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# Dyes and its various removal techniques for sustainable environment

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**ABSTRACT**

Dye effluents pollute water. To avoid this issue, dye effluents must be treated before release. This study tested numerous colour removal methods for biological, chemical, and physical performance. This review investigated the effectiveness of biological, chemical, and physical dye removal methods. Dye industries can decrease water pollution by treating dye wastewater with the above methods. Few approaches removed 90% of dye particles from wastewater, while most removed over 80%. The review conclude that various researchers have studied physical, chemical, and biological dye-removal technologies are actively employed and developed. The techniques can be adopted for the removal of dye from various pollutant sources depends on their removal efficiency.

**Keywords**: dyes, effluent, dye removal technique, physical, chemical, biological

## INTRODUCTION

Dyes are chemicals that can adhere to surfaces or fabrics to add colour. Synthetic dyes are widely used in a variety of high-tech industries, including textiles, paper, leather tanning, food processing, plastics, cosmetics, rubber, printing, etc. (Dawood et al., 2014). Dyes can be categorised in a variety of ways depending on industrial uses, chemical kinds, or chromophore structures (Morsy, et al., 2020). The ability of dyes to absorb light radiation in the visible spectrum, which has wavelengths between 380 and 750 nm (Gürses, et al., 2016). Dyes are chemical substances made up of two groups in their molecules, the auxochrome and the chromophore (Benkhaya, et al., 2020). The chromophore, which is the visible spectrum's absorber which is active site of the dye (Gürses, A., et al., 2016). The chromogenic molecules' auxochrome may enhance the acidic groups and the colour of the dye (Piaskowski, et al., 2018). Dyes can also be classified as cationic, anionic, or non-ionic. Cationic dyes, such as Methylene blue (MB), Rhodamine B (RhB), Malachite green (MG), Rhodamine 6G (Rh6G), and Crystal violet, have cationic functional groups that can dissolve into positively charged ions in an aqueous solution (CV). Because the onium group is the most common cationic functional group, the majority of the cations are $N^+$ ions. Acid orange 7 (AO7), Eosin Y (EY), Methyl orange (MO), Acid red 14 (AR14), Alizarin red S (ARS), Rose Bengal (RB), Phenol red (PR), and other anionic dyes are available. Anionic functional groups can be found in all anionic dyes (Chiu et al., 2019). Dyes are an important source of pollution in the hydrosphere because of their resilience. As a result, the water body will take on an unattractive hue, sunlight penetration will be reduced, and photochemical and biological attacks on aquatic life will be prevented (Mustafa T., et al., 2014). In general, there is no precise data on the amount of dyes that are released into the environment. The discharge of sufficient amounts of synthetic dyes into the environment has presented challenges for environmental scientists. Adsorption, coagulation, advanced oxidation, and membrane separation are some of the processes used to remove dyes from wastewater. The problem of removing dye molecules from water sources is now a significant environmental concern (Chandrakant et al., 2016; AfshinMaleki., et al., 2017). Techniques for recovering and reusing dye effluent will come under the spotlight if a reliable solution is not created in the near future since, clean water sources may start to rapidly decline. Finding a reliable method to permanently remove dye particles from textile effluents would be very beneficial for the environment (Yaguang Peng., et al., 2018). From the literature review it could be identified that variety of effective dye removal methods have been analyzed. Despite the abundance of efficient dye removal techniques available, not all of them are efficient or even viable to employ due to their flaws. (NargesManavi., et al., 2017). In order to successfully and swiftly remove considerable volumes of dye from wastewater without introducing further contaminants, a dye removal method must meet certain criteria. It is advised that toxins be removed from wastewater using a method that doesn't produce any riskier byproducts. The three methods of dye removal discussed in this paper includes biological, chemical, and physical. The methods mentioned are can remove dye particles from wastewater efficiently and quickly without creating any negative by-products.

## Classification of dyes:

There are several different categories for commercial dyes. Its structure, colour, and manner of application are used to categorize it. Dyes are classified based on their particle charge upon dissolving in an aqueous application medium and they are: cationic (all basic dyes), anionic (direct, acid, and reactive dyes), and non-ionic (dispersed dyes).

