles like cobalt ferrite have come to be considered as good candidates since they are high surface area, easy to separate and their adsorption efficiency is increased. Nevertheless, isolated nanoparticles are likely to be aggregated, less stable, and perform poorly in actual effluent systems. As a solution to these challenges, the research of composite material hybrids with natural, low-cost biomaterials has become more popular. *Ficus religiosa* bark is a plant-based material that contains a large number of functional groups, biodegradability, and environmental compatibility that has synergistically positive effects in increasing the adsorption capacity and sustainability. However, the literature in assessment of such composite systems in removing reactive dyes such as Synozol Yellow in real life situations is conspicuously lacking. Thus, the purpose of the study is to explore the decontamination capacity of cobalt ferrite nanoparticles and their composite with the *Ficus religiosa* bark towards the effective adsorption of Synozol Yellow dye in wastewater with an emphasis on enhancing the adsorption efficiency, adsorption stability, and applicability in complicated aqueous systems.

Material and Method

There are several phases involved in creating Cobalt Ferrite ($CoFe_2O_4$) nanoparticles. This is a broad overview of the procedure.

Material and Equipment:

Cobalt chloride hexahydrate
Iron chloride hexahydrate
Sodium hydroxide
Ficus religiosa bark
Beaker

Funnel
Distilled water
Equipment's for Filtration (e.g. filter paper)
Drying apparatus (e.g. oven)
Weighing balance

Preparation of Cobalt Ferrite ($CoFe_2O_4$) nanoparticles

We dissolved 31.8 g of cobalt chloride hexahydrate and 55.6 g of iron chloride hexahydrate in 1000 mL of distilled water to initiate the experiment, ensuring that the ingredients were thoroughly mixed. After that, 11.5 g of sodium hydroxide (NaOH) was dissolved in 1000 mL of distilled water to prepare the NaOH solution. This solution was gradually added to the first solution, and titration occurred while the mixture was continuously stirred. Following this, filter paper was used to obtain the precipitate from the solution. Finally, the produced cobalt ferrite nanoparticles were dried in an oven at 80 °C(HASSAN, 2021).

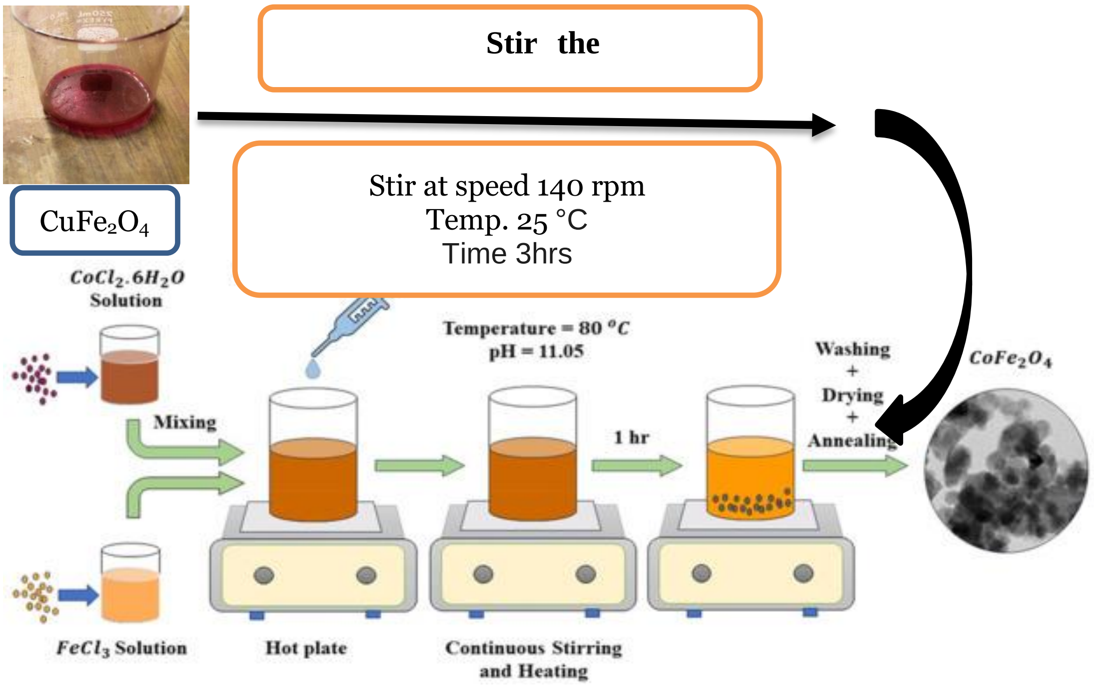


Fig 1: Preparation of Cobalt Ferrite ($CoFe_2O_4$) nanoparticles

Preparation of Biochar

Ficus religiosa bark was used to produce the biochar. Prior to the experiment, the *Ficus religiosa* bark was collected and allowed to dry. Based on previous thermogravimetric results on a similar *Ficus religiosa* bark feedstock reported by McCaffrey, biochar formation was assessed in laboratory-scale studies using a muffle furnace at temperatures between 400 °C and residence times ranging from 30 to 90 minutes. All experiments were conducted with a heating rate of 20 °C/min(Rao et al., 2022).

Preparation of Composite of cobalt ferrite with biochar

In 200 mL of distilled water, 0.1 M $CoCl_2 \cdot 6H_2O$ (4.83 g in 200 mL) and 0.2 M $FeCl_3 \cdot 6H_2O$ (16.16 g in 200 mL) were dissolved. Subsequently, 5 g of biochar was added to the metal salt solution, and the mixture was stirred for two hours to allow adsorption of metal ions. A 2M NaOH solution was then added dropwise until the pH reached 11, and the suspension was agitated for an additional hour to facilitate the formation of metal hydroxides on the biochar surface. $CoFe_2O_4$ crystallization was achieved by heating the mixture in an autoclave at 180 °C for 12 hours. After completion, the composite was filtered and centrifuged, then washed repeatedly with distilled water and ethanol until a neutral pH was obtained. The final product was dried overnight at 80 °C(Zeng, 2020).

