CLASSIFICATION OF TEXTILE DYES BASED ON THEIR STRUCTUREAND CHARACTERISTICS

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Abstract: Pollution has been a major problem for our environment since long back. Water pollution plays a major role in water pollution. Mainly water pollution is caused by industries and mainly the textile industry. The textile industry release wastewater. Soil flora and aquatic ecosystems are affected by this wastewater. wastewater also affects human health and animal health. The textile industry released coloured wastewater and which contains 10 and 200 mg/L of dye and mixture coagulation. Wastewater alters oxygen levels and pH. Chemical and physical methods are used for treating wastewater but they are costly and time-consuming. Theuse of microorganisms or microbial enzymes with the physiochemical method shows better results with economic viability. Very complex synthetic dyes decolourize by the microbes and they ensure a non-toxic process. Wastewater contains dyestuff. Dye are two types one is a natural dye and the second one is a synthetic dye. Natural dyes are made from plants and they are nature-wise non-carcinogenic. Dye production worldwide is 800000 tons per year. Dyestuff also affects human health like irritation, respiratory problems, and the immune system. <1 ppm of dye is highly visible in the water.

Keywords: dyes, wastewater, microorganisms, dye-degrading bacteria, Synthetic dyes

Introduction:

In modern life, Major cause of water pollution is waste produced by industrialization and urbanization. Water is most important for life on planet Earth. Industry releases wastewater and sewage which is a major source of environmental toxicity. Soil flora and aquatic ecosystems are also affected by wastewater. The textile industry is the main source of environmental problems(Sakpal & Tarfe, 2021).

The reason for water pollution is the disposal of industrial and other types type of effluent in the water bodies. Water pollution effected directly or indirectly our health(Varjani et al., 2020).

Physical or chemical methods are used for the treatment of textile effluent but the use of microorganisms or microbial enzymes with the physicochemical method shows better results with economic viability. Microbes decolourize very complex synthetic dyes and ensure a non-toxic process. The treatment and effectiveness of dyestuff depend on the activity and flexibility of the microorganisms. Adsorption on microbial biomass or biodegradation of dyes by the cell or enzymes is the major way for decolourization (Jamee & Siddique, 2019).

Under controlled conditions, bacterial strains like Shewanella obediences MR-1, Bacillus cereus MAM-B11, Bacillus cereus MAM-B22, Bacillus sp. MZS10 and Acinetobacter baumannii YNWH 226 are the decolourized dyes efficiently (Siddiqui et al., 2023).

Dye is used for colouring clothes. It is of two types one is a natural dye and the second one is a synthetic dye. Natural dye is made from flowers, vegetables, wood, roots, insects, etc. In controlled laboratory conditions synthetic dyes are produced and show greater stability than natural dyes(John et al., 2020). Natural dyes are nature-wise non-carcinogenic. Plant dyes are probable sources of natural dyes because of their easy availability and rich. Natural dyes have low toxicity and low allergic reaction(Miah, 2016). Synthetic dye made from petrochemicals. It is soluble in water and easily absorbed and it is also very fast in coloration as compared to natural dyes. Dye production is 800000 tons per year worldwide. A large amount of dye is used in the textile industry. The textile industry releases a huge amount of wastewater. Soil and water are contaminated by releasing wastewater and polluting the environment and it can alter oxygen levels and pH. Dyestuff also affects human health like irritation, respiratory problems, and the immune system(Jamee & Siddique, 2019; Roy et al., 2018; Zhul-Quarnian et al., 2018).

Dyes and other effluents are removed the various methods like physicochemical, biological, chemical, and physical. Biological treatment is more popular because they have many advantages like it is cheap, and most importantly it is environmentally friendly. Microorganisms require low preparation and they are easily available and maintained. Algae, bacteria, fungi, and yeast are types of microorganisms and they decolourize many dyes (Varjani et al., 2020).

The textile industry released coloured wastewater and which contains 10 and 200 mg/L of dye and mixture coagulation(Jamee & Siddique, 2019).

These are physicochemical methods and it is used for decolorizing textile effluents. But physicochemical methods are costly and inefficient and sometimes produce hazardous by-products(Sriram & Reetha, 2015). Synthetic dye is important for such industries as textile, paper printing, food, pharmaceutical leather, and cosmetics. There are many types of dyes like acid dyes, reactive dyes, direct dyes, basic dyes, vat dyes, disperse dyes, metal complex mordant, and sulfur dyes(Hassaan & El Nemr, 2017).

