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Methodologies of Removal of Dyes from Wastewater: A Review

S. Sophie Beulah[1*] **and K. Muthukumaran**[2]

[1]*Government College of Engineering, Tirunelveli, 627 007, Tamilnadu, India.*
[2]*Government College of Technology, Coimbatore, 641 013, Tamilnadu, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Dyes have been used in several industries, like paper-making, textiles, plastic, leather tanning, cosmetic and foods industries since Eighteenth century. Effluents containing dyes reduce the penetration of sunlight into natural bodies of water, thus leading to a decrease of both photosynthetic activity and the concentration of dissolved oxygen. The presence of dyes in watercourses is both aesthetically unacceptable and also toxic to aquatic ecosystem and human health. The effluent treatment technologies being used now a days for removal of dyes from wastewater includes coagulation, biological methods, adsorption, advanced oxidation processes, membrane technology, electrochemical methods, nano technology etc. In this review, extensive information is presented with regard to different techniques adopted for dyes removal from the available literature.

Keywords: Wastewater; dyes; electrocoagulation; advanced oxidation process; adsorption; membrane technology; biological methods; nano technology.

**Corresponding author: E-mail: sophie.beul@gmail.com;*

1. INTRODUCTION

A dye is a coloured substance that chemically bonds to the substrate to which it is being applied. The dye is generally applied in an aqueous solution. They contain a group of atoms called as chromophores responsible for the colour of the dyes. Dyes are usually used by many industries such as dyestuffs, textile, paper, plastics, tannery, and paints, to colour their products and also consume substantial volumes of water. As a result, they generate a considerable amount of coloured wastewater [1].

Dyes can be classified according to their constituents, colours and applications. Azo dyes, anthraquinone dyes, phthalocyanine, indigoid dyes, nitroso dyes, nitro dyes and triarylmethane dyes based on the classification of chemical structure. Azo, anthraquinone and triarylmethane dyes are the most important groups among these dyes. The classification based on the different applications for the dyes are vat, mordant and disperse dyes [2]. The dyes used in the textile industry are classified as cationic dyes- includes basic dyes, anionic dyes- includes acid dyes, reactive dyes, azo dyes, direct dyes, non-ionic dyes- includes disperse dyes that do not ionize in aqueous media [3].

Synthetic dyes possess certain properties which makes them unaltered long time such as resistance to abrasion, photolytic stability, resistance to chemical and bacterial attack. Therefore, most of these compounds pose a double environmental problem from both the aesthetic and toxicological standpoint. Their presence in water causes phenomena such as eutrophication, underoxygenation, colour and odour alteration, as well as persistence and long-term bioaccumulation [4]. The wastewater containing dyes is usually discharged directly into nearby rivers, drains, stagnant ponds or lakes. Dyes absorb and reflect sunlight entering the water and thus can interfere with the growth of bacteria and impede photosynthesis in aquatic plants [5]. The presence of very small amounts of dyes in water (less than 1 ppm for some dyes) is highly visible and undesirable [6]. Many of these dyes are also toxic and even carcinogenic, and this poses a serious hazard to aquatic living organisms also [7]. It is necessary to eliminate dyes effectively prior to their final discharge to the water sources. There are several reported treatment methods for the removal of dyes from effluents and these technologies can be divided into three categories: physical, chemical and biological methods. This review paper presents the various methods of removal of dyes from wastewater from the available literature.

2. LITERATURE REVIEW

2.1 Various Dyes Removal Methods

2.1.1 Electrocoagulation

Electrocoagulation technique uses a direct current power source between metal electrodes immersed in polluted water. The electrical current causes the dissolution of metal plates including iron or aluminum into wastewater. The metal ions generation takes place at the anode and hydrogen gas is released from the cathode. The metal ions, at an appropriate pH, forms a wide range of coagulated species and metal hydroxides that destabilize and aggregate the suspended particles or precipitate and adsorb dissolved contaminants. The hydrogen gas would also help to float the flocculated particles out of the water [8]. Electrocoagulation provides some significant advantages such as simple equipment, easy operation, small retention time, high velocities, reduced amount of sludge, and no chemical additives [9]. High electrical energy and high cost are needed resulting in the limited use [2].

Sandeep Thakur et al (2016) employed electrocoagulation method and investigated the influence of different variable parameters like inter electrode distance, initial conductivity, time of electrolysis, pH of the solution and initial concentration of dye and the efficiency to remove Malachite Green dye (Basic Green 4) from aqueous solution. An electrocoagulation set up was designed using stainless steel as an electrode. Then different parameters were studied using known concentration (150 mg/L) and initial COD (256 mg/L) of prepared dye contaminated synthetic solution in a batch mode. The results showed that a very high decolorization of 99.50% and the reduction of COD upto 85.71% was achieved with in 20 min electrolysis time, 1 cm of inter electrode distance and initial conductivity (1.5 mS) at pH 8. [10].

