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A Review of Biological Degradation of Reactive Dyes by Using Bacterial Isolates from Dye Effluent Contaminated soil

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ABSTRACT: Textile companies are responsible for one of the world's main environmental pollution problems. Textile wastewater comprises colours that are combined with a variety of pollutants in varying concentrations. One of the industries that produce a lot of wastewaters is the textile industry. The most important concern with textile waste effluent is the strong colour of the water. The dumping of these wastes into receiving water has negative environmental consequences. Because of the presence of aromatics, metals, chlorides, and other hazardous compounds, dyes may have a major impact on photosynthetic activity in aquatic habitats. They may also be poisonous to some aquatic organisms. The goal of this work was to use bacteria isolated from dye-contaminated soil to break down textile reactive dyes. Textile dyes that are commercially accessible have been biodegraded. The pour plate method and percentage decolourization were used to test the effects of violet 6B, yellow HE4G, orange 2R, and red 88 on bacteria recovered from the dye effluent sample. Preliminary studies, plating on selective media, and biochemical assays were used to separate different bacteria from the textile dye effluent.

KEYWORDS: Degradation, Decolorization, Classification, Reactive dyes, Effluent contaminated soil

I. INTRODUCTION

Industrial textile wastewater adds to the complexity by including unknown volumes and variations of many different colours, as well as low BOD/COD ratios, which can reduce biological decolourization efficacy [1]. Around 10000 different dyes and pigments are used in the textile industry around the world. Azole dyes account for more than half of all dyes used in the industry [2]. Rubber, textiles, cosmetics, plastics, leather, food, and other industries all employ different types of colours. Making paper in wastewaters, the variety of these colours can be detected. "Those who have been discharged from these industries" In general, dyes have a long shelf life. They are usually non-biodegradable and are exposed to light, heat, and oxidising chemicals [3]. They are colourless, highly viscous, resilient, have long hydration durations, and are compatible with other printing pulp components [4]

DYES:

Dyes are organic compounds with colour that are used to colour a variety of substrates such as cosmetics, paper, pharmaceuticals, leather, fur, greases, hair, waxes, plastics, and textiles. "Dyes are chemical substances that can attach themselves to surfaces or fabrics to give them colour [3].

Basic, acid, reactive, direct, vat, and disperse dyes are among the many types of dyes used in various industries. Except for dispersion and vat dyes, all of these dyes are water-soluble. Apart from the vat and disperse dyes, colours contain quantities of metals such as chromium, copper, lead, zinc, and cobalt. Dye effluents from the industry are noted for their intense colour and organic content. In addition, it is hazardous [3].

Dyes are coloured compounds that may transfer their colours to a matrix, which could be fibre, paper, or any other thing. They must adhere to a cloth impregnated with their solution, and the coloured fixed dyes must be lightfast as well as resistant to water, dilute acids, alkalis, various organic solvents used in dry cleaning, soap solutions, detergent, and other chemicals [5].

Reactive dyes are extensively used because of their favourable characteristics of bright colour and low energy consumption during application [6].

The majority of dyes the used in various industries is poisonous and carcinogenic, providing a significant risk to both individuals and the marine ecology [7]. The introduction of coloured effluents into the aquatic media prevents sunlight, preventing algal and aquatic plants from photosynthesis [8].

II. CLASSIFICATION OF DYES:

1]. NATURAL DYES:

Colourants (dyes and pigments) generated from animal and vegetable components without the use of chemicals are known as natural dyes. Mordant dyes are the most common, but there are also vat, solvent, pigment, and acid variants. Colours generated from natural sources such as plants, animals, and minerals are known as natural colours.

Fabrics, food, cosmetics, and medications are all dyed with these colours [4]. Natural colours, which have been used since ancient times, are primarily derived from plants, whereas synthetic dyes are created artificially from chemical compounds [9].

Natural products such as jackfruit, onion, eucalyptus, turmeric, weld, and henna were commonly used in the early textile business. As a result, they're largely used in the food sector nowadays [3].

The Cassia singulars plant can be utilized as a natural colouring source [10]. These dyes can provide not only a diverse range of dyes, but also a rich and diverse source of dyestuff. However, they could also be considered safe, environmentally friendly, and low-cost treatments, with the added bonus of being able to colour in one step [11].

Natural dyes have several advantages, including the fact that they require no special care, beautiful and rich in tones, act as a health cure, have no disposal issues, have no carcinogenic effect, are easily biodegradable, require a simple dye house to apply on matrix, and are extracted and applied under reaction conditions.

Natural dyes have some drawbacks, such as limited colour availability, poor colour output, complex dyeing processes, poor fastness qualities, and difficulties combining hues [5].