Textile wastewater contaminates the aquatic environment and aquatic animals. Wastewater effect the reduction of sunlight penetration and the process of photosynthesis(Zhul-Quarnian et al., 2018; Roy et al., 2018). After China, India is the second largest exporter of dyestuffs. Untreated effluent is the major source of consumed metal dyes, phenol, and aromatic amines. Aromatic amines are mutagens and carcinogens to human beings. The kidney, liver, and gastrointestinal tract are affected by the dyes. Natural dyes are used for dying clothes in the ancient age but they are difficult to process and also expensive(Sakpal & Tarfe, 2021).

Only less than 1 ppm of dye is visible in the water. Release wastewater has strong colour, highly fluctuating pH, salts, a large number of suspended solids, heavy metals, chlorine, sulfides, temperature, and COD concentration. In 1856 first synthetic dye was reported. There are 40000 dyes and pigments that have different chemical structures and more than 3500 are used for practice. Xanthan dyes, azo dyes, nitroso dyes, triphenylmethane dyes, and anthraquinone dyes, are classes of synthetic dyes (Ezhilarasu, 2016).

Azo dyes (R1N=N-R2) are well-known industrially synthesized organic compounds. At dye concentrations more than 1 mgL-1 is noticeable and 300mgL-1 concentration of dye is reported in effluents from the manufacturing process(Tony et al., 2009).

In the textile industry, reactive dyes are spaciously used because of their big size which results in high abutment to bind with cellulose fiber. Reactive dyes increasing because of their demand and account for four times as much as conventional dyes. One kilogram of cotton used in the reactive dyeing process consumes 70 L of fresh and soft water(Karim et al., 2018).

Bacillus sp, Enterobacter spp, and Pseudomonal sp are strains of bacteria that degrade the dyestuff. In textile dyeing, colour photography pharmaceuticals, paper printing, cosmetics and industries synthetic dyes are spaciously used(Kumar & Saravanan, 2015).

We know that bacteria are used for dye decolourization. Yeast has more advantages compared to bacteria and filamentous fungi. They do not grow rapidly. They have properties to resist unfavourable environments like filamentous fungi. Some yeast can treat high-strength organic wastewater such as food industry effluents. Without analyzing the constituent microbial population microbial consortia are used as black boxes for environmental remediation. The black box is an unknown specific gene transformation in the microbial system which also occurs naturally and gives variations in the ecosystem. Carbon and nitrogen source are used for dye degrading(Jadhav et al., 2008).

Two-thirds dye of the total dyestuff is used in the textile industry. Coagulation/adsorption and electrolysis or ozonation is the chemical or physicochemical treatment and they completely destruction of dye molecules. Effluents contaminated with azo dyes cannot decolourize easily because of their strong electron-withdrawing group(Asad et al., 2007). Adsorption on activated carbon, chemical precipitation, photolysis, chemical oxidation and reduction, electrochemical treatment, flocculation, froth floatation, ion exchange, membrane filtration, ozonation, reverse osmosis etc. is the methods of decolourization of dye from wastewater(Barapatre & Jha, 2020).

Electrochemical removal, coagulation-flocculation, membrane separation, photochemical and microbial degradation, and adsorption are the healthy and safe environment traditional techniques for removing dyes from aqueous solution(Poots et al., 1978; Rose et al., 2023). Basic and diazo direct dyes have the highest rates of toxicity. For adsorbents activated carbon is the most widely used because of its large surface area, micro-porous structure, high adsorption capacity, etc(Garg et al., 2004). Use of UV-Vis spectrophotometer at λmax=594nm for the dye degradation(M. A. N.

Khan et al., 2015). For dye removal, adsorption is the simplest process. Activated carbon is the most effective adsorbent(S. Wang & Zhu, 2006).

$$\text{Decolourization \%} = \frac{\text{initial absorbance} - \text{final absorbance}}{\text{Initial absorbance}} \times 100$$

(Kumar & Durai, 2015).

