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Efficiency of recent advances for effective dye removal from the textile effluent – A Review

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Abstract: The most dye wastewater is produced in the textile sector (54 percent), representing more than half the global environmental effluent. Textile wastewaters are hazardous effluents comprising toxic complex components that, if not treated properly, have a significant negative influence on the environment, causing harm to aquatic ecosystems as well as human health and necessitating treatment prior to discharge into natural reservoirs. To address this issue, it is necessary to establish a long-term and efficient way of treating dye effluents. Many dye removal technologies such as physical, chemical and biological approaches were used for the treatment. In this review study, we will look at several dye treatment methods, their effectiveness, and new breakthroughs in nanotechnology in dye treatment.

Keywords: Membrane filtration, Adsorption, Textile dye, Ion exchange, Electro coagulation, Fenton, Chitin, Nanoparticles, Carbon nanotubes

1. INTRODUCTION

Over 80,000 tons of dyestuff are manufactured in India. Textile industries are the main consumers of dyestuffs, accounting for up to 80% of total consumption. Toxic chemicals in the dye effluent might be teratogenic, carcinogenic and mutagenic to aquatic species including fish, representing a major health risk to humans. More than 10,000 industrial dyes are believed to be available worldwide; the textile sector alone uses more than 3,600 distinct chemical dyes, and also the global yearly dyestuffs output totals more than 7×105 tones. Textile companies discharge azo dyes in wastewater in concentrations ranging from 5 to 1500 mg/L. Dyes are classified as vat, Sulphur, reactive, direct, azo, basic and dispersion dyes based on the chemical composition of the chromophore group [1].

India has 2324 textile industries, including Karnataka 41, Tamil Nadu 741, and Gujarat 523[2]. Depending on the type of dye utilized, 30-50 liters of water are necessary to produce one kilograms of cloth. Textile dyeing and other finishing operations are estimated to contribute 17 to 20% of water pollution in industries, according to the World Bank. In India, the industrial sector is expected to create 55000 million cubic meters of wastewater every day, of which 68.5 million is thrown straight into rivers and streams before treatment. Heavy metals including iron, lead, chromium, zinc, copper and nickel are found in trace amounts in textile manufacturing effluent. The large amount of water used in the textile dyeing process, as well as its dangerous nature, require treatment (Anuj Kumar Yadav et. al. [1]).

There are several approaches for removing textile dye, some of which are given below:

Chemical treatment (e.g., PAC, BacEnz, and poly), biological treatment (e.g., cow dung and jaggery, fungus Phanerochaete chrysosporium), physical treatment (Reverse osmosis, ultrafiltration), Hybrid treatment (biological and chemical treatment or physical and chemical treatment). Biosorption Technique (Organic adsorbents or Non-Organic adsorbents) [3], Ion Exchange Technique, Coagulation and Flocculation Technique, Electro coagulation Technique Ozonation and chemical coagulation, Fenton [4].

2. METHODS

There are several methods such as physical, chemical, biological and hybrid.

2.1 Physical methods

2.1.1 Ion exchange:

Because ion exchangers cannot catch a wide range of dyes due to the presence of diverse additives in wastewater, standard ion exchange systems are not widely compatible with wastewater dye. The waste water is used as an ion exchange resin until all of the accessible exchange sites get saturated in this method. This method effectively eliminated both anionic and cationic dyestuffs. The high expense of regenerating organic solvents from the ion exchanger is a key disadvantage of the method [4].

2.1.2 Adsorption

The following four processes comprise the sorption mechanism on the sorbent during the removal process:

(1) Advective transport: Migration of solutes from immobilized film layer to bulk solution via diffusion, axial dispersion or advective flow;
(2) Film transfer: Affinity and Penetration of solute particles in the immobile water film layer;
(3) Mass transfer: Adherence of solute particle to adsorbent surface. Finally, there's intraparticle diffusion, which involves the movement of a solute into the pores of an adsorbent [5]. Types of Adsorption: Physical adsorption, layered adsorption and chemical adsorption [21].