A batch-scale experiment was conducted to evaluate the effectiveness of $CoFe_2O_4$ nanoparticles for dye removal. A stock solution of the dye was prepared, and solutions of varying concentrations were obtained by appropriate dilution of the stock solution. The effects of pH, initial dye concentration, adsorbent dosage, and contact time were systematically investigated.

Stability and Reusability Assessment

The stability and recyclability of cobalt ferrite ($CoFe_2O_4$) nanoparticles were assessed by conducting multiple degradation cycles under actual operating conditions. After each cycle, changes in the catalyst's structural integrity and catalytic activity were investigated using characterization techniques.

Characterization

The functional groups present on the adsorbent surface were identified using Fourier transform infrared spectroscopy (FTIR). The materials and nanoparticles were fully characterized using scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM–EDX) and X-ray diffraction (XRD). The elemental composition of the adsorbent was determined by energy-dispersive X-ray spectroscopy (EDX), while surface morphology and imaging were obtained using scanning electron microscopy (SEM).

Batch scale adsorption study

A batch-scale experiment was conducted to assess the efficiency of cobalt ferrite nanoparticles and *Ficus religiosa* biochar for dye removal. A stock solution of the dye was prepared, and different concentrations were obtained by diluting the respective stock solution. The effects of pH, initial dye concentration, adsorbent dosage, and contact time were studied.

Table 1: Detail of experimental conditions for batch scale for sequestration of synozol yellow dye

Process	Material dosage mg/L	Dye Concentration mg/L	pH range	Exposure time (min)
$CoFe_2O_4$	50,100,150, 200	100,150,200, 250	2, 4, 6, 8	30, 60, 130, 3hours
Ficus religiosa Biochar	50,100,150, 200	100,150,200, 250	2, 4, 6, 8	30, 60, 130, 3hours

Data Analysis

The equilibrium sorption data were analyzed using the Langmuir, Freundlich, Timkin, and Dubinin–Radushkevich (D–R) isotherm models. Additionally, least-squares methods were applied for data analysis.

$$q_e = \frac{\left(C_0 - C_f\right)}{M_a} \times V_w \qquad (1)$$

Here, the quantity of Synozol dye adsorbed per unit weight of the adsorbent (mg g^{-1}) was denoted, where C_0 represented the initial dye concentration (mg L^{-1}) and Cf represented the equilibrium dye concentration (mg L^{-1}). V indicated the volume of solution used in the experiment. The removal efficiency (R%) of the Synozol dye was calculated accordingly.

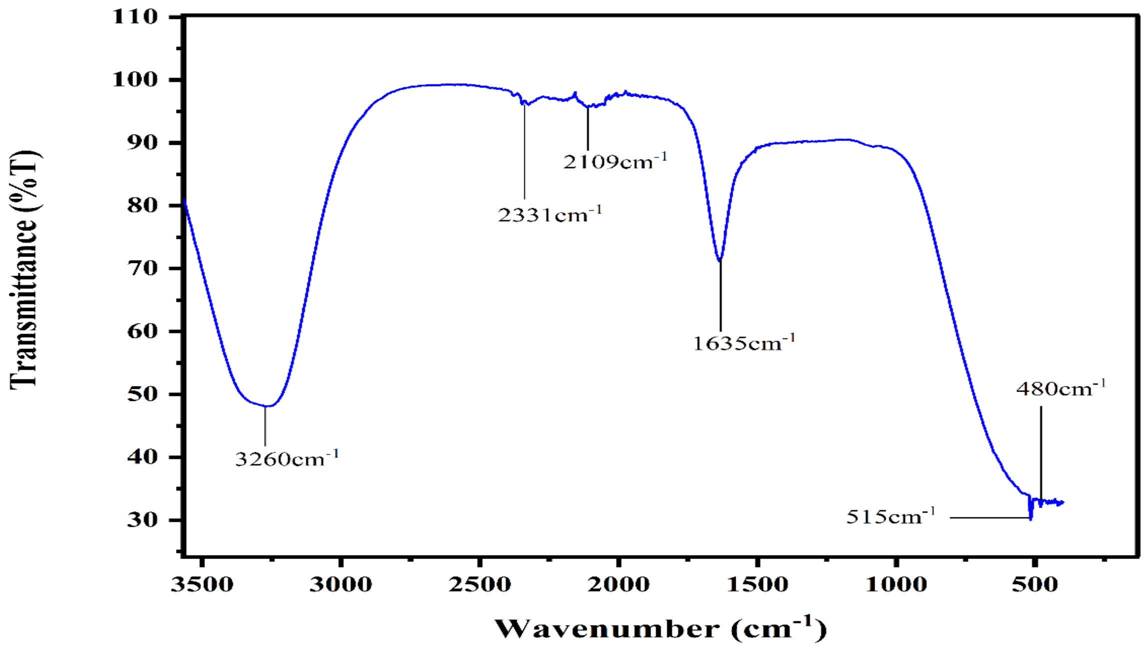
$$R = \left(\frac{C_0 - C_f}{C_0}\right) \times 100 \qquad (2)$$

Results

Characteristics of Adsorbents

FTIR analysis Copper ferrite

It is a FTIR (Fourier Transform Infrared) spectrum, or a graph that represents the absorbance of a material to infrared light at varying wavenumbers (cm -1). The FTIR is applied in the determination of functional groups and chemical bonds in a sample



~3260 cm^{-1}

Broad absorption band

O–H stretching (hydroxyl groups, usually of water, alcohols or surface -OH)

- ~2331 cm^{-1} and ~2109 cm^{-1}

Weak absorption features

→ Can be related to CO_2 in air or triple bond stretching (C_3C or C_3N) depending on sample.