Jorge Vidal et al (2017) carried out the electrocoagulation of the textile dye acid black 194. Synthetic samples of the textile dye acid black 194 (AB194, CI 22910) were treated by this method using iron anodes at two different initial pH values The elimination of the dye using iron electrodes was effective by applying high current densities (5.0 and 10.0 mA cm^{-2}), reaching a total discolorization in less than 60 minutes and a total organic carbon decay over 75%. It was established that the best experimental conditions of pH and current density are 8.5 and 5 mA cm^{-2}, respectively [11].

2.1.2 Advanced oxidation processes

Advanced Oxidation Process (AOP) is a chemical treatment method that grows in the wastewater management industry. Advanced oxidation processes (O_3, O_3/H_2O_2, O_3/UV, H_2O_2/UV, O_3/H_2O_2/UV, $Fe^{2+}/\ H_2O_2$) for the degradation of non-biodegradable organic contaminants in industrial effluents are attractive alternatives to conventional treatment methods. AOPs are based on the generation of very reactive and oxidizing free radicals and have been used with an increasing interest due to the their high oxidant power. Production of those radicals is achieved either using single oxidants or combinations of ozone, hydrogen peroxide and UV radiation and also, with the combination of hydrogen peroxide with ferrous ions in the so-called Fenton's reagent .Although AOPs have a significant advantages over conventional treatment methods since chemical oxidation do not result in high amount of either chemical or biological sludge and almost complete demineralization of organics is possible, the main limitation with AOPs lies in the high cost of reagents or energy sources like ultraviolet light [12]. The basic principle of AOP includes the production of hydroxyl radicals (OH•), which can be generated from hydrogen peroxide (H_2O_2), ozone, photo-catalysis or oxidizing agents together with the use of ultraviolet rays. The OH• is primarily responsible for the decomposition of organic compounds [13].

Mohamed A. Hassaan etal (2017) examined the viability of applying ozone and ozone combined with ultraviolet to degrade the content of synthetic wastewater containing Direct Blue 86 (DB-86) dye. The tested parameters, which included pH, initial concentration of DB-86 dye and time of reaction, were tested in a batch reactor to achieve optimum operating circumstances. The study showed that pH and initial concentration of DB-86 dye controlled the efficiency of the decolorization process. The maximum decolorization was obtained at pH 11. More than 98% of color removal was reported after 35 min of O_3 treatment (for 100 ppm dye concentration). Kinetic analyses showed that colour removal of DB-86 dye followed first-order kinetics. The rate of color removal was primarily relative to the initial DB-86 dye concentration. The effect of seawater on the efficiency of the process was studied. Gas Chromatography Mass Spectrum analysis of treated synthetic DB-86 dye solution was performed at the end of the pre-treatment time to study the final degradation products of DB-86 dye. The obtained results revealed that ozonation processes had reduced the zooplankton toxicity belonging to the raw solution and had improved the biodegradability of the DB-86 dye wastewater [14].

Maha A. Tony et al (2019) analysed the role of the particle size of an iron source in the photo-Fenton system for textile dyeing wastewater oxidation. In this respect, a facile synthesis of Fe_2O_3 nanoparticles via a simple sol–gel route using $FeCl_3$ with different molarities was investigated. The treatment of wastewater effluents containing the reactive dye Procion Blue MX-7RX from a real textile dyeing facility, was investigated using the synthesized Fe_2O_3 nanoparticles as a source of the Fenton's reagent photocatalyst. The reaction was initiated and enhanced using an artificial UV source for increasing the hydroxide radical yield. System parameters such as the initial dye load in wastewater, H_2O_2 and Fe_2O_3 nanoparticles concentrations, pH and the working temperature were investigated for process optimization. The quality of water in this investigation was examined by making measurements of chemical oxygen demand, total suspended solids and dye removal which decreased during the illumination time. The effects of different Fe_2O_3 nano particles based on the varying precursor solution molarities on the wastewater remediation were investigated, and the highest dye removal value of 83% and a chemical oxygen demand reduction of 88% was obtained [15].