### Cationic dyes:

Wool, nylon, acrylic, and silk dyeing all frequently use cationic dyes. Based on substituted aromatic groups, these colours have various chemical structures. This particular set of dyes is regarded as a poisonous colourant and can have negative consequences such allergic dermatitis, skin irritation, mutations, and cancer. These dyes are known as basic dyes because they require a positive ion, usually a zinc chloride or hydrochloride molecule. Cationic dyes possess a positive charge within their molecules and create coloured cations in solution. They're also soluble in water. Numerous dyes, including cationic azo and methane dyes, as well as anthraquinone, di- and tri-arylcarbenium, phthalocyanine, and a variety of polycarbocyclic and solvent dyes, have cationic functionality. Azo dyes have better characteristics, are more powerful, and are less expensive than anthraquinone dyes, which are both expensive and ineffective. Basic dyes provide strong colour intensity, brilliance, and visibility. In dye adsorption, cationic dyes including Basic blue 41, Basic red 46 (Eren., et al., 2010) Methylene blue and Crystal violet were heavily utilised as models. The textile industry uses methylene blue, a significant basic colour, extensively ( Deniz., et al., 2011). Humans exposed to methylene blue may experience symptoms such as a rapid heartbeat, shock, vomiting, cyanosis, jaundice, quadriplegia, and tissue necrosis etc. Studies on the adsorption of Methylene blue dye have used a variety of agricultural solid wastes, including peanut hulls, castor seed shells, coconut shells, guava leaves, neem leaves, and gulmohar plants. Strong dye adsorption capabilities have been shown for all of these wastes.

### Anionic dye:

Anionic dyes demand negatively charged ions. Anthraquinone, triphenylmethane, azoic, and nitro dyes are some examples of anionic dyes that exhibit distinct structural differences but have the property of having ionic substituents that make them water-soluble. Anionic dyes also include a wide range of other dyes from the most diverse families of dyes. From a chemical standpoint, a substantial portion of the reactive dyes fall under the category of anionic azo dyes. Direct dyes are also categorised within the anionic dyes category. Most reactive dyes have a reactive group, which they use to interact with cotton, wool, and other substances to form covalent bonds. Reactive dyes are undesirable to release into the environment because of the hydrolysis of reactive groups in the aqueous phase.

Direct dyes are another type of anionic dye, and a significant fraction of the anionic azo dyes group are reactive colours. Most reactive dyes have a reactive group, and when they interact with cotton, wool, and other substances, they create covalent bonds. Given their low degree of fixing as a result of reactive group hydrolysis in the aqueous phase, reactive dyes shouldn't be released into the environment. Acid is used to colour all fibres, including those made of silk, wool, polyamide, modified acrylic, and polypropylene. Acid dyes are water solubleand are poisonous and they are made of organic sulphonic acids. The removal of Acid scarlet, Acid turquoise blue, and Indigo carmine by organo-bentonite as well as other anionic dyes has been the subject of numerous investigations utilising a variety of adsorbents. Using sepiolite, acid black 26, acid green 25, acid blue 7, and bagasse ash, brilliant yellow can be created. Reactive Yellow 4 (RY4) is created by apatitictricalcium phosphate and apatiticoctocalcium phosphate. Reactive Brilliant Red, Acid Fuchsine, Orange IV, and Methyl Orange are also produced by ammonium-functionalized MCM-41. Mango seeds, soy meal, bagasse, and bamboo are just a few examples of the agricultural solid wastes that have been extensively used recently as easily accessible, cost-effective adsorbents for the adsorption of anionic dyes. (Mohamad AmranMohdSalleh., et al., 2011)