- ~1635 cm^{-1}

Strong, sharp dip

→ H -O -H bending (adsorbed water) or C = C in certain materials.

• ~515 cm^{-1} and ~480 cm^{-1}

Low-wavenumber absorptions

→ Metaloxygen (MO) vibrations or lattice vibrations (usually in metal oxides, ceramics or inorganic compounds).

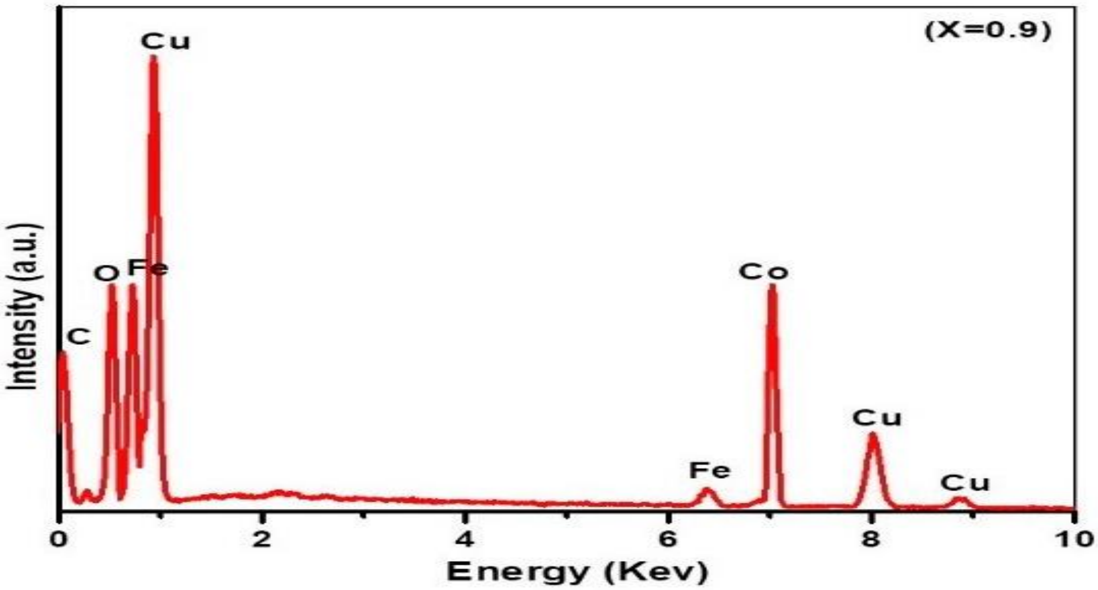
The spectrum indicates the following:

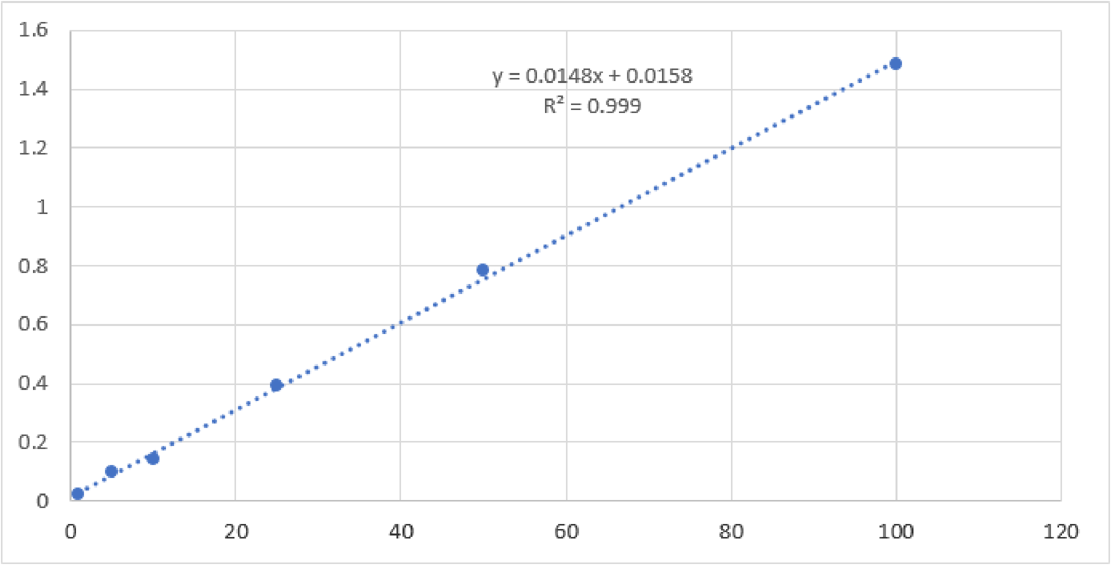
o Groups of hydroxyl or water.

o Potential CO_2, or triple bond vibrations.

o Metal-oxygen bonds, which is an inorganic or oxide-based material(Chen et al., 2019).

Energy Dispersive X-Ray (EDX) Copper Ferrite





This is an EDS (Energy Dispersive X-ray Spectroscopy) spectrum that indicates the composition of the elements of the sample.