2.1.3 Adsorption

Adsorption has been found to be one of the most effective and established treatment of wastewater in textile industry as it is an economically achievable process for dyes removal and/or decolourization of textile effluents. The process involves the transfer of soluble organic dyes from wastewater to the surface of the adsorbent which is solid and highly porous material. The adsorbent adsorbs each compound to be removed to its capacity and when it is 'spent' should be replaced by fresh material. The spent adsorbent may be either regenerated or incinerated. The main factors which influence dye adsorption are: interaction between dye and adsorbent, surface area and particle size of adsorbent, pH, temperature and time duration of contact. The most commonly used adsorbent is activated carbon. Activated carbon has been engineered for optimum adsorption of large, negatively charged or polar molecules of dyes. The cationic mordant and acid dyes are removed with high removal rates whereas dispersed, vat, direct, pigment and reactive dyes are removed with moderate removal rates. Bio sorption has been studied using various less expensive adsorbents of agricultural wastes which can adsorb and accumulate dyes and other organic compounds The advantage of using these materials is mainly due to their widespread availability and low cost, also their regeneration is not required. Though the use of low cost adsorbents for textile dye removal is lucrative but a vast amount of adsorbents are required [16].

Charu Arora et al (2019) prepared chenopodium album ash as effective adsorbent for the removal of a hazardous dye, crystal violet, from its aqueous solutions. Two techniques, that is, batch and column operations have been used to explain the removal process. Column capacity was found to be lesser than the batch adsorption capacity. Batch adsorption studies were conducted as a function of adsorbent dose, equilibrium pH, contact time, initial dye concentration, kinetics and freundlich isotherms. Extent of adsorption has been found to be greater at neutral pH. The process of adsorption was best described by the pseudo-first-order and intraparticle diffusion kinetics models. The adsorption data fitted to Freundlich isotherm. Negative free energy favors the spontaneity of adsorption process while positive enthalpy and entropy values indicate endothermic and random nature of adsorption [17].

Vandana Gupta et al (2017) analysed the percent color removal of Red RB dye from aqueous solution by using activated carbon prepared from plant material Belpatra Bark and showed that it increased with the decrease in initial dye concentration, particle size, temperature and pH of the solution. It also increased with increasing dosage of adsorbent. From the thermodynamic analysis, it was proved that adsorption process was exothermic, feasible and spontaneous. It was found that it can remove maximum 94.0% dye in 20 mg/L dye concentration having 75- 299 μm particle sizes of adsorbent, 0.5 gm adsorbent dosage at 320 K temperature and 3.0 pH in only 40-45 minutes [18].

2.1.4 Electrochemical methods

Among the electrochemical treatment methods, electrochemical oxidation is of particular interest in the treatment of wastewaters polluted with organic compounds. In the electrochemical oxidation process, the organic and toxic pollutants present in wastewater such as dye usually destroyed by either the direct or indirect oxidation process. In a direct anodic oxidation process, the pollutants are first absorbed on the anode surface and then destroyed by the anodic electron transfer reaction [19]. In an indirect oxidation process, strong oxidants such as hypochlorite/chlorine, ozone or hydrogen peroxide can be regenerated by the electrochemical reactions during electrolysis [20]. The electrochemical technique offers high removal efficiencies and has lower temperature requirements compared to non-electrochemical treatment. In addition to the operating parameters, the rate of pollutant degradation depends of the anode material [21]. The main drawback of chemical methods is the high cost which prevents it from being extensively used in industry [16].

Noor H Jawad et al(2018) studied the degradation of methylene blue dye from aqueous solution by direct electrochemical oxidation technique. For this purpose an electrochemical cell was used comprising of two electrodes made from graphite as anode and stainless steel 316 grade as cathode. Different operating parameters that affected the treatment process such as current density, electrolyte temperature and initial dye concentration was studied. The reaction mechanism was studied and the kinetics followed a pseudo first order reaction. Results revealed that at 20°C electrolyte temperature, 10 mA/cm^2 current density, 0.5 g/L Na_2SO_4 as supporting electrolyte and 60 min electrolysis time, the decolorization percents for initial concentrations of M.B. 50 and 400 mg/L were 72.51% and 77.94% respectively while at 60°C the decolorization percent 99.75% and 99.60% respectively [22].

Ali Asghar Najafpoor et al (2017) assessed the performance of each of the electro-oxidation and electro-reduction pathways in the removal of reactive red 120 (RR120) from synthetic textile effluents using a novel electrochemical reactor. A two-compartment reactor divided by cellulosic separator was applied in batch mode using graphite anodes and stainless steel cathodes. Central Composite Design was used to design the experiments and find the optimal conditions. The operational parameters were initial dye concentration (100–500 mg L^{-1}), sodium chloride concentration (2500–12,500 mg L^{-1}), electrolysis time (7.5–37.5 min), and current intensity (0.06–0.3 A). The results showed that electro-oxidation was much more efficient than electro-reduction in the removal of RR120. Under optimal conditions (RR120 = 200 mg.L^{-1}, NaCl = 7914.29 mg.L^{-1}, current intensity = 0.12 A, and reaction time = 30 min), the dye was removed as 99.44 and 32.38% via electro-oxidation and electro-reduction mechanisms, respectively, with consuming only 1.21 $kwhm^{-3}$ of electrical energy [23].