Classification based on dyeing activity and Characteristics

Reactive dyes, dispersive dyes, Acid dyes, Sulfer dyes, Basic dyes, Direct dyes, Mordant dyes, Vat dyes, Azoic dyes, and pre-metallized dyes.

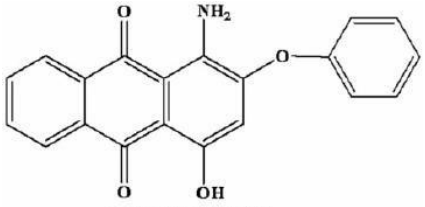
Reactive dyes

They are nitrogen-containing heterocyclic rings carrying halogen substituents. S…F…T…X is the general formula for the structure of the reactive dyes. Were, S: Solubilizing group; F: Chromophore; T: Briding group; X: Reactive system. Reactive dyes are composed of two portions A. Chromogen and B. Reactive system. They are azo compounds linked by an azo bridge. Procyon yellow MX-5B, Cibacron brilliant red B, Trimaran red Z-2B, Reactive Black 5, Reactive yellow 2, Procyon Blue MX 2G, Remazol red RB, Remazol Golden Yellow RNL, Remazol Blue B, Remazol Turquoise Blue G133, Remazol Blue and Remazol Orange etc. this are the type of reactive dyes (Gowri et al., 2014). Reactive Blue 19 is sonophotocataly degraded by the use of sulfur-doped TiO2 nanoparticles(M. A. N. Khan et al., 2015).

Dispersive dyes

These are traditionally non-ionic chemicals. Dispersive dyes are very sensitive to time, temperature, pH, electrolyte, concentration etc. used for the polyester fabric. Above 100°C dispersive dye is coming into action. Generally, they are free from ionizing groups because they are non-ionic dyes. They have very low water solubility or are insoluble in water. They have the smallest molecular size of all dyestuffs. They do not pass off any chemical change during the dying process (Ovi & Mahmud, 2021).

Structure of dispersive dye

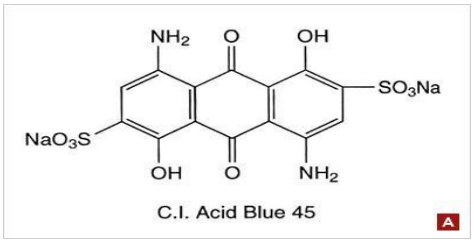


C. I. Disperse Red 60

Acid dyes

Acid dyes are primary organic acids. They are soluble in water, and anionic dyes and are primarily applied on such types of nitrogenous fibres like wool, silk, and nylon they all contain basic groups(Musa et al., 2013). 'Acid dye' name arises from the process of dying carried out by an acidic aqueous solution (pH 2.0-6.0). The majority of mordant and premetallized dyes are also acid dyes(Sekar, 2011).

Structure of acid dye



C.I. Acid Blue 45

Biodegradation optical density (OD), pH 7.0, temperature 37ºC, 10% inoculums and 100 mg/L dye these factors confirmed the biodegradation process. The textile dye is generally converted into azo, reactive, triphenylmethane, heterocyclic, polymeric compositions etc(Afrin et al., 2021).

Classification of dye based on reactivity & chemical composition

Dyeing characteristics of acid dyes allow them to be categorized into the following four types:(Sekar, 2011).

Level dyeing or equalizing dyes effect is shown by the liposome, especially cationic liposome on cotton fibers. 85ºC is a dye-fixing temperature and the level dyeing effect is achieved at this temperature. Cationic liposome & sodium chloride are used as promoting agents for the dyeing and level-dyeing of cotton fibers. lipid globules are another name for liposome and they are primarily made of phospholipids (Ru et al., 2018).

Fast acid dyes have somewhat molecular weight and most of the time mono sulfonated ones compared to the typical levelling dyes. Need of level dyeing with good washing and sweat fastness, fast acid dye is used (Sekar, 2011).

Milling acid dyes is a process where woollen material is treated with a weakly alkaline solution. They have higher molecular weight and high substantive for wool compared to the levelling or fast acid dyes. Milling acid dyes are less soluble in water and they have sulphonate groups. In the presence of sodium acetate or ammonium sulphate dyeing with milling dyes has been done at a pH of 5.0 to 7.0. they have poor levelling capability due to having low rates of diffusion in wool. They have ionic bonding and dye and fibre are bound together by intermolecular interactions. milling acid dyes have good washing fastness. They have strong fastness for light and they are fast to alkaline processing. (Sekar, 2011).