2.1.3 Membrane filtration:

The membrane separation technique is capable of clarifying, concentrating and especially constantly separating dye from wastewater [24]
The principle is extremely simple: the membrane functions as a very particular filter, which allows the flux of water and collects suspended particles and other materials. Nano-filters (NF) are widely employed in the textile industry processing, especially for the wastewater treatment in a dyeing process, among all kinds of relevant membrane filters. In several reactive dyes' solutions experiments the effectiveness of about 100% dye removal was shown by combination of membrane filtration with coagulation-flocculation treatments [25].
The quality of the final product is supposed to result in reverse osmosis, nanofiltration, ultrafiltration or microfiltration using membrane processes.

2.1.4 Irradiation

The radiation technology techniques usually use highly oxidizing species, including OH radicals, which provide a high electrochemical oxidation potential and then break apart macromolecules of dye into less dangerous and smaller compounds in a chain of processes [22].

2.1.5 Electro coagulation

The process of electrocoagulation (EC) involves reduction and an oxidation reaction in which contaminant destabilization occurs as an electrolyte solution is applied to the electrical current. EC is consisting electrodes and an electrolytic cell coupled to an external supply of energy. Anodic dissolution produces locally coagulants in conjunction with OH^- ions and cathode H_2 gas in EC process. These in situ coagulants form the hydroxide and/or metal polyhydroxide (Al or Fe) flocks.
The principal electrode reactions are:
(Anode) $Al \rightarrow Al^{3+} + 3e^-$
(Cathode) $3H_2O + 3e^- \rightarrow 2H_2 + 3OH^-$
The EC process efficiency is determined by the voltage.

2.2 Chemical method

2.2.1 Advanced Oxidation process (AOP)

The AOP is a wastewater treatment process that is gaining popularity. For the breakdown of non-biodegradable organic pollutants in industrial effluents, advanced oxidation procedures (O_3, O_3/H_2O_2, UV/O_3, UV/H_2O_2, $O_3/H_2O_2/UV$, Fe^{2+}/H_2O_2) are interesting alternatives to standard treatment methods. AOPs are based on the formation of highly reactive and oxidizing free radicals, and their great oxidant power has aroused people's curiosity. The formation of hydroxyl radicals (OH•) from hydrogen peroxide, photo-catalysis, ozone or oxidizing agents, as well as the utilization of ultraviolet light, is the fundamental principle of AOP. The breakdown of organic molecules is predominantly accomplished by the OH• [28].

2.2.2 Fenton

The hydrogen peroxide and iron salt mixture have both been employed for the treatment of inorganic material and organic matter. The technique is based on the development of reactive oxidation species that are able to disintegrate wastewater pollutants effectively [4].
$H_20_2 + Fe^{2+} \rightarrow Fe^{3+} + HO^- + HO''$
$HO'' + RH \rightarrow H_20 + R''$
$R'' + Fe^{3+} \rightarrow R^+ + Fe^{2+}$
$R^+ + H_20 \rightarrow ROH + H^+$
The produced OH^- would like the unsaturated dye molecule employed in this experiment to attack the organic substrate RH. This destroys and decolorizes the chromophore / chromogen of the dye molecule [10].

2.2.3 Photochemical

Photocatalysis is a process which involves solar or artificial light activation of the semiconductor (TiO_2). The absorption of high-energy photons into the "bandgap" energy leads to the promotion of oxidation number band electron for the conductive band, formed by a gap in the oxidation number band.

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Mechanisms for degradation from the conduction band reaction, by other ion species, which constitute a hydroxyl radical [26]. In this approach, presence of H_2O_2 destroys dye molecules to CO_2 and H_2O by UV irradiation. The generation of excessive amounts of hydroxyl radicals causes degradation. The rate of dye removal is determined by the strength of pH, UV radiation, dye bath composition, and dye structure. UV light can be used to activate compounds like H_2O_2. This can be done in either a batch or continuous column format. UV radiation causes H_2O_2 to break down into two hydroxyl radicals.
H_2O_2 + hv 2OH*

2.2.4 Coagulation

Coagulation is the agglomeration by adding a chemical agent to suspended particles. The surface charges and the development of complicated hydrous oxide will be reduced. Naturally, colloids not agglomerating are considered stable. Coagulation involves processes for compression of charging neutralization, sweeping (or) coagulation and bridges, ionic layers [21].