2]. SYNTHETIC DYES:

Synthetic dyes are a type of brightly coloured organic compounds that are primarily used to tint textiles and attach themselves to the fibre molecules through chemical bonding. Synthetic dyes are divided into two categories: chemical structure and application methods [5]. Synthetic dyes have nearly totally supplanted natural colours, particularly in the fabric and textile industries [2].

Synthetic dyes are split into three categories based on the created fibre's nature. cellulose fibre dyes, protein fibre dyes, and synthetic fibre dyes are the three types. Textile, dyeing, printing and other industrial applications use synthetic dyes [12]. Synthetic dyes are being discharged directly into natural water bodies as textile discharges or effluents from these enterprises (after the dyeing processes) [12]. Synthetic dyes can induce a rise in BOD (biochemical oxygen demand) and COD (chemical oxygen demand) levels in wastewater [13].

(2.1) CELLULOSE FIBER DYES:

Plants such as linen, cotton, ramie, rayon, lyocell, and hemp produce cellulose fibre. With reactive dyes, direct dyes, indigo dyes, and sulphur dyes, these fabrics produce flawless results [9].

(2.1.1) REACTIVE DYES:

Chemical structures in reactive dyes are complex, forming covalent bonds. Connections formed between reactive groups of the functional groups of cellulose and agile functional groups of molecules of dye. The most common dyes are reactive dyes. Because of their numerous advantages, ordinary dyes are widely used. Bright colours and stable structures are produced by functioning in mild circumstances.

Reactive dyes are nitrogen-containing heterocyclic rings with halogen substituents that undergo nucleophilic substitution with cellulose fibre. The structure of reactive dyes has the following general formula: [14].

X... S... F... T

Where, S stands for the solubilizing group, F for chromophore, T for Bringing group and X for reactive system.

Reactive dyes are made up of two parts, The chromogen, as well as the reactive system [15].

Reactive dyes are those that have groups in their ions or molecules that react with other groups in fibres to generate covalent dye-fibre interactions [16]. Due of their significantly excellent fastness qualities and simplicity of application, reactive dyes are the most extensively used type of dyes [17].

They are noted for their excellent pigmentation, long-lasting effect, ease of manipulation over a wide temperature range, and versatility due to their versatility. A variety of reactive groups capable of forming covalent connections with a variety of fibres [4]. Because of their brightness of shade, wide colour range, versatile application processes, and all-around good colourfastness features of the resultant y dyeing reactive dyes are the most preferred dyes for dyeing cotton [18].

(2.1.2) DIRECT DYES:

A number of new direct dyes were synthesized from non-genotoxic diamines and examined as prospective alternatives to certain benzidine-based dyes in prior work in our laboratories [19]. Due to its occurrence in numerous industrial effluents such as textile, tannery, paper, soap, cosmetics, polishes, wax, and so on, direct dye was chosen for the adsorption experiment [20].

These are azo dyes that are applied to cotton-silk blends in neutral or slightly alkaline baths with added electrolytes. These dyes are used to colour materials such as cellulose, wool, nylon, and silk [5]. To improve their fabric binding abilities, they are coupled with inorganic electrolytes and anionic salts in the form of sodium sulphate (Na_2SO_4) or sodium chloride (NaCl) [9].

(2.1.3) INDIGO DYES:

The colour indigo, or dark blue, is classified as a vat dye, which was formerly insoluble in water but became so after an alkaline reduction.

Indigo dyes are primarily utilised in blue denim dyeing, which explains why they are produced in such large quantities all over the world [9]. Because pure indigo is just slightly water-soluble, it's perfect for use as a pigment. [21]. Indigo was traditionally obtained from plants of the genus *Indigofera*, which are native to the tropics, and was utilised in the textile business [22].

(2.1.4) SULPHUR DYES:

Sulphur dyes accounted for 9.1% of total US dye production and 15.8% of dyes for use on cellulosic fibres in 1966, with global production estimated at 110,000–120,000 tonnes per [15].

Starting materials typically comprise aromatic compounds with at least one nitro, nitroso, amino, modified amino, or hydroxyl groups, such as benzene, naphthalene, diphenyl, diphenylamine, azobenzene, and others. Sulphur dyes are mostly used to colour textile cellulosic materials or blends of cellulosic fibres and synthetic fibres, but they also have limited uses in the dyeing of silk and paper, as well as on certain types of leathers [15]

In terms of fastness qualities, sulphur dyes can be thought of as spanning the gap between direct dyes and vat dyes, however they differ greatly among themselves. The most changeable property is light fastness which, as one might anticipate, decreases as the depth of shade decreases [24]. Cotton fibres are frequently dyed using sulphur dyes [25].