**Dyes and environment:**

Dyes are one of the most dangerous substance in industrial wastes. Dyes are one of the organic pollutant, significantly causing the environmental pollution which are released by various industries into the water bodies and soil which in turn disturb the total ecosystem. It has been estimated than nearly 7 lakh tones of dyes were produce annually and about 10% of which are released to the environment (Ajmal, et al., 2014). Dyes inhibit the reoxidation capacity of water bodies and blocks the biological activity aquatic organism. They cut off penetration of sunlight and inhibit photosynthesis of aquatic plants. Acidic, basic, dispersive, direct, and azo groups are examples of common dyes used in various industries. Azo dyes are very common in textile dyeing. Textiles industry is the largest contributors to dye pollution. Azo dyes have greater half -life of about 2,000 hours under the sunlight. It causes many disorders in animals, humans and aquatic life. The dye pollutant cause serious environmental issues mainly disturbing the water and soil ecosystem. Hence, it is essential to adopt some techniques to remove the pollutants which are affecting the environment. Some approaches to remove pollutant from water include adsorption membrane, filtration, biodegradation, photocatalytic degradation, liquid extraction, nano-filtration, oxidation, reverse osmosis, UV irradiation, etc (Gusain et al., 2019). Because dyes are naturally resistant substances, it is difficult and impractical to degrade them. Synthetic dye molecules have complex and stable structural compositions because they contain auxochromes and chromophores (Han X., et al., 2012). The way dyes are created specifically prevents dye from fading quickly in dyed textiles. They dissolve in the presence of water, detergents, or other cleaning solutions because they are made of intricateorganic ingredients. Even when exposed to high temperatures, oxidising chemicals, or intense light, dye molecules can resist destruction. (Mahmoud., et al., 2018).

**Dye removal methods:**

Until the late 1990s, there was no set restriction on the amount of dye that may be discharged into the environment, so dye removal techniques were limited to simple water purification techniques like equalisation and sedimentation. (GergoMezohegyi, et al., 2012). Dye concentrations can be observed at even very low levels, and they are more visibly offensive in contaminated wastewater bodies. In addition, some colours are detrimental to aquatic life and people. The treatment of dye wastewater for reuse has attracted a lot of attention due to the lack of dependable sources of clean, natural water. Large quantities of dyes must be removed utilising an effective method in a timely, affordable, and non-polluting manner (Katheresan et al., 2018). The three major categories of traditional colour removal methods are physical, chemical, and biological processes.

**Biological method:**

The typical biological approach is the most common and often used dye removal method to remediate dye wastewater in most nations. It is often referred to as the standard technique combines aerobic and anaerobic procedures before dye effluents are released into the environment (Mahmoud et al., 2018). Its low cost and ease of use are the key factors that led to this method being the norm for dye removal. In actuality, coloured water can still be found in the environment because this treatment alone is insufficient to completely remove harmful particles from textile dye effluent. The standard method treats the wastewater's need for chemical oxygen, but it does not remove toxins or dyes from the water (Yuan Pan., et al., 2017). In addition to this method, other conventional biological dye removal techniques include adsorption by microbial biomass, algal degradation, enzyme degradation, fungal cultures, microbial cultures, as well as pure and mixed culture. Some type of live creature is used in biological dye removal techniques. It is advisable to utilize this method carefully and to respect engineering ethics. These days, the use of enzymes to remove dye is becoming more and more well-known because it is thought that biological dye removal procedures are the most affordable and secure ones. The primary drawback of this technology, which involves living beings, is how quickly it grows. Biological dye removal procedures frequently experience system instability since it can be difficult to forecast a systems development rate and reactivity.

**Chemical methods:**

The term “chemical dye removal methods” refers to techniques that remove dye by applying chemistry or its theories. The two types of chemical processes that can be used to remove dye are called chemical oxidation techniques and traditional chemical treatments. The traditional methods for removing chemical dyes include advanced oxidation process, electrochemical destruction, Fenton reaction dye removal, oxidation, ozonation, photochemical reactions, and ultraviolet radiation. The conventional chemical approach has the advantages of low sludge production and high pollutant removal effectiveness, while some of the drawbacks of chemical treatment methods include high operating and chemical expenses and secondary waste (Piaskowski et al., 2018). Oxidation is a valuable and efficient chemical approach for the aim of treating large volumes of wastewater (Muruganandham, et al., 2014). Chemical oxidation is a process that breaks down organic molecules by using strong oxidizing agents including ozone, hydrogen peroxide, chlorine, and potassium permanganate. Natural chemical oxidation takes place when oxygen and air are present, but it is insufficient for heavily contaminated wastewater. Thus, it is crucial to develop methods for effectively eliminating pollutants.