2.3 Biological method

2.3.1 Biofilm

Biofilms are arrangements of microorganisms that form a cooperative consortium and are enclosed in a matrix. Various types of solid materials are introduced to bioreactors to offer attachment sites for biofilm growth, with good impacts on both active biomass and pollutant degradation rates. The combined effects of adsorption and biodegradation are responsible for the best fit for the pseudo-second-order model. It is understood that in order for the dye to be degraded, it must first be adsorbed on the biofilm and made available to the immobilized microbes. Because the difference between the dye concentrations in the biofilm and the liquid medium is greater at the start of the process, adsorption is stronger at first, but as the gap between the concentrations reduces, adsorption diminishes. The dye begins to be destroyed by the microorganisms after being adsorbed in the biofilm, and the adsorption and biodegradation processes continue simultaneously [29].

Method	Advantages	Disadvantages	Reference
Physical Method			
Ion exchange	There is no adsorbent loss during regeneration. It is environmentally friendly, can offer a great volume of treated water at a cheap cost, and requires little maintenance. It's a popular method for removing heavy metals from wastewater.	Not all dyes are compatible with this method. It required material regeneration or disposal. Calcium sulphate, iron fouling, organic matter adsorption, chlorine contamination and bacterial contamination are all downsides of this procedure.	[33]
Adsorption (activated Carbon) Adsorption	Wide range of dye removal It is considered better than other ways in terms of contaminant removal, design simplicity, availability of low-cost materials, initial cost, flexibility, regeneration of some adsorbent, and design simplicity.	Cost of activated carbon It generates solid waste. Some adsorbents required steam or vacuum to regenerate. This method necessitated monitoring and maintenance costs.	[34],
Membrane filtration	Removes all forms of dyes This technique creates high-quality output with flexible operating	Production of concentrated sludge. Membrane fouling occurs as a result of the process, resulting in a reduction in permeate flux.	[35],[36]

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	parameters, reduces energy usage and is favorable to the environment. Integration into other processes and operations without chemicals or additives is simple.	The cost of equipment might be high.	
Irradiation	At the lab scale, adsorbent loss and effective oxidation are observed. This method is effective for removing contaminants, including a wide range of microorganisms, without causing any long-term effects. It also removes total suspected particles and turbidity. It is easy to use and takes less contact time.	It necessitates a large amount of dissolved O_2. Irradiation with a high dose is required. It has the potential to be harmful to humans and aquatic life. It doesn't get rid of a certain amount of color.	[5],[6]
Electro-kinetic coagulation	Economically feasible	Production of high sludge.	[6]
Chemical Method			
Oxidative process	Applicability simplicity.	The [H_2O_2] agent must be activated in some way.	[6]
Fenton's reagent	Highly efficient.	Sludge production	[31]
Photochemical	There is no sludge formed, and foul odors are much avoided.	By-products are formed.	[33]
Electrochemical destruction	There is no chemical consumption and no sludge buildup.	Dye removal is reduced when flow rates are rather high.	[6]
Coagulation	This chemical method is more efficient and takes less time. This procedure is feasible from a financial standpoint. .	It is frequently costly, and Excessive sludge accumulation provides a difficulty of disposal. It's also possible that there will be secondary pollution.	[34],[35],[37]
Biological Methods			
Adsorption by dead/living microbial biomass	Certain dyes have a significant affinity for microbial interaction.	Not appropriate for all dyes	[6]
Decolorization by white-rot fungi	Using enzymes, white-rot fungi can degrade dyes	production has been proved to be unreliable.	[32]

Biological Process	When compared to other chemical and physical processes, it is frequently the most cost-effective option. Fungi, bacteria, algae, yeasts and are among the microorganisms that can accumulate and break down various contaminants.	This needs a huge area and is restricted by diurnal sensitivity as well a lack of design, toxicity of some chemicals, and operation flexibility. It is unable to remove complex organic stuff such as dye, polymer, drug and so on.	[5]

Table 1: - Represents different Dye treatment methods advantages and disadvantages.