Super-milling acid dyes are considerably more hydrophobic compared to the milling dyes but they are equivalent. They also have good wash fastness and it has excellent light fastness.

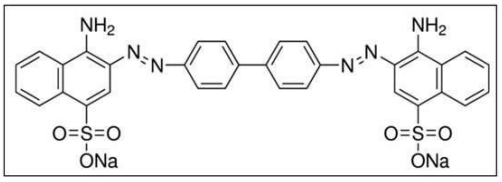
Types of azo dyes

There are many types of azo dyes like reactive brilliant red, acid violet 7, malachite green, reactive black 5 (sulfonated azo dye), disperse red 1 and disperse red 13, and Congo red (Chaturvedi, 2019).

Malachite green dye

C23H25CIN2 is the molecular formula of malachite green dye. They are water-soluble and nature is cationic. They are present in green colour crystal form but appear blue colour in liquid medium. The weight of malachite green is 364.911 g/mol and the maximum wavelength is 618 nm(Raval et al., 2016).

Structure of malachite green dye



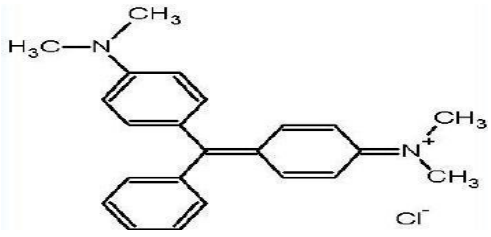
Malachite green is also used in aquaculture as a therapeutic agent(Culp & Beland, 1996). Malachite green is also known as a micro-pollutant and they present in industrial effluent and cause penetrability in green flora. The malachite green affects the food chain and they adhere to the environment for a long time duration because of the non-biodegradable compound (Sharma et al., 2023).

Malachite green does not require mordant in the textile industry to put blue colour to silk, wool, jute and leather and in dye cotton, they use with mordant. Iron-based dye molecules are good electron donors and acceptor (Sharma et al., 2021). They discharge in waters and affect aquatic life and cause detrimental effects on, the liver, gill, kidney, intestine and gonads for aquatic animals (Wang et al., 2008). The malachite green dye is a cationic triaryl methane dye and they are aromatic xenobiotic compounds malachite green also causes environmental pollution (Kooravand et al., 2021).

Bacterial strain DD4 degrade malachite green dye up to 10mg/100ml with 90.1% of decolonization. At pH 7 and temperature 28ºC and 10% bacterial inoculum containing medium DD4 showed good degradation. DD4 was identified as staphylococcus species (Kumar and Durai, 2015).

Congo Red Dye

Congo red dyes are used in textile manufacturing because they have a large variety of shades and consume low energy and resistance to decolouring. They have aromatic rings and chromophore groups. Congo red is a carcinogen because they have aromatic amine. Adsorption, coagulation-flocculation, ion exchange, ultrasound irradiation, mineralisation and photocatalysis are the process of removal of Congo red dye from polluted water(Harja et al., 2022).



Congo red dye is the type of azo dye and C32H22N6Na2O6S2 is the molecular formula and 696.68 g mol-1 is the molecular weight. This is the first direct dye discovered by Paul Bottiger in 1884. CR 4B, C.I. 22120, Cottonq red B, Cotton red C, Direct red 28, Cosmos red, Direct red Y, and Direct red R are the many names of Congo red dye. They contain acidic auxochromes (-SO3H) and two azo chromophores with a benzene structure (Siddiqui et al., 2023).

Structure of Congo red dye

Congo red is the anionic diazo dye based on benzidine and they cause allergic reactions. They are present in an aqueous solution depending on pH and molecular structure. From aquas solution removal of Congo red dye use Pinus pinaster bark(Litefti et al., 2019).

"Benzidinediazo-bis-1-napthtylamine-4-sulfonic acid" is the unique chemical configuration. Many disease-like difficulties in breathing, shortening of breathing, diarrhoea, nausea, and vomiting; therein, and dye can also induce cancer and mutation. Congo red dye also affects water quality aesthetic and makes water turbid, affect in solar radiation transmission and reducing photosynthetic activity(Rose et al., 2023).