2.1.5 Biological methods

Biological material such as algae, bacteria, fungi and yeasts have an ability to disintegrate as well as absorb varieties of synthetic dyes [24]. Biological based methods employed for degradation of the effluent from the textile industries have been successfully used. The bioremediation is economically feasible, environmental-friendly and generates less volume of sludge when compared with other techniques. It causes the degradation of synthetic dyes to a comparatively less toxic inorganic compound because of breakdown of bond (i.e., chromophoric group) and finally helps in removal of color [25]. Some disadvantages are biological methods take much time and cannot degrade complicated dyes [26].

Inès Mnif et al (2015) isolated Citrobacter sedlackii RI11 from acclimated textile effluent after selective enrichment on synthetic dyes and assessed for malachite green (MG) biotreatment potency. Results indicated that this bacterium has potential for use in effective treatment of MG contaminated wastewaters under shaking conditions at neutral and alkaline pH value, characteristic of typical textile effluents. Also, the newly isolated strain tolerated higher doses of dye and decolorize up to 1,000 mg/L of dye. When used as microbial surfactant to enhance MG biodecolorization, Bacillus subtilis SPB1-derived lipopeptide accelerated the decolorization rate and maximized the decolorization efficiency at an optimal concentration of biosurfactant of about 0.075%. Studies ensured that MG removal by this strain could be due to biodegradation and/or adsorption [27].

Eslami H et al (2017) evaluated the biodegradation of methylene blue (MB) from aqueous solution by bacteria isolated from contaminated soil. Medium containing 50, 100, 200, 400, 800 and 1000 mg/L of methylene blue, 50 mL of salt medium with glucose and 2.5 mL of brain-heart infusion medium containing bacteria were prepared. The results of dye removal were analyzed using UV/Vis spectrophotometer at 665 nm. The results of purification and identification of the bacterial species which degraded methylene blue indicated that Pseudomonas aeruginosa was the dominant bacteria. In this study, the removal efficiency of bacteria was attained from 82.25 to 97.82 % with an increase in initial MB concentration from 50 to 200 mg/L. With increase in MB concentration from 200 to 1000 mg/L, removal efficiency was reduced to 43.08%. The optimum concentration of MB removal was 200 mg/L. It was evident from the results that the bacteria had used methylene blue as an auxiliary source of carbon apart from glucose [28].

2.1.6 Membrane technology

Membranes are widely used in different industries of separation processes because of their ability to control materials passing through the membrane, thus achieving a high degree of separation always, making these processes widely acceptable. Two pressure driven membranes are reverse osmosis (RO) and nanofiltration (NF) membranes. NF is characterized by a membrane pore size between 0.5 and 2 nm It is used to achieve separation between sugars, other organic molecules and multivalent salts on one hand and monovalent salts, ions and water on the other. RO or hyperfiltration is characterized by a membrane pore size in the range of 0.5 nm.. The ability of RO membranes to remove both organic and inorganic compounds has made it attractive for the treatment of contaminated drinking water supplies [29]. Prevention of membrane fouling in these advanced membrane separation processes is considered as a critical challenge for ensuring their economic viability [3].

Jiaqi Cheng et al (2020) fabricated a new type of deacetylated cellulose acetate and polydopamine composite nanofiber membrane by electrospinning and surface modification. The membrane was applied as a highly efficient adsorbent for removing methylene blue (MB) from an aqueous solution. The morphology, surface chemistry, surface wettability, and effects of operating conditions on MB adsorption ability, as well as the equilibrium, kinetics, thermodynamics, and mechanism of adsorption, were systematically studied. The adsorption capacity of the nanofiber membrane reached up to 88.2 mg/g at a temperature of 25°C and a pH of 6.5 after adsorption for 30 h. The experimental results showed that the adsorption behavior of composite nanofibers followed the Weber's intraparticle diffusion model, pseudo-second-order model, and Langmuir isothermal model. A thermodynamic analysis indicated that endothermic, spontaneous, and physisorption processes occurred [30].

Nada Mustafa H. AL – Nakib (2013) examined the removal of dyes from wastewater by reverse osmosis process. Two dyes were used direct blue 6, and direct yellow. Experiments were performed with feed concentration (75 – 450 ppm), operation temperature (30 – 50 °C) and time (0.2 – 2.0 hr). The membrane used is thin film composite membrane (TFC). It was found that modal permeate concentration decreased with increasing feed concentration and time operating, while permeate concentration increased with increasing feed temperature. Also it was found that product rate increased with increasing temperature, but it decreased with increasing feed concentration and time. The concentration of reject solution showed an increase with increasing feed concentration of dyes and feed temperature, while decreases with increasing time operating of reverse osmosis unit. The maximum rejection for direct blue 6 and direct yellow are 98.89% and 98.30% respectively. The maximum recovery percentage for direct blue 6 and direct yellow are 17.84% and 18.20% respectively [31].