Method	**Dyes/ Toxic Metal removed**	**Efficiency %**	**Reference**
Physical			
Ion exchange (Amberlite IRA 958 anion resins)	C.I. Acid Orange 7, C.I. Direct Blue 71 and C.I. Reactive Black 5	The experiment is best carried out in batches under shaking conditions at 180 rpm. The best conditions for this experiment were a 0.5 g anion dose, a 3-hour contact duration, a dye concentration of 10 mg/L, a pH of roughly 5, and a temperature of 24°C.Maximum efficiency (%) : 88.3	[17]
Adsorption by treated sawdust	Malachite green	Formaldehyde and sulphuric acid were used to treat sawdust. It was discovered that sawdust treated with sulphuric acid eliminates more dye than sawdust treated with formaldehyde. When the adsorbent dosage is 0.4 g/100 ml, the pH is around 6 and 9, and the temperature is approximately 26°C, the procedure removes the most dye. Maximum efficiency (%) : 99.8	[15]
Irradiation	Acidic indigo carmine	Contact period of 21 hours, starting dye concentration of 120 mg/L, irradiation dosage of 5.3 kGy, and pH of 2.8 are ideal conditions for this experiment. Maximum efficiency (%) : 98.2	[14]
Electrocoagulation	Procion Black 5B-Reactive dye	The highest decolorization efficiency for iron and aluminium electrodes were at 97.06 and 94.27 percent, respectively.	[9]
Chemical			
Oxidation	Alizarin Yellow R	94.8±1.5%	[13]

Fenton		COD is removed at a rate of roughly 90% on average. Furthermore, the average percent decolorization is greater than 97 percent.	[10]
Fenton reaction (advanced photo-oxidation technique)	Acid orange	The optimal conditions for achieving high dye removal were 0.75 g/L ferrous sulphate, 0.75 g/L hydrogen peroxide, 3 ml/L starting dye concentration, pH 3, and a reaction duration of 40 minutes. The COD level in the dye solution that had been treated had been significantly reduced. Maximum efficiency (%) : 95.5	[12]
Photochemical degradation (with titanium dioxide and UV)	Methylene blue	To improve dye removal in this technique, titanium dioxide was immobilised with polyvinyl alcohol. Initial dye concentration of 20 mg/L, UV light intensity of 4 W, liquid volumetric flow rate of 2 mL/min, and wavelength of 254 nm were determined to be ideal process conditions. The maximal dye removal reaction time was less than 20 hours. Maximum efficiency (%) : 99	[19]
Coagulation/flocculation (ferric chloride sludge from sewage plant)	Acid red 119	Response surface approach was used to optimize the process. Coagulant dose of 236.68 mg, beginning dye concentration of 65.91 mg/L, and starting pH of 3.5 are the best conditions for dye removal. Maximum efficiency (%): 96.53	[16]
Biological			
Immobilized rice straw biomass	Methylene Blue	Maximum dye removal in 2 days at 1% adsorbent dose, 300 mg/L dye concentration, pH value 7, and 30°C temperature. Maximum efficiency (%): 88	[18]
Immobilized Aspergillus Niger fungal biosorbent	Malachite Green Reactive Black (98.2%) Congo Red (84.6%)	At a dye concentration of 15 mg/L, maximum dye adsorption occurred when the fungal adsorbent dose was 15 g/L and the contact period was 72 hours. The pH of the solution was fixed to 5.0 and the temperature of the solution was kept at 32 °C to achieve maximal adsorption. The optimal agitation speed for the procedure is 140 rpm. Maximum efficiency (%): 82.6	[20]
Chitin	Pb2+	The maximum adsorption was predicted to be 99.7% at pH 9, with a contact period of 200 minutes, a biosorption dose of 5 g/L, an initial lead concentration of 20 mg/L, a temperature of 30°C, and an agitation speed of 200 rpm.	[7]
Others			
Ni_2Fe_{10}, Ni_5Fe_{10}, and $Ni_{10}Fe_{10}$	Orange G	97%, 99%, and 98%, respectively	[8]
ZnO nanocomposites	600ppm Conc	99% at 6pH, 30 C, 0.9 mg/ml dosage	[11]

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	Textile dye		
Fe_2O_3 NPs (Punica granatum) seeds extract.	reactive blue 4 dye	95.08% was achieved with 56min of reaction time	[30]

Table 2: Efficiency of Various Dye Removal Methods

2.4 Nanoparticles

Surface area, adsorption capacity, porosity, and mechanical stability all need to be as high as feasible, other aspects such as cost-effectiveness, sustainability, easy regeneration, and selectivity for an adsorbent to be effective. For the treatment of wastewater, a variety of adsorbents are now used. Agricultural, industrial wastes, domestic, organic, polymers, and inorganic materials are all used to make these adsorbents. However, the adsorbents made from the foregoing low-cost materials have low adsorption effectiveness in most circumstances. As a result, more effective, advanced and capable adsorbents for the efficient treatment of contaminated wastewater have become necessary. Nano-adsorbents have high surface area, adsorption capacity, porosity, mechanical stability and also can penetrate deeper, function faster, and have great pollutant binding ability, allowing them to efficiently cleanse wastewater. Nano-adsorbents can be fabricated into nanoparticles, nanofilms, nanotubes and nanowires.