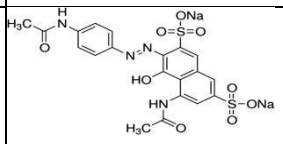
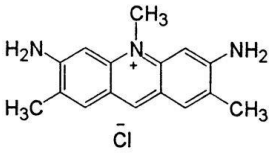
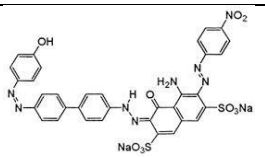
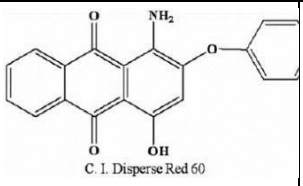
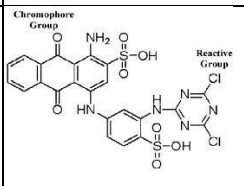
Methylene blue

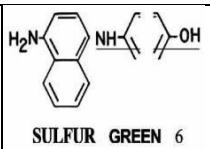
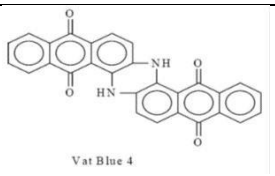
Methylene blue

It is carcinogenic, and they are non-biodegradable and they cause many health problems and disease. Methylene blue is released in the source of natural water. For the removal of methylene blue from the water we use an advanced oxidation process that's name photodegradation. (Khan et al., 2022). It is a blue-coloured, aniline-based dye. For dying cotton methylene blue first developed dye. It is also used in the treatment of disease Alzheimer's, this is brought on by oxidative stress, neuroinflammation, and mitochondrial malfunction.(Kayabasi & Erbas, 2020). In the study, we found that spent tea was used as an adsorbent for cationic dye (methylene blue) because they are non-conventional and low cost at 30ºC. (Hameed, 2009).

Structure of methylene blue dye

Table 1: Different types of dyes with their structure and activities (Chaturvedi, 2019)

Dye class	Characteristics	Fibre	Pollutants	Structure	Example
Acidic	Water soluble anionic compounds.	Wool, nylon, and cotton blends.	Color: Organic acids, unfixeddyes.		Picric acid, nigrosine, India ink, eosin.
Basic	Water soluble, appliedin weakly acidic dye baths, very bright dyes.	Acrylic, cationic, polyesters, nylon, cellulosic, and proteinfibers.	Nil.		Methylene blue, crystal violet, carbol fuchsin, safranin, malachite green.
Direct	Water soluble, anionic compounds, applied without mordants.	Cotton, rayon cellulosic fibers.	Color salts, unfixed dye, cationic fixing agents, surfactants, deformer, retarding agents.		Direct fast brown M, Brilliant Yellow, direct black, chlorazol violet N.
Dispersive	Insoluble in water	Polyester, acetate, modacrylic, nylon, triacetate, and olefin fibers.	Color organic acids, carriers,leveling agents, phosphates, lubricants, and diluents.		Foron, terasil, dispersal, samaron, SRA setile, dispersive red 60, dispersive orange 1.
Reactive	Water soluble, anionic compounds, largest class.	Cotton, cellulosic, and wood fibers.	Colors, salts, alkali, unfixeddye, surfactants.		Procion red H-E_3B(C.I. Reactive red 120), Remazol Black B (C.I. Reactive Black5), Remazol Brilliant Red FG(C.I. Reactive Red 227).

Sulphur	Organic compounds containing sulfur.	Cotton, cellulosic fibers.	Colors, alkali, oxidizing agents, reducing agents and infixed dye.	 SULFUR GREEN 6	Calcogen, pyrogene, thinol, solfo, Sulfogene, Thional, Mitsui Sulphur.
Vats	Oldest dyes, chemically complex, water-insoluble.	Cotton, cellulosic, and wood fibers.	Colors, alkali, oxidizing agents, reducing agents.	 Vat Blue 4	Blue vat dyes, green vat dyes, orange vat dyes, violet vat dyes, red vat dyes, brownvat dyes, black vat dyes etc.

Conclusion:

This review directs the role, class and structure of different dyes use in textile industry. These information can be use for the further research on how these dyes can be degrade so the pollution causes by these dye can be reduce and can turn into non contaminant water source.

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