(2.2) PROTEIN FIBER DYES:

Silk, cashmere, angora, mohair, and wool are all protein fibres derived from animals. Because they are sensitive to high pH levels, they are coloured with indigo. To obtain a molecule of an insoluble colour on the fibre, a water-soluble acid dyestuff is used [9].

(2.2.1) AZO DYES:

These dyes contain an azo component ($-\text{N}=\text{N}-$), which is utilised in cotton fabric dyeing. In the dyeing procedure, the fibre is first treated with a coupler, then azo dye is applied. This sort of dye reacts quickly to light [5]. Azo dyes make up roughly 50% of all dyes used in the textile industry, and as a result, they pose a significant environmental threat [26].

The global production of azo dyes is estimated to be around 1 million tonnes per year. There may be an azo bond connection ($-\text{N}=\text{N}-$). Mono azo dyes have one azo linkage several times. Azo dyes are the most common type of synthetic dye. Azo dyes account for over 70% of all dyes used in the industry. Textile, cosmetic, leather, pharmaceutical, paper, paint, and food industries all use them [15]. Azo dyes are divided into three classes based on the number of azo groups in their structure (mono, di, and poly) [9].

Azo dyes make up the largest and most flexible group of dyes, accounting for more than half of the yearly dye production (estimated at 1 million tonnes in 1994) [27]. Only one natural azo compound (4–40 dihydroxy azo benzene) has been reported thus far [28].

(2.2.2) ANTHRAQUINONE DYES:

Anthraquinone dyestuffs are widely employed in the textile dyeing industry; red dyestuff in particular has been used for a long time. These dyes are well-known for their water solubility, vibrant colours, and outstanding fastness. Junctions with azo dyes could be formed using the anthraquinone structure [9]. Plants, animals, and insects can all produce anthraquinone-based red colours [4].

From many thousands of years ago until the late 19th century, anthraquinones were commonly found in the most prevalent red natural colourants used in textile dyeing [29].

(2.2.3) TRIARYLMETHANE DYES:

They are made of two groups of sulfonic acid, triphenylmethane dyes are commonly used in the textile industry for colouring wool and silk protein fibres (SO_3H). If they only have one sulfonic acid (SO_3H) autochrome in their chemical structure, they can be employed as indicators. The solubility of these dyestuffs in water, as well as their wide and strong colour spectrum, make them popular [9].

(2.2.4) PHTHALOCYANINE DYES:

Green and blue hues are produced through a reaction between the 1,4- Dicyanobenzene molecule and a metallic atom (Nickel, Cobalt, Copper, etc.) in the phthalocyanine family of dyes. They have a variety of intrinsic qualities, including high lightfastness, oxidation resistance, water solubility, and chemical stability [9].

Their use accounts for 30–40% of overall dye use, and they are widely used on nylon, cotton, wool, and silk [34]. Phthalocyanine reactive dyes are water-soluble, difficult to discharge, and resistant to oxidative and bacterial breakdown, making decolorization a difficult task [35].

(2.3) SYNTHETIC FIBER DYES:

Fabrics made of synthetic fibres include spandex, polyester, acrylic, polyamide, polyacetal, polypropylene and acetate. Because of their extensive application range, they are used in 60 percent of global fibre manufacturing. Direct dyes, basic dyes, and disperse dyes are used to colour these fibres [9].

(2.3.1) DISPERSE DYES:

These dyes are colloidal and hydrophobic fibres soluble. Polyester, nylon, acetate and triacetate fibres are commonly dyed with these dyes. They are usually administered as a dispersion from a dye bath using the direct colloidal absorption method [5]. *Disperse dyes are usually non-ionic compounds with low water solubility, allowing them to retain a higher level of substantivity for hydrophobic fibres like polyester, nylon, and acetate* [36].

Disperse dyes are synthetic colourants for hydrophobic substrates that are extensively used in textile dyeing as commercial blends. They are frequently employed in big quantities, and substantial volumes of wastewater can be generated because of the vast amounts of water needed in the dyeing procedures and the high proportion of dye that remains in the water bath. These dyes are usually intractable or only soluble in small amounts. Water-based, non-ionic, and applied to hydrophobic fibres from an aqueous dispersion [15].

Monocyclic dyes with low molecular weights make up the majority of dispersed dyes (about 50%). In dye bath circumstances, they have no ionic solubilizing groups, hence they are effectively non-ionic, although being extremely polar [37]. The most prevalent sensitizers among textile dyes are disperse dyes (DD's), although contact sensitivity to DD's may go undetected because the clinical presentation does not suggest textile dermatitis [38].