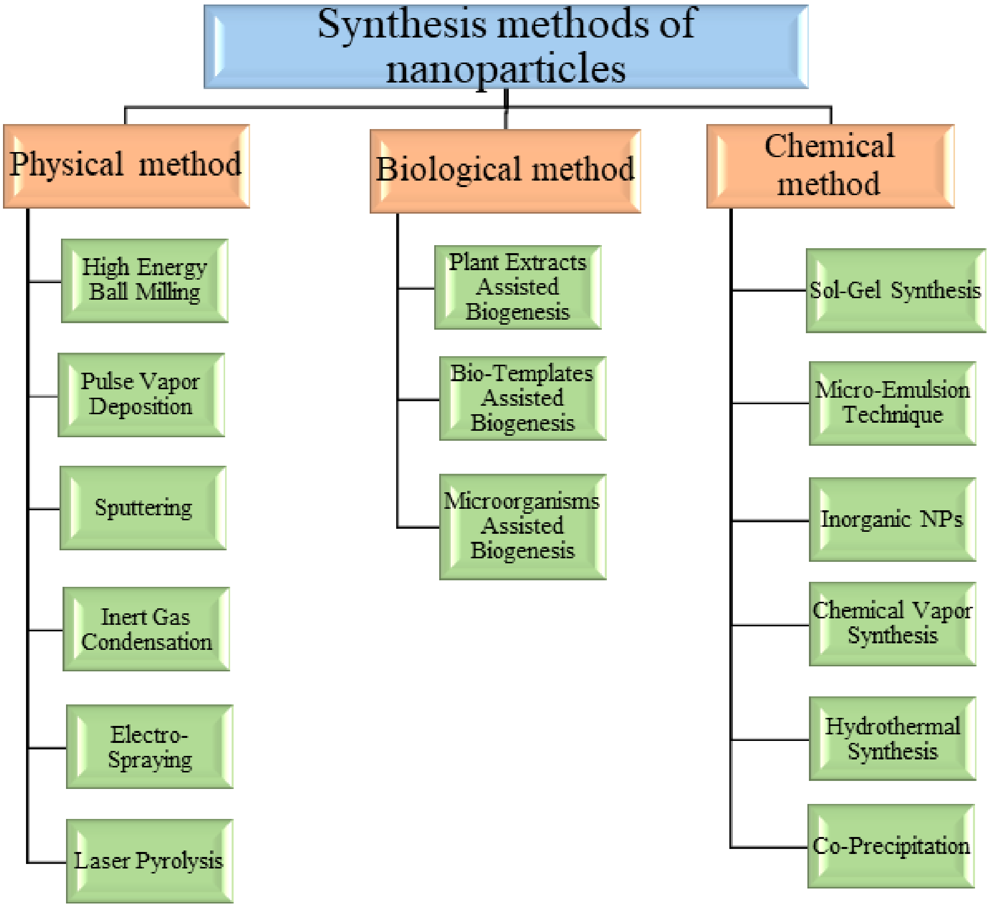

Figure1: Various methods for producing a wide range of nanoparticles.

2.4.1 Carbon nanotubes

The adsorbent's efficacy against congo red was examined by examining the effects of a variety of batch parameters such as time, temperature, solution pH, adsorbate–adsorbent contact time and initial dye concentration. In an equilibrium period of 60 minutes, multi-walled carbon nanotubes were able to remove 92 % of congo red [27].

(Fouzia Mashkoor et al) experiment evaluated multi-walled carbon nanotubes with activated carbon adsorption of reactive red M-2BE. The increased adsorption ability of multi-walled carbon nanotubes has been attributed to the larger pore diameter of multi-walled carbon nanotubes, which allows for better adsorbate dye diffusibility.