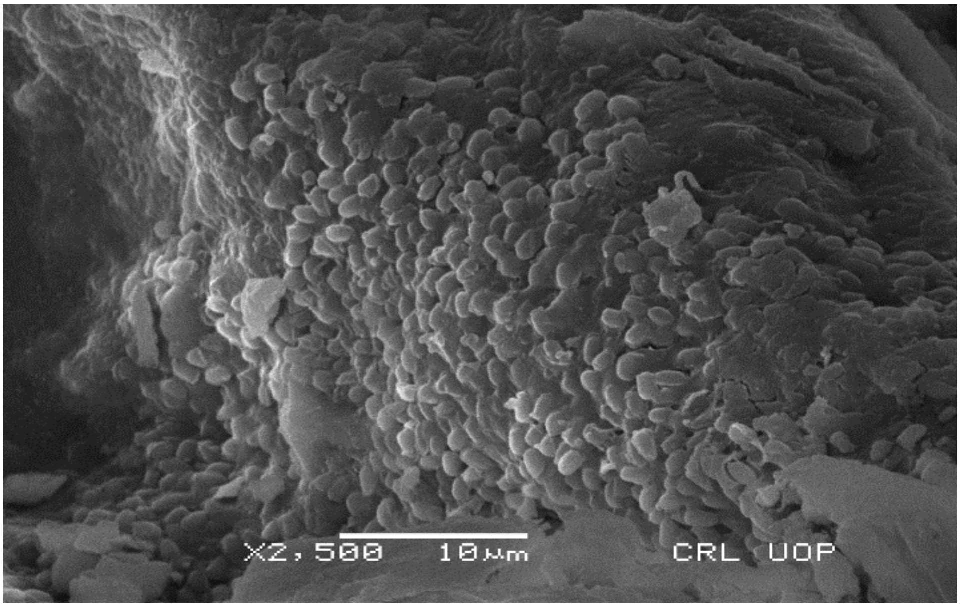
The x-axis (Energy, keV) is the energy of X-ray and the y-axis (Intensity) is the abundance of the element.

Co peaks are strong and prove cobalt to be a prime component of the material.

Co and Fe Peaks show the existence of cobalt and iron in a lesser quantity.

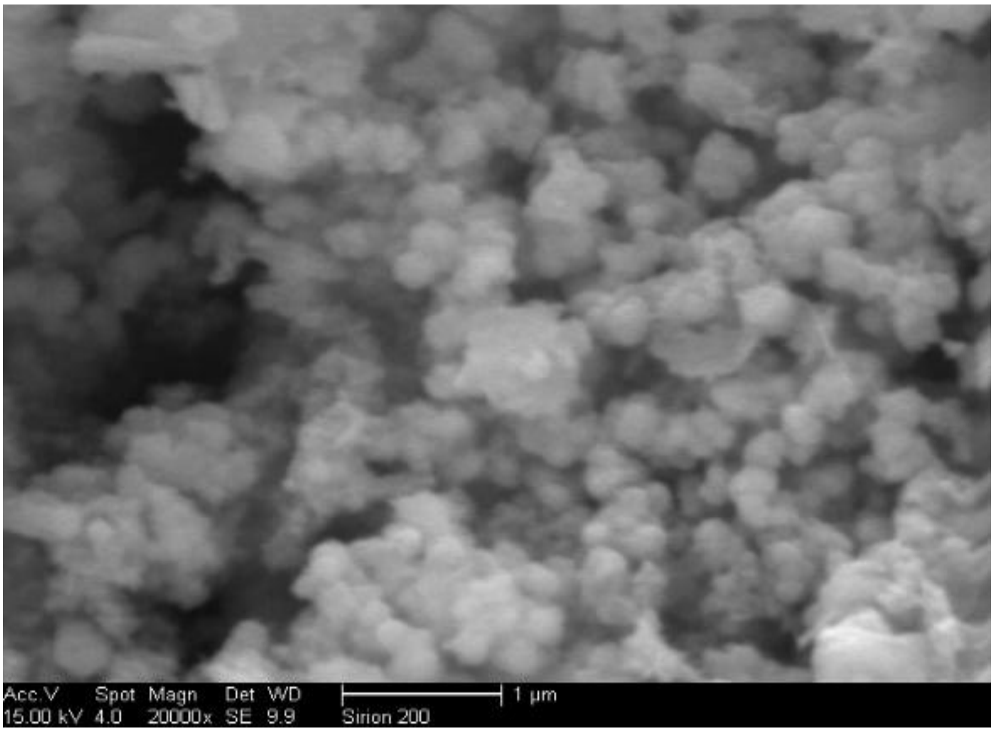
The O peak is low energy which implies the presence of oxygen possibly because of formation of oxides whereas the C peak can be attributed to contamination of the surface or sample holder(Petrosino et al., 2022).

Scanning Electron Microscopy (SEM) Copper Ferrite



The present image is a Scanning Electron Microscopy (SEM) image of the surface morphology of the prepared sample. The image is captured at a magnification of x 2, 500 and a scale bar of 10 0m, which shows micro-scale structure. The surface is rough and highly agglomerated, made of particles which are densely packed and of irregular shape. This agglomeration implies that the particles have high interparticle interactions and may clustering occurs during the synthesis of drying process. The porous texture is uneven and it enlarges the surface area, which is useful when required in catalysis, adsorption, or electrochemical reactions. On the whole, SEM image confirms that the morphology is not uniform and granular, and there is good connectivity of the particles.

Biochar:



The image represents a Scanning Electron Microscope (SEM) micrograph of biochar captured at 20,000× magnification. The SEM analysis reveals the surface morphology and microstructural characteristics of the biochar material.

Key features observed:

The biochar exhibits a highly irregular, porous, and heterogeneous surface structure.

Numerous agglomerated carbon-rich particles are visible, forming a rough and uneven texture.

The presence of micro- and nano-scale pores can be observed, which are characteristic of biochar produced through pyrolysis.