2.1.7 Nano technology

Nanomaterials refer to the materials with one or more external dimensions in the range between 1 and 100 nm. The small size offers nanomaterials extraordinary properties like extremely large surface area, more surface active sites, quantum effect, unique electron conduction property, etc. These unique properties greatly benefit the performance of nanomaterials when used as adsorbents, catalysts, sensor, or in other application. Thus, nanomaterials bring new opportunities for the revolution of the dye-contaminated wastewater treatment technologies. Many nanomaterials show superior performance than bulk materials. Some researchers found that the nanomaterials could promote the biodegradation of dyes in wastewater However, some challenges, such as high cost and poor separation performance, still limit their engineering application [32].

Ravindra D. Kale et al (2016) synthesized nickel nanoparticles and used it to decolourize dye effluent. C. I. Reactive Blue 21 was taken as the reference dye and polyvinyl pyrrolidone (PVP) was used as a stabilizer to prevent agglomeration of nanoparticles. Characterization of nanoparticles was done by a laser light scattering particle size analyzer, X-ray diffraction analysis and transmission electron microscopy. Various parameters like pH, dye concentration, nanoparticle concentration, alkali addition, salt addition and duration studied for dye decolourization. To confirm the attachment of degraded products of dye on the nanoparticles, FT-IR analysis was done. About 98% colour removal with simultaneous reduction in chemical oxygen demand was achieved [33].

Edris Bazrafshan et al (2013) assessed singlewalled carbon nanotubes as an adsorbent for the successful removal of Reactive Red 120 (RR-120) textile dye from aqueous solutions. The effect of various operating parameters such as initial concentration of dye, contact time, adsorbent dosage and initial pH was investigated in order to find the optimum adsorption conditions. Equilibrium isotherms were used to identify the possible mechanism of the adsorption process. The optimum pH for removing of RR-120 dye from aqueous solutions was found to be 5 and for this condition maximum predicted adsorption capacity for RR-120 dye was obtained as 426.49 mg/g. Also, the equilibrium data were also fitted to the Langmuir, Freundlich and BET equilibrium isotherm models [34].

2.1.8 Ion exchange resins

Among the wide group of sorbents used for dyes removal from wastewaters anion exchangers resins are very popular. Anions exchangers as reactive polymers are macromolecular compounds, insoluble in water and organic solvents, constructed from a spatially cross-linked porous matrix containing reactive functional groups. These groups have ion-exchange (anion-exchange or cation-exchange), oxidizing, reducing or complex-forming properties. They may have the ability to react with different type with organic and inorganic compounds. The anion exchangers are quite popular adsorbents of various types of pollutions. Anion exchangers are characterized by high sorption efficiency, selectivity as well as a well developed specific surface. The role of anion exchangers in wastewater treatment is to reduce the amount of pollutants emitted to the environment by converting them into a less toxic form or finally removing them [35]. Anion exchange resins, in particle form, entail certain disadvantages when employed in packed-bed operations, which include slow pore diffusion, low accessible flow rates, high pressure drop and flow channeling [36]

Akazdam S et al (2017) studied the removal of Acid Orange 7(AO7) dye from wastewater using the macroporous strongly basic anion exchange resin Amberlite FPA-98 using the batch method. The adsorbent was characterized by Fourier Transform-Infrared Spectroscopy and X Ray Diffraction. FTIR results showed complexation and ion exchange appear to be the principle mechanism for AO7 adsorption. Batch adsorption studies were carried out under various