2.4.2 Nano-engineered Adsorbent

The employment of nanoparticles in the water treatment process opens up a whole new world of possibilities. The use of nanoparticles in water treatment processes opens up a new avenue of nanoparticle use. This article attempts to bring you up to date on the current status of nano-based adsorbents in the water treatment process, as well as the dyes sorption by various types of nanomaterials and their sorption efficiencies. Iron oxides/hydroxides, zero-valent iron (ZVI), titanium oxide, zinc oxide, aluminium oxide and copper oxide nanoparticles, as well as their composites, are commonly utilized as adsorbents to remove colors from water these days.

Using the borohydride chemical reduction process, researchers created zero valent iron nanoparticles and used them to remove azo dyes. Another study found that zero valent iron nanoparticles have the highest adsorption capacity for removing vat green dye from wastewater. Iron oxide, which is made up of several phases like magnetite (Fe_3O_4), maghemite (-Fe_2O_3), hematite (-Fe_2O_3), and akaganeite (-Fe_2O_3), has also been used to remove colors from water.

Magnetic Fe_3O_4 core-shell ZVI Nanoparticles were synthesized and used to remove MB and CR dyes. CR and MB had maximal adsorption capacities of 11.22 mg/g and 44.38 mg/g, respectively. Mixing iron oxides and ZVI nanoparticles with other organic and/or inorganic components has also resulted in advancements in these materials. Adsorption is also caused by the dye's molecular size and the number of groups attached to the dye. Although a nano-sized adsorbent with a large surface area can effectively remove dye molecules, the depleted nano-sized particles are difficult to separate from the water after adsorption, which could lead to toxicity if exposed for long periods of time. These issues can be mitigated in some cases by using magnetic nanoparticles, such as iron oxides. More work is needed, to make the process more efficient and advanced. Adsorption is often a non-selective process, thus undesired contaminants from wastewater can be absorbed onto the solid support. This has an unanticipated effect on the dye-sorption capacity of the support solid. Significant efforts have been made in the water treatment approach using modified nanoparticles to address these flaws. Nanoparticles, particularly magnetic nanoparticles, were added into the solid support to help the adsorbent surface separate from the water after adsorption while also increasing the active sites [38].

3. CONCLUSION

This study on the basis of a wide variety of physical, chemical and biological dyes removal technology was examined, with the significant advantages, disadvantages and drawbacks for each such technology which involves dye decoloration, by making a basic comparison between different physicochemical approaches such as photocatalying, electrochemical adsorption and organic techniques. The primary inconveniences of physical techniques such as adsorption, ion exchange, and membrane filtration have merely been shifted to a new phase of the dye molecule rather than eliminated and are only effective in tiny effluent volumes. The primary adverse factors in the creation of effective pretreatment mechanisms were ozonation, chemical oxidation and electrochemical degradation. biological methods are unable to remove complex organic stuff such as dye, polymer, drug and so on. Nanosized materials, nevertheless, provide enormous potential for water revolution, particularly for decentralized water treatment technology. In addition, some modified nanomaterials must be synthesized that are efficient, effective, simple to handle, and eco-friendly. Cost, difficulties and marketing of these wastewater treatment systems must also be taken into consideration.

Conflicts of Interest

There is no conflict of interests

REFERENCE

[1]. A. K. Yadav, C. Jain, and D. Malik, “Toxic characterization of textile dyes and effluents in relation to human health hazards,” Journal of Sustainable Environment Research, vol. 3, no. 1, pp. 95–102, 2014.

[2]. Datta Madam war, Onkar Tiwari, Kunal Jain, “Mapping of Research Outcome on Remediation of Dyes, Dye Intermediates and Textile Industrial Waste”, A Research Compendium Department of Biotechnology Ministry of Science & Technology Government of India New Delhi Compiled By: June 2019.

[3]. N. R. J. Hynes, J. S. Kumar, H. Kamyab, J. A. J. Sujana, O. A. Al-Khashman, Y.Kuslu, A. Ene, and B. Suresh, “Modern enabling techniques and adsorbents baseddye removal with sustainability concerns in textile industrial sector-a comprehensivereview, ”Journal of cleaner production, p. 122 636, 2020.