The clustered morphology suggests the collapse and reorganization of the biomass structure during thermal decomposition.

Scale interpretation:

Based on the 1 µm scale bar, the observed features indicate nanometer to sub-micron sized pores and particles, contributing to a large specific surface area.

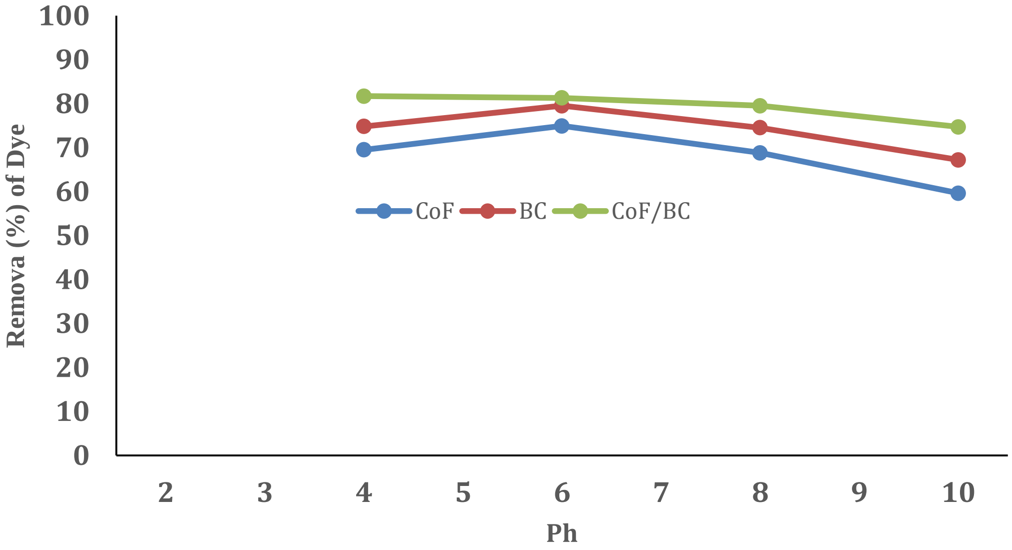
Significance:

The porous structure of biochar enhances its adsorption capacity, making it suitable for applications such as soil amendment, pollutant removal, wastewater treatment, and carbon sequestration. The rough surface also provides active sites for nutrient retention and microbial colonization.

Overall, the SEM image confirms the successful formation of porous biochar with a well-developed microstructure, which is a key factor influencing its physicochemical properties and environmental performance.

BATCH SCALE EXPERIMENT

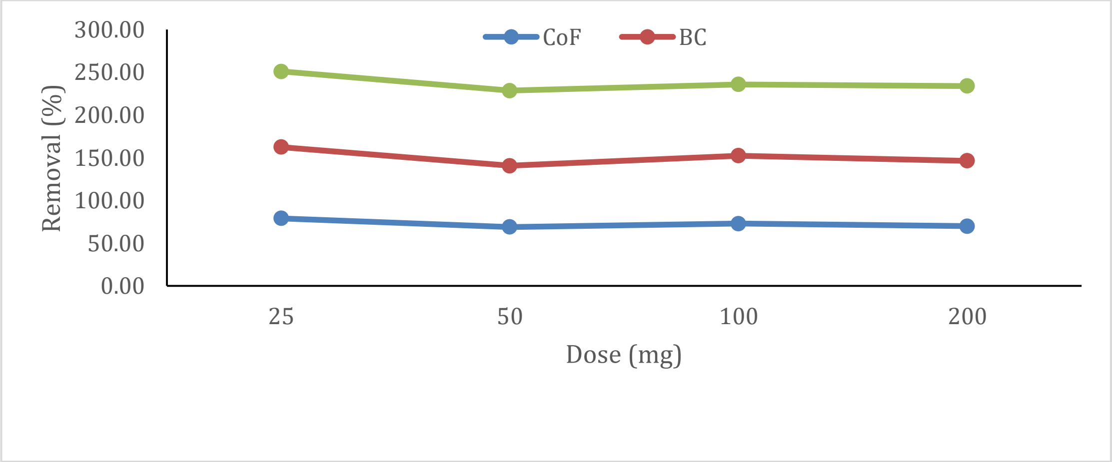
Effect of pH



The curve indicates the impact of pH on the percentage removal of a dye, probably through the use of CoF as an adsorbent. X-axis: The level of pH. Y-axis: This is the percentage of dye removal. The dots on the graph are the percentage of dye removal that has been measured in various pH levels. The line indicates the data points on the visualization of the trend.