Table 1. Removal of dyes by various methods

Methods	Dyes	Removal efficiency	References
Electrocoagulation	Malachite Green	99.5 %	Sandeep Thakur et al (2016)
Electrocoagulation	Acid black 194	Total discolourization	Jorge Vidal et al(2017).
Advanced oxidation process-ozone treatment	Direct Blue 86	More than 98 %	Mohamed A. Hassaan etal(2017)
Fenton'S reagent-H_2O_2 and Fe_2O_3 nanoparticles/UV	Procion Blue MX-7RX	83 %	Maha A. Tony et al(2019)
Adsorption by Chenopodium album	Crystal Violet	9.42 mg/g	Charu Arora et al(2019)
Adsorption by Belpatra Bark Charcoal	Red RB dye	94 %	Vandana Gupta et al(2017)
Electrochemical oxidation	Methylene Blue	99.75 %	Noor H Jawad et al(2018)
Electrochemical oxidation	Reactive red 120	99.44 %	Ali Asghar Najafpoor et al (2017)
Citrobacter sedlackii RI11 bacterium	Malachite Green	83.1 %	Inès Mnif et al(2015)
P. aeruginosa bacteria	Methylene blue	97.82 %	Eslami H et al(2017)
Deacetylated cellulose acetate and polydopamine composite nanofiber membrane	Methylene blue	88.2 mg/g	Jiaqi Cheng et al(2020)
Reverse Osmosis-Thin film composite membrane	Direct blue 6, Direct yellow	The maximum rejection of dye direct yellow is 98.30 % and for direct blue 6 is 98.89%	Nada Mustafa H. AL – Nakib(2013)
Nickel nano particles	C. I. Reactive Blue 21	98 %	Ravindra D. Kale et al(2016)
Single walled carbon nano tubes	Reactive red 120	426.49 mg/g.	Edris Bazrafshan et al(2013)
Anion exchange resin Amberlite FPA-98	Acid Orange 7 dye	200 mg/g	Akazdam S et al(2017)
Anion exchange resins of various matrices (Amberlyst A 23, Amberlite IRA 67 and Lewatit MonoPlus MP 62).	Remazol Black B	66.4, 282.1 and 796.1 mg g^{-1} for Amberlite IRA 67, Amberlyst A 23 and Lewatit MonoPlus MP 62, respectively.	Monika Wawrzkiewicz et al (2011)

Table 2. Summary of advantages and disadvantages of the removal methods

Removal methods	Advantages	Disadvantages
Electrocoagulation	Simple equipment, easy operation, small retention time, high velocities, reduced amount of sludge, no chemical additives	High electrical energy and high cost are needed resulting in the limited use.
Advanced oxidation process	Doesn't result in high amount of chemical or biological sludge, complete demineralization of organics is possible	High cost of reagents or energy sources like ultraviolet light
Adsorption with agricultural wastes	Widespread availability, low cost	Vast amount of adsorbents are required
Electrochemical methods	High removal efficiencies, lower temperature requirements compared to non electrochemical treatment	High cost
Biological methods	Economically feasible, environmental friendly, generates less volume of sludge	Biological methods take much time and cannot degrade complicated dyes
Membrane technology	Control materials passing through the membrane, achieves high degree of seperation	Prevention of membrane fouling is considered as a critical challenge for ensuring their economic viability
Nano technology	Many nanomaterials show superior performance than bulk materials. Nanomaterials could promote the biodegradation of dyes in wastewater	High cost and poor separation performance
Ion exchange resins	High sorption efficiency, selectivity	Anion exchange resins, in particle form when employed in packed-bed operations has slow pore diffusion, low accessible flow rates, high pressure drop and flow channeling

parameters such as contact time, pH, initial dye concentration, adsorbent dosage, agitation speed, and solution temperature on the removal of AO7. The best fit for isotherm was obtained by Langmuir model with a Langmuir maximum monolayer adsorption capacity of 200 mg/g at 303°K. The adsorption kinetic data fitted very well with the pseudo-second-order kinetic model. The results obtained show that the concentrated solution gives better removal efficiencies. The Gibbs energy was increased from 298 to 323°K indicating a decrease in feasibility of adsorption at higher temperatures [37].

Monika Wawrzkiewicz et al (2011) made use of the weakly basic anion exchange resins of phenol-formaldehyde (Amberlyst A 23), polyacrylate (Amberlite IRA 67) and polystyrene (Lewatit MonoPlus MP 62) matrices for removal of the reactive dye Remazol Black B (RBB) from aqueous solution and wastewater were investigated. RBB sorption on the anion exchangers was a time dependent process. Colour reduction percentiles of 75.2, 33.9 and 25.1% in wastewater treatment were found after 216 h of phase contact time with Lewatit MonoPlus MP 62, Amberlyst A 23 and Amberlite IRA 67, respectively. Inorganic salts and anionic surfactant action influenced RBB uptake by the anion exchangers. The amounts of dye retained by the anion exchangers increased with a rise in temperature. The maximum sorption capacities calculated from the Langmuir model were 66.4, 282.1 and 796.1 mg g^{-1} for Amberlite IRA 67, Amberlyst A 23 and Lewatit MonoPlus MP 62, respectively [38].

In general the factors responsible for the various removal processes are 1. Electrocoagulation-electric current, metal electrodes, appropriate pH. 2. Advanced oxidation processes-Generation of very reactive and oxidizing free radicals, pH, initial concentration of dye, time, temperature 3. Adsorption-Interaction between dye and adsorbent, surface area and particle size of adsorbent, pH, temperature and time duration of contact 4. Electrochemical methods-electrodes, current density, electrolyte temperature, initial dye concentration 5. Biological methods-pH, concentration of dye, 6. Membrane technology-membrane pore size and pressure, temperature, pH, feed concentration, 7. Nanotechnology-nanomaterial properties like surface active sites, nanoparticle concentration, pH 8. Ion exchange resins-ion exchange properties of functional groups, pH, time, dosage. These factors vary in general according to the physical, chemical and biological methods of removal of dyes.