[4]. M. P. Shah, “Azo dye removal technologies,” Advances in research and applications, p. 169, 2018.

[5]. H. Patel, “Charcoal as an adsorbent for textile wastewater treatment,” Separation Science and Technology, vol. 53, no. 17, pp. 2797–2812, 2018.

[6]. N. Sivarajasekar, R. Baskar, et al., “Agriculture waste biomass valorisation for cationic dyes sequestration: A concise review,” J. Chem. Pharm. Res, vol. 7, no. 9, pp. 737–48, 2015.

[7]. I. Anastopoulos, A. Bhatnagar, D. N. Bikiaris, and G. Z. Kyzas, “Chitin adsorbents for toxic metals: A review,” International journal of molecular sciences, vol. 18, no. 1, p. 114, 2017.

[8]. S. L. Foster, K. Estoque, M. Voecks, N. Rentz, and L. F. Greenlee, “Removal of synthetic azo dye using bimetallic nickel-iron nanoparticles,” Journal of Nanomaterials, vol. 2019, 2019.

[9]. S. Raghu and C. A. Basha, “Chemical or electrochemical techniques, followed by ion exchange, for recycle of textile dye wastewater,” Journal of Hazardous Materials, vol. 149, no. 2, pp. 324–330, 2007.

[10]. W. Kuo, “Decolorizing dye wastewater with fenton’s reagent,” Water Research, vol. 26, no. 7, pp. 881–886, 1992.

[11]. E. Nakkeeran, S. J. Varjani, V. Dixit, and A. Kalaiselvi, “Synthesis, characterization and application of zinc oxide nanocomposite for dye removal from textile industrial wastewater,” 2018.

[12]. E. E. Ebrahiem, M. N. Al-Maghrabi, and A. R. Mobarki, “Removal of organic pollutants from industrial wastewater by applying photo-fenton oxidation technology,” Arabian Journal of Chemistry, vol. 10, S1674–S1679, 2017.

[13]. D. Cui, Y.-Q. Guo, H.-Y. Cheng, B. Liang, F.-Y. Kong, H.-S. Lee, and A.-J. Wang, “Azo dye removal in a membrane-free up-flow biocatalyzed electrolysis reactor coupled with an aerobic bio-contact oxidation reactor,” Journal of hazardous materials, vol. 239, pp. 257–264, 2012.

[14]. M. M. Sari, “Removal of acidic indigo carmine textile dye from aqueous solutions using radiation induced cationic hydrogels,” Water Science and Technology, vol. 61, no. 8, pp. 2097–2104, 2010.

[15]. V. Garg, R. Gupta, A. B. Yadav, and R. Kumar, “Dye removal from aqueous solution by adsorption on treated sawdust,” Bioresource technology, vol. 89, no. 2, pp. 121–124, 2003.

[16]. S. S. Moghaddam, M. A. Moghaddam, and M. Arami, “Coagulation/flocculation process for dye removal using sludge from water treatment plant: Optimization through response surface methodology,” Journal of hazardous materials, vol. 175, no. 1-3, pp. 651–657, 2010.

[17]. M. Wawrzkiewicz and Z. Hubicki, “Anion exchange resins as effective sorbents for removal of acid, reactive, and direct dyes from textile wastewaters,” Ion Exchange Studies and Applications, pp. 37–72, 2015.

[18]. A. Kumar, M. Kumar, N. R. Bishnoi,et al., “Kinetic study of methylene blueremoval on immobilized biomass left after enzyme production using response surfacemethodology,”Journal of Applied Life Sciences International, pp. 1–9, 2016.

[19]. Jan Šíma*Pavel Hasal , “Photocatalytic Degradation of Textile Dyes on aTiO2/UV System “, 2013.

[20]. M. Z. Alam, M. J. H. Khan, N. A. Kabbashi, and S. A. Sayem, “Development of an effective biosorbent by fungal immobilization technique for removal of dyes,” Waste and biomass valorization, vol. 9, no. 4, pp. 681–690, 2018.

[21]. A. K. Popuri and B. Pagala, “Removal of dye from textile industry dyeing effluent using adsorption and coagulation methods,”

[22]. M. R. Bhuiyan, M. M. Rahman, A. Shaid, and M. Khan, “Decolorization of textile wastewater by gamma irradiation and its reuse in dyeing process,” Desalination and Water Treatment, vol. 54, no. 10, pp. 2848–2855, 2015.