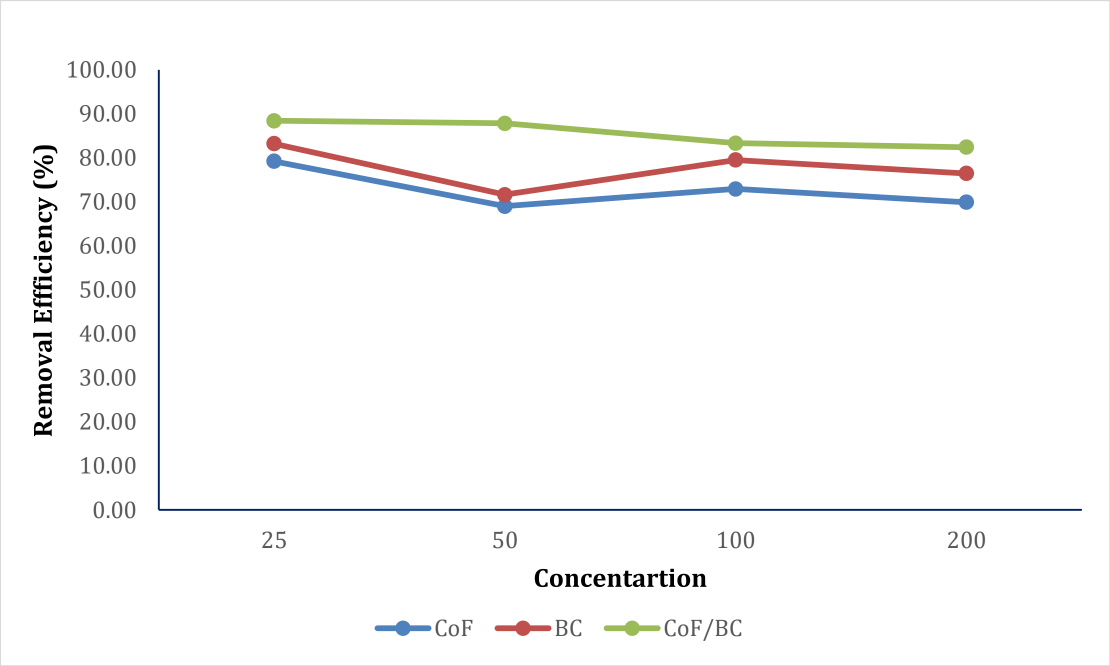
Interpretation:
The score of the maximum percentage of removal of dyes is at a pH of approximately 6. The lower the pH, the lower the percentage will be removed. The percentage of removal starts to decline at a slower rate with an increase in the pH above 6.

Effect of Dose



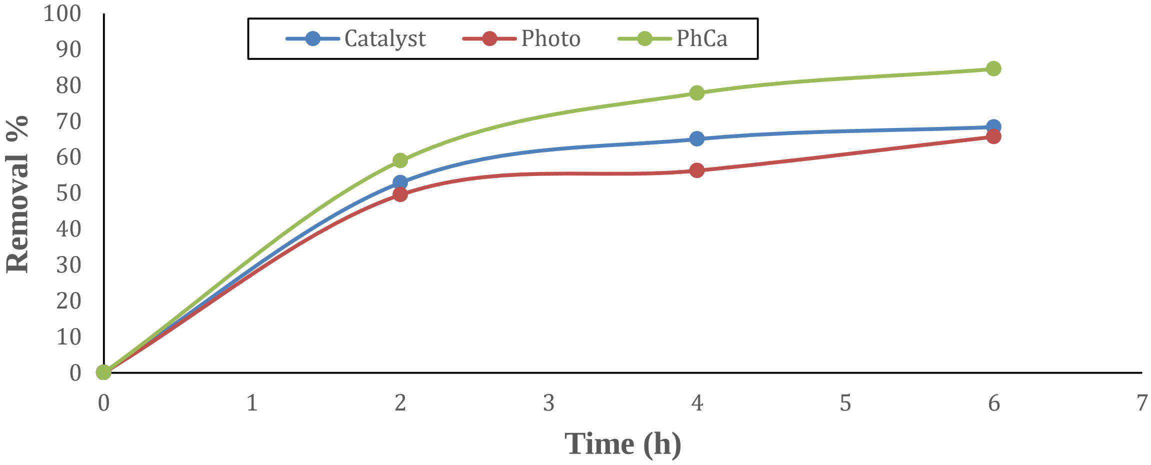
The graph is aimed at illustrating the dependence between the dose of CoF (probably a cobalt-based compound) and the percentage of dye removal in a solution. X-axis: The dose of CoF in grams/100 units (probably in mL or g) of solution.Y-axis: The percentage of dye removed off the solution. Curve: The curve downward indicates that the higher the dose of CoF, the higher the percentage of dye removal. This implies that CoF works effectively in eliminating the dye with increasing doses resulting in increased efficiency of the dye.

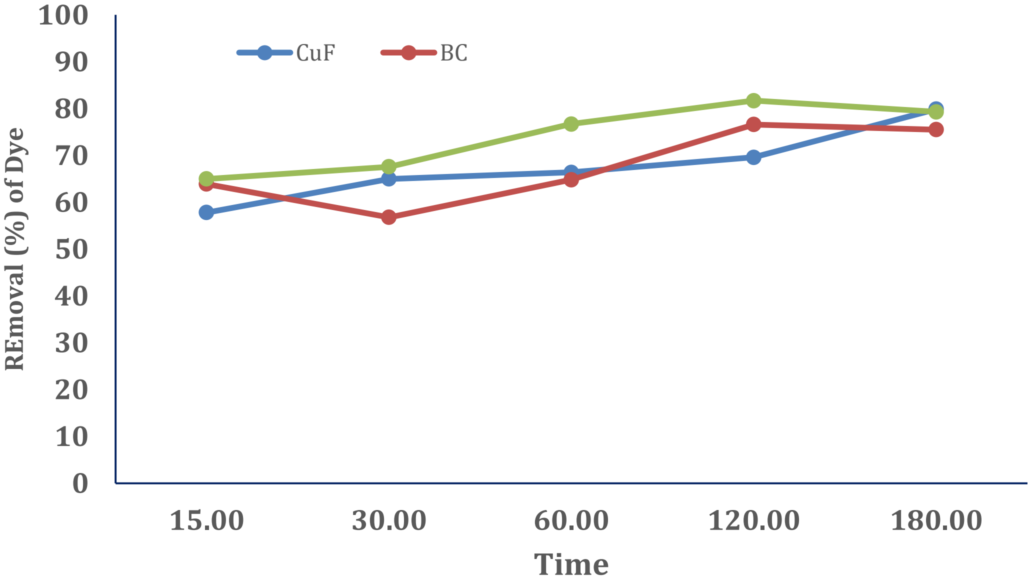
Effect of Concentration



The graph depicts the relationship between the CoF concentration and the per cent of dye removal.
x -axis: the CoF concentration (probably in milligrams per liter or other unit).
y-axis is the percentage of dye removed.
* With the concentration of CoF, the percentage of dye removal is elevated.
The correlation seems to be a non- linear relationship that is, the rate of dye.