3. CONCLUSION

In this paper, an attempt has been made to review various methodologies of dyes removal from wastewater like electrocoagulation, advanced oxidation processes, adsorption, electrochemical process, bioremediation, membrane techniques, nano technology, ion exchange resin. The researchers have shown promising results by using these techniques which can be used solve the global environmental issue of water pollution by remediation of dyes from wastewater and save the precious water sources for future use. Future research works may include real industrial dye effluents treatment using the above methodologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Grégorio C. Non-conventional low-cost adsorbents for dye removal: a review. Bioresource Technology. 2006;97:1061–1085.
2. Wenqian Ruan, Jiwei Hu, Jimei Qi, Yu Hou, Chao Zhou, Xionghui Wei. Removal of dyes from wastewater by nanomaterials: A review. Advanced Materials Letters. 2019;10(1):9-20.
3. Mokif LA. Removal methods of synthetic dyes from industrial wastewater: A review. Mesopotamia Environmental Journal. 2019;5(1):23-40.
4. Sirés I, Guivarch E, Oturan N Oturan MA. Efficient removal of triphenylmethane dyes from aqueous medium by in situ electrogenerated Fenton's reagent at carbon-felt cathode. Chemosphere. 2008;72:592-600.
5. Joshi M, Bansal R, Purwar R. Colour removal from textile effluent. Indain Journal of Fiber and Textile Research. 2004;29:239-259.
6. Banat IM, Nigam P, Singh D, Marchant R. Microbial decolorization of textile-dyecontaining effluents: a review. Bioresource Technology. 1996;58:217–227.
7. Kyzas GZ, Fu J, Matis KA. The change from past to future for adsorbent materials in treatment of dyeing wastewaters. Materials. 2013;6:5131–5158.
8. Chen G. Electrochemical technologies in wastewater treatment. Seperation and Purification Technology. 2004;38:11–41.
9. Holt PK, Barton GW, Wark M, Mitchell CA. A quantitative comparison between chemical dosing and electrocoagulation. Colloids and Surfaces. 2002;A211:233–248.
10. Sandeep Thakur Chauhan MS. Removal of malachite green dye from aqueous solution by electrocoagulation with stainless steel electrodes. International Journal of Engineering Sciences and Research Technology. 2016;5(6):515-521.
11. Jorge Vidal, Carolina Espinoza, Nicole Contreras, Ricardo Salazar. Elimination of industrial textile dye by electrocoagulation using iron electrodes. Journal of the Chilean Chemical Society. 2017;62(2):3519-3524.
12. Sundararaman TR, Ramamurthi V, Partha N. Decolorization and COD removal of reactive yellow 16 by fenton oxidation and comparison of dye removal with photo fenton and sono fenton process. Modern Applied Science. 2009;3(8):15-22.
13. Krishnan S, Rawindran H, Sinnathambi CM, Lim JW. Comparison of various advanced oxidation processes used in remediation of industrial wastewater laden with recalcitrant pollutants. Proceeding of 29th Symposium of Malaysian Chemical Engineers IOP Conf. Series: Materials Science and Engineering. 2017;206:1-11.
14. Mohamed A. Hassaan, Ahmed El Nemr, Fedekar F. Madkour. Testing the advanced oxidation processes on the degradation of Direct Blue 86 dye in wastewater. Egyptian

Journal of Aquatic Research. 2017;43:11-19.