[23]. A. Kothai, C. Sathishkumar, R. Muthupriya, R. Dharchana,et al., “Experimentalinvestigation of textile dyeing wastewater treatment using aluminium in electrocoagulation process and fenton’s reagent in advanced oxidation process,”MaterialsToday: Proceedings, vol. 45, pp. 1411–1416, 2021.

[24]. A. L. Ahmad, W. A. Harris, B. S. Ooi, et al., “Removal of dye from wastewater of textile industry using membrane technology,” Jurnal Teknologi, 31ˆa–44, 2002.

[25]. H. Reza Rashidi, “Meriam nik sulaiman n, awanis hashim n, rosmani hassan c,redzuan ramli m, synthetic reactive dye wastewater treatment by using nano-membrane filtration,”Desalination and water treatment, vol. 55, no. 1, pp. 1–10,2014

[26]. N. de Brito-Pelegrini, P. de Tarso Ferreira Sales, and R. Pelegrini, “Photochemical treatment of industrial textile effluent containing reactive dyes,” Environmental technology, vol. 28, no. 3, pp. 321–328, 2007.

[27]. F. Mashkoor, A. Nasar,et al., “Carbon nanotube-based adsorbents for the removalof dyes from waters: A review,”Environmental Chemistry Letters, vol. 18, no. 3,pp. 605–629, 2020.

[28]. S. S. Beulah and K. Muthukumaran, “Methodologies of removal of dyes fromwastewater: A review,”International Research Journal of Pure and Applied Chem-istry, pp. 68–78, 2020.

[29]. J. Mulinari, C. J. de Andrade, H. de Lima Brand˜ao, A. da Silva, S. M. d. A. G. Ulson, A. A. U. de Souza, et al., “Enhanced textile wastewater treatment by a novel biofilm carrier with adsorbed nutrients,” Biocatalysis and Agricultural Biotechnology, vol. 24, p. 101 527, 2020.

[30]. I. Bibi, N. Nazar, S. Ata, M. Sultan, A. Ali, A. Abbas, K. Jilani, S. Kamal, F. M. Sarim, M. I. Khan, et al., “Green synthesis of iron oxide nanoparticles using pomegranate seeds extract and photocatalytic activity evaluation for the degradation of textile dye,” Journal of Materials Research and Technology, vol. 8, no. 6, pp. 6115–6124, 2019.

[31]. N. H. Ince and G. Tezcanlı, “Reactive dyestuff degradation by combined sonolysisand ozonation,”Dyes and pigments, vol. 49, no. 3, pp. 145–153, 2001.

[32]. E. A. Erkurt, H. A. Erkurt, and A. Unyayar, “Decolorization of azo dyes by white rot fungi,” in Biodegradation of Azo Dyes, Springer, 2010, pp. 157–167.

[33]. F. I. Hai, K. Yamamoto, and K. Fukushi, “Hybrid treatment systems for dye wastewater,” Critical Reviews in Environmental Science and Technology, vol. 37, no. 4, pp. 315–377, 2007.

[34]. Y. Fu and T. Viraraghavan, “Fungal decolorization of dye wastewaters: A review,”Bioresource technology, vol. 79, no. 3, pp. 251–262, 2001.

[35]. M. Joshi, R. Bansal, and R. Purwar, “Colour removal from textile effluents,” 2004.

[36]. S. Barredo-Damas, M. I. Alcaina-Miranda, M. I. Iborra-Clar, A. Bes-Pia, J. A.Mendoza-Roca, and A. Iborra-Clar, “Study of the uf process as pretreatment of nfmembranes for textile wastewater reuse,”Desalination, vol. 200, no. 1-3, pp. 745–747, 2006.

[37]. O. J. Hao, H. Kim, and P.-C. Chiang, “Decolorization of wastewater, ”Criticalreviews in environmental science and technology, vol. 30, no. 4, pp. 449–505, 2000.

[38]. N. Tara, S. I. Siddiqui, G. Rathi, S. A. Chaudhry, A. M. Asiri,et al., “Nano-engineered adsorbent for the removal of dyes from water: A review,”Current Ana-lytical Chemistry, vol. 16, no. 1,pp.14–40,2020.