Effect of Time





* X-axis: The X-axis is time, but the time is not denoted.
* Y-axis: Responsive to the percentage of dye removed.
* Plot Area: This area is probably the best conditions to remove dye with the most percentage of dye removed. This point can be taken to be a particular condition or treatment implemented and lead to a reduction in the removal percentage.

Disscusion

The findings of this research demonstrate that cobalt ferrite nanoparticles and their composite with *Ficus religiosa* bark have a great potential in removing Synozol Yellow dye in wastewater. The high decolorization efficiency is observed as a result of the synergistic action between the adsorption and the surface interaction between the dye molecules and the adsorbent materials.

The improved performance of CoFe2O4/*Ficus religiosa* is probably due to the presence of oxygen-containing active groups (hydroxyl group and carboxyl group) on the vegetable product. These functional groups enable electrostatic attraction and hydrogen bonding to the anionic dye molecules increasing adsorption capacity. Also, the porous support of the biomass gives more active sites where the dye is uptaken; this is more efficient in general (Alam et al., 2025; Matinise, 2025).

The pH of the solution was very important in dye removal because it affected the surface charge of the adsorbent and ionization state of dye molecules. The increased removal efficiencies in the acidic environment could be attributed to the fact that there is increased electrostatic attraction between positively charged adsorbent surface and negatively charged dye ions. The present case of pH-dependent behavior is not new and has been observed in other earlier experiments with reactive azo dyes and metal-oxide based adsorbents (Azeez et al., 2018; de Farias Silva et al., 2020).

Magnetic characteristics of cobalt ferrite were used to speedily and effectively extract the adsorbent out of treated water, using an external magnetic field. This characteristic is very important in eliminating secondary pollution and operational expenses that come with filtration or centrifugation and therefore enables the process to be more practical in large scale (Vinosha et al., 2021).

In comparison to the traditional treatment techniques, including coagulation, bio-degradation, and adsorption on activated carbon, the developed composite will have beneficial characteristics in the context of reusability, separation rate, and sustainability.

The use of *Ficus religiosa* bark, a biomass that is free and cheap, also contributes to the improvement of the environmental and economic feasibility of the treatment process.

Conclusion

This study was able to prove the efficiency of cobalt ferrite nanoparticles as well as their composite with *Ficus religiosa* bark in the removal of Synozol Yellow dye in wastewater. This composite material had a higher dye removal potential than cobalt ferrite alone due to improvements in surface characteristics and the availability of natural functional groups as a result of the plant biomass. The adsorbent was magnetically active which made collecting and reusing the adsorbent easy, whereas the adsorption of cobalt ferrite was known to have a significant drawback to the traditional adsorption processes.
The results indicate that $CoFe_2O_4$-derived bio-composites are a potential solution that is economical and environmentally friendly in the treatment of textile effluents contaminated with dye. Such a strategy is in line with sustainable wastewater management and the idea of a circular economy. To further confirm the practical usefulness of such a treatment method at the industrial level, future research ought to be conducted on the regeneration cycles, its application on actual textile wastewater, and evaluation of the degradation by-products.

References

Abd El-Fattah, W., Shahid, M., Ashraf, S., Sandhu, Z. A., Guesmi, A., Ben Hamadi, N.,…Raza, M. A. (2025). Solar-Activated Titanium-Based Cu 4 O 3/ZrO 2/TiO 2 Ternary Nano-Heterojunction for Rapid Photocatalytic Degradation of the Textile Dye Everzol Yellow 3RS. *Catalysts (2073-4344)*, *15*(8).

Al Montasir, M. S., Rabbi, M. B. U., Sani, A. A., & Islam, M. R. (2025). Sustainable Innovations in Textile Coloration Machinery and Process Enhancements. In *Sustainable Coloration Techniques in Textiles* (pp. 55-89). Springer.

Alam, M. W., Dhanda, N., Almutairi, H. H., Al-Sowayan, N. S., Mushtaq, S., & Ansari, S. A. (2025). Green ferrites: eco-friendly synthesis to applications in environmental remediation, antimicrobial activity, and catalysis—a comprehensive review. *Applied Organometallic Chemistry*, *39*(2), e7962.

Apau, E., Tawiah, B., & Boadi, M. A. (2025). Advancement in Natural Dyes Extraction and Application for Textile Finishing. In *Advances in Textile Materials and Processing Techniques for Sustainability* (pp. 77-131). Springer.

Aykaç Özen, H., Temiz, E., & Çoruh, S. (2025). A water footprint inventory for a textile organization: a case study in the denim washing industry based on the integrated reverse osmosis system. *Integrated Environmental Assessment and Management*, *21*(4), 823-832.

Azeez, F., Al-Hetlani, E., Arafa, M., Abdelmonem, Y., Nazeer, A. A., Amin, M. O., & Madkour, M. (2018). The effect of surface charge on photocatalytic degradation of methylene blue dye using chargeable titania nanoparticles. *Scientific Reports*, *8*(1), 7104.

Barnard, C., Dawson, J., Lizotte, M., Baird, E., Reedman, A., Ropars, P.,…Archambault, P. (2023). Annual Scientific Meeting 2022 Conference Book of Abstracts Compilation de Resumes pour la Conference Annuelle Scientifique 2022. *Arctic Science*, *9*(1), 4-146.