**Physical methods:**

Huge volumes of dissolved matter are often separated using physical methods, and essential molecules used in the initial operations are also recovered and reused. To remove dyes, a number of physical techniques have been explored, such as ion exchange, adsorption, and membrane filtering (Yagub, et al., 2014). Effective dye removal usually involves flocculation or coagulation. This method is frequently used as a pre-treatment step to remove colours from effluents (Yeap, K.L., et al., 2014). To remove the dyes from water for reuse, filtration techniques such reverse osmosis, microfiltration, and nanofiltration are utilised; however, this method is not economical due to the high maintenance expenses. Adsorption is a different physical technique that is more effective than coagulation for decolorizing colours. Although it uses inexpensive adsorbents such polymeric resins and bentonite clay, it is not cost-effective because the adsorbents are typically only utilised once (Morsy, et al., 2020).

**Efficiency of dye removal methods:**

The various dye removal methods have been put to the test by several research in terms of biology, chemistry, and physics. It could be noted that not all dye removal treatments can guarantee a successful dye removal. There are instances where the outcomes of a dye removal process can be impacted by the parameters set for dye removal. Aside from the membrane filtering (physical) method, which was demonstrated to be an unsuccessful dye removal procedure, there are many dye removal techniques. Chemical dye removal techniques, which ranged from 88.8 to 99%, achieved the highest percentage of colour removal. Moreover, chemical dye removal techniques typically result in the formation of new pollutants and depend on the pH of the dye solution, with the possible exception of emerging electrochemical destruction technologies. If at all possible, avoid using chemical dye removal techniques because of the importance placed on its drawbacks. (Jing Wang., et al., 2017) Among the dye removal methods, physical or biological, are successful. With a clearance rate ranging from 76 to 90.1%, the enzyme degradation technique comes out on top among biological dye removal techniques. A reliable and appropriate method for removing dyes is enzymatic dye degradation. The main benefit of this strategy is that it can be repeated and is inexpensive, efficient, and non-toxic. The only negative is that it yields an erratic quantity of enzymes, however this issue can be easily resolved by selecting the appropriate source material and extraction method. On the list of physical dye removal processes, the adsorption method's greatest removal percentage is 99%. Adsorption dye removal is a great method for removing dyes since it can quickly break down almost any dye or dye mixture. In a manner similar to the enzyme degradation method, the adsorption procedure can likewise be carried out repeatedly until the adsorbent is exhausted. The biggest disadvantage of this strategy is that some adsorbents might be somewhat expansive due to their inherent high efficiency. This issue can be overcome by picking affordable raw materials to be converted into different adsorbents. Both the enzyme degradation and adsorption techniques are useful for removing dye, thus future dye removal technologies should consider merging them into a single dye removal technology.

## Conclusion:

Water pollution has many causes, one of which being the presence of dye effluents in environmental water bodies. Before releasing dye effluents into the environment, dye effluents must be treated using effective dye removal techniques in order to prevent this problem. In this study, the biological, chemical, and physical efficacy of several dye removal techniques were examined. This review article covered the effectiveness of biological, chemical, and physical dye removal techniques. The aforementioned techniques can be used to treat dye effluent in order to significantly reduce the pollution in the water generated by industries that use dye. While a few methods removed 90% of the dye particles from wastewater, the majority of the dye removal methods described were able to remove more than 80% of the dye particles. Many dye-removal systems based on physical, chemical, and biological (coagulation, chemical, and biological) processes are being actively used and being developed. The usage of dye has to be reduced to save the environment and if it is used then the waste water or the related waste material should be properly removed before its discharged into the environment.

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