15. Maha A. Tony, Shehab A. Mansour. Removal of the commercial reactive dye Procion Blue MX-7RX from real textile wastewater using the synthesized Fe_2O_3 nanoparticles at different particle sizes as a source of Fenton's reagent. Nanoscale Advances. 2019;1:1362-1371.
16. Rummi Devi Saini. Textile Organic Dyes: Polluting effects and elimination methods from textile waste water. International Journal of Chemical Engineering Research. 2017;9(1):121-136.
17. Charu Arora, Deepti Sahua, Dipti Bhartib, Vinita Tamrakara, Sanju Sonia, Sadanand Sharma. Adsorption of hazardous dye crystal violet from industrial waste using low-cost adsorbent Chenopodium album. Desalination and water treatment. 2019;167:324-332.
18. Vandana Gupta, Anupam Agarwal, Singh MK, Singh NB. Removal of red RB dye from aqueous solution by Belpatra Bark Charcoal (BBC) Adsorbent. Journal of Materials and Environmental Sciences. 2017;8(10):3654-3665.
19. Louhichi B, Ahmadia MF, Bensalah N, Gadri A, Rodrigo MA. Electrochemical degradation of an anionic surfactant on boron-doped diamond anodes. Journal of Hazardous Materials. 2008;158:430.
20. Yang CH, Lee CC, Wen TC. Hypochloride generation on Ru-Ti binary oxide for the treatment of dye wastewater. Journal of Applied Electrochemistry. 2000;30:1043.
21. Mohan N, Balasubramanian N, Ahmed Basha C. Electrochemical oxidation of textile wastewater and its reuse. Journal of Hazardous Materials. 2007;147:644–651.
22. Noor H Jawad, Sarmad T Najim. Removal of methylene blue by direct electrochemical oxidation method using a graphite anode. IOP Conference Series: Materials Science and Engineering. 2018;454:012023.
23. Ali Asghar Najafpoor, Mojtaba Davoudi, Elham Rahmanpour Salmani. Decolorization of synthetic textile wastewater using electrochemical cell divided by cellulosic separator. Journal of Environmental Health Science and Engineering. 2017;15:11.
24. Ali H. Biodegradation of synthetic dyes-a review. Water, Air and Soil. Pollution. 2010;213:251–273.
25. Babu SS, Mohandass C, Vijayaraj AS, Dhale, MA. Detoxification and color removal of Congo Red by a novel Dietzia sp. (DTS26)–a microcosm approach. Ecotoxicology and Environmental Safety. 2015;114:52–60.
26. Can OT, Kobya M, Demirbas E, Bayramoglu M. Treatment of the textile wastewater by combined electrocoagulation. Chemosphere. 2006;62(2):181–187.
27. Inès Mnif, Raouia Fendri, Dhouha Ghribi, Malachite green bioremoval by a newly isolated strain Citrobacter sedlakii RI11; enhancement of the treatment by biosurfactant addition. Water Science and Technology. 2015;72.8:1283-1293.
28. Eslami H, Sedighi Khavidak S, Salehi F, Khosravi R, Fallahzadeh RA, Peirovi R, Sadeghi S. Biodegradation of methylene blue from aqueous solution by bacteria isolated from contaminated soil. Journal of Advances in Environmental Health Research. 2017;5(1):10-15.
29. AWWA Membrane Technology Research Committee: Committee Report: Membrane processes in potable water treatment: AWWA. 1992;59.
30. Jiaqi Cheng, Conghua Zhan, Jiahui Wu, Zhixiang Cui, Junhui Si, Qianting Wang, Xiangfang Peng, Lih-Sheng Turng. Highly efficient removal of methylene blue dye from an aqueous solution using cellulose acetate nanofibrous membranes modified by polydopamine. ACS Omega. 2020;5:5389−5400.
31. Nada Mustafa H. AL – Nakib. Reverse osmosis polyamide membrane for the removal of blue and yellow dye from waste water. Iraqi Journal of Chemical and Petroleum Engineering. 2013;14(2):49-55.
32. Zhengqing Cai, Youmin Sun, Wen Liu, Fei Pan, Peizhe Sun, Jie Fu. An overview of nanomaterials applied for removing dyes from wastewater. Environmental Science and Pollution Research. 2017;24:15882–15904.
33. Ravindra D. Kale, Prerana B. Kane. Colour removal using nanoparticles. Textiles and Clothing Sustainability. 2016;2:4.
34. Edris Bazrafshan, Ferdos Kord Mostafapour, Ali Reza Hosseini, Ataolah Raksh Khorshid, Amir Hossein Mahvi. Decolorisation of Reactive Red 120 Dye by Using Single-Walled Carbon Nanotubes in Aqueous Solutions. Journal of chemistry. 2013;4.

35. Ewelina Polska-Adach, Monika Wawrzkiewicz, Zbigniew Hubicki. Removal of acid, direct and reactive dyes on the polyacrylic anion exchanger. Physicochemical Problems of Mineral Processing. 2019;55(6):1496-1508.
36. Muhammad Imran Khan, Shahbaz Akhtar, Shagufta Zafar, Aqeela Shaheen, Muhammad Ali Khan, Rafael Luque, Aziz ur Rehman. Removal of congo red from aqueous solution by anion exchange membrane (EBTAC): Adsorption Kinetics and Themodynamics. Materials. 2015;8: 4147-4161
37. Akazdam S, Chafi M, Yassine W, Gourich B. Removal of acid orange 7 Dye from aqueous solution using the exchange resin amberlite FPA-98 as an efficient adsorbent: kinetics, isotherms, and thermodynamics study. Journal of Materials and Environmental Sciences. 2017;8(8):2993-3012.
38. Monika Wawrzkiewicz, Zbigniew Hubicki. Remazol Black B removal from aqueous solutions and wastewater using weakly basic anion exchange resins. Central European journal of chemistry. 2011;9(5):867-876.

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