Catarino, M. L., Sampaio, F., & Gonçalves, A. L. (2025). Sustainable Wet Processing Technologies for the Textile Industry: A Comprehensive Review. *Sustainability*, *17*(7), 3041.

Chen, W., Lu, Z., Xiao, B., Gu, P., Yao, W., Xing, J.,…Wang, S. (2019). Enhanced removal of lead ions from aqueous solution by iron oxide nanomaterials with cobalt and nickel doping. *Journal of Cleaner Production*, *211*, 1250-1258.

Chmelová, D., Ondrejovič, M., & Miertuš, S. (2024). Laccases as effective tools in the removal of pharmaceutical products from aquatic systems. *Life*, *14*(2), 230.

de Farias Silva, C. E., da Gama, B. M. V., da Silva Gonçalves, A. H., Medeiros, J. A., & de Souza Abud, A. K. (2020). Basic-dye adsorption in albedo residue: Effect of pH, contact time, temperature, dye concentration, biomass dosage, rotation and ionic strength. *Journal of King Saud University-Engineering Sciences*, *32*(6), 351-359.

de Souza, J. C., Avelino, E. R. A. F., Bessegato, G. G., da Costa, R. d. C. G., Carneiro, P. A., de Oliveira, D. P.,…Valnice Boldrin Zanoni, M. (2025). Comprehensive review of hair dyes: Physicochemical aspects, classification, toxicity, detection, and treatment methods. *ACS omega*, *10*(27), 28567-28586.

Delfino, S., Villa, D. C., Giannetti, A., Tomasino, D. V., Oldani, C., Storti, G., & Sponchioni, M. (2025). Short Side-Chain Perfluorosulfonic Acid Aquivion: From Production to Application. *Macromolecular Materials and Engineering*, e00262.

El Ouadrhiri, F., Saleh, E. A. M., & Lahkimi, A. (2025). From Mineral Salts to Smart Hybrids: Coagulation–Flocculation at the Nexus of Water, Energy, and Resources—A Critical Review. *Processes*, *13*(11), 3405.

Ferri, E. N., & Bolelli, L. (2025). Wastewater remediation treatments aimed at water reuse: recent outcomes from pilot-and full-scale tests. *Applied Sciences*, *15*(5), 2448.

Guild, R., Wang, X., & Quijón, P. A. (2025). Climate change impacts on coastal ecosystems. *Environmental Research: Climate*, *3*(4), 042006.

HASSAN, A. A. (2021). SYNTHESIS OF IRON AND COBALT CONTAINING IONIC LIQUIDS AND THEIR APPLICATION IN MICROEXTRACTION AND ADSORPTION.

Leppanen, M. T., Sourisseau, S., Burgess, R. M., Simpson, S. L., Sibley, P., & Jonker, M. T. (2024). Sediment toxicity tests: A critical review of their use in environmental regulations. *Environmental Toxicology and Chemistry*, *43*(8), 1697-1716.

Matinise, N. (2025). Recent Advances Review in Plant Extracts-Driven Green Synthesis of Binary-Metal Oxide Nanomaterials for Sustainable Nanotechnology. *Scientifica*, *2025*(1), 2888408.

Nurullah, A., Khatun, M. S., & Ritchie, L. (2025). Industrial Wastewater Disposal and Its Socio-Environmental Consequences: Evidence from the Uttara Export Processing Zone, Bangladesh. *Sustainability*, *17*(17), 7716.

Petrosino, P., Pirrie, D., Santoro, L., & de Gennaro, R. (2022). Scanning electron microscopy (SEM) in forensic geoscience. In *Mineralogical analysis applied to forensics: A guidance on mineralogical techniques and their application to the forensic field* (pp. 61-91). Springer.

Rajendran, S., Kalairaj, A., & Senthilvelan, T. (2025). A comprehensive review on enzymatic decolorization of various azo dyes using laccase for the abatement of industrial pollution. *Biomass Conversion and Biorefinery*, *15*(9), 13079-13101.

Rani, J., Santhanam, S., Guru, R., & Seidu, R. K. (2025). Sustainable Finishing Processes: Enhancing Performance with Minimal Impact. *Advances in Textile Materials and Processing Techniques for Sustainability*, 161-199.

Rao, Y. K., Dhanalakshmi, C. S., Vairavel, D. K., Surakasi, R., Kaliappan, S., Patil, P. P.,…Lalvani, J. I. J. (2022). Investigation on forestry wood wastes: pyrolysis and thermal characteristics of Ficus religiosa for energy recovery system. *Advances in Materials Science and Engineering*, *2022*(1), 3314606.

Vinosha, P. A., Manikandan, A., Preetha, A. C., Dinesh, A., Slimani, Y., Almessiere, M. A.,…Nirmala, G. F. (2021). Review on recent advances of synthesis, magnetic properties, and water treatment applications of cobalt ferrite nanoparticles and nanocomposites. *Journal of Superconductivity and Novel Magnetism*, *34*(4), 995-1018.

Yabalak, E., Alhroub, F., Alterkaoui, A., & Dizge, N. (2025). One-step hydrothermally-assisted persulfate treatment: a sustainable approach for highly concentrated denim scrap wastewater. *International Journal of Environmental Science and Technology*, 1-14.

Yadav, S., Tiwari, K. S., Sharma, M. K., Meena, P., Usmani, N., & Agnihotri, L. (2025). Micelle Dyeing: Green Chemistry for Modern Coloration. In *Sustainable Coloration Techniques in Textiles* (pp. 267-283). Springer.

Zeng, S. (2020). *Production, Characterization and Application of Engineered Biochars Made from Agricultural Wastes for Effective Remediation of Emerging Contaminants in Water*