(2.3.2) BASIC DYES:

Cationic dyes, such as acrylic, cationic dyeable polyester, and cationic dyeable nylon, establish ionic connections with anionic fibres. These are amino derivatives that are mostly utilised for paper applications [5].

These dyes are commonly used on acrylic, paper, and nylon substrates; however, some modified polyester substrates can also benefit from their use. Due to their weak migratory capabilities at the boil, basic dyes are frequently used with retarders. Basic dyes are water-soluble and produce coloured cations in solution, which are electrostatically attracted to negative-charged substrates [15].

Because they change into colourful cationic ions that dye anionic fibre textiles, basic dyes are also known as cationic dyes. Their leader is Cyanine, triarylmethane, anthraquinone, diarylethene, diazo hemocyanin, oxazine, hemocyanin, thiazine, and hemocyanin are some examples of structures [9]. Cationic dyes, often known as basic dyes, are frequently employed in the dyeing of acrylic, nylon, silk, and wool [39].

III. CHARACTERISTICS OF DYE EFFLUENT:

Metals, dyes, and other contaminants are found in the wastewater emitted by dye plants. Industrial wastes (liquid and solid) are commonly produced as a result of manufacturing processes, and they contain any material that can be reduced during the product manufacturing process. Liquid waste (wastewater generated by companies) is hazardous to both existing living beings and the environment because it contains a variety of toxic pollutants. The qualities and nature of industrial effluent, on the other hand, are determined by the type of production process and products [40].

Colour, pH, suspended solids (SS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), metals, temperature, and salts are all high in dye effluents. As a result, it is critical to monitor and compare these parameters with standard concentrations during the treatment process before discharging the related effluent to the receiving water body. Other metrics such as total organic carbon (TOC), ammonia–nitrogen (NH₄–N), nitrate-nitrogen (NO₃–N), and orthophosphate–phosphorus (PO₄–P) must be monitored as well [41].

Characterization of textile process effluent streams is critical for developing water treatment and reuse techniques [42]. Dyeing machines appear to be the primary source of textile effluent containing dyes [43].

Individual unknown dye identification in a coloured effluent or watercourse is difficult and requires to do advanced analytical methods (e.g., individual and/or coupled spectrophotometry, G/L chromatography, and mass spectrometry procedures), determination and appreciation in various operating situations [44]. The pH, TDS, and COD of effluents generated in each procedure, as well as the equivalent ozone-treated effluents, were measured using standard wastewater analysis methods [45]. Bleaching and washing operations produce the majority of dye effluent in the textile sector [46].

Water is mostly utilized for cleaning raw materials and flushing stages; desizing, scouring or wearing, bleaching, mercerizing, dyeing, washing, neutralization, and salt bath are the most common water-based process steps [47].

IV. EFFECT OF DYE ON ENVIRONMENT:

The presence of untreated dyes in water bodies poses the greatest hazard to the environment since many of these reactive dyes obstruct the photosynthetic process of hydro photo by preventing light from passing through, resulting in the synthesis of toxic aromatic amines, for example, are generated under the oxy-oxidation process. Due to the discharge of untreated waste, the receiving media has a gen deficient environment.

Dye effluent is a term that refers to a substance that has been some studies on azo dyes linked them to a variety of malignancies in various organs, including the bladder, spleen, and liver, as well as normal aberrations in model organisms and chromosomal malformations in mammal's cells [48]. Due to their high thermal and light stability, dyes resist biodegradation and become more persistent in the environment, posing a number of environmental risks [49].

Spinning, knitting or weaving, and wet-processing are the three primary procedures. The latter includes various steps such as sizing, desizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing. Wet processing procedures in each of these operations generate massive amounts of effluent and pollutants. Desizing is one of the most common sources of wastewater contaminants, accounting for up to 50% of the Biological Oxygen Demand (BOD) load. In addition to having a high BOD, the scouring process utilises the most water in the preliminary stages. Chemical handling, water conservation, and high pH values are all key pollution hazards in the bleaching process.

Also scouring, bleaching, dyeing, and printing with pentachlorophenol (PCP), which is removed from the fabric and dumped into the wastewater. It is hazardous and bioaccumulate due to its considerable stability against natural breakdown processes (*Bhatia et al., 2011*). Some metals, such as Cr, As, Cu, and Zn, are present in these effluents and are capable of creating a variety of medical problems, including discharge, skin ulceration, sickness, severe aggravation of skin, and dermatitis.

Other natural and microbiological contaminating factors have also been discovered in material effluents [50]. Respiratory issues caused by dye particles inhaled are the most common hazard of reactive dyes. They can sometimes influence a person's immune system, and in severe situations, this might result in a strong reaction when the individual inhales the dye again [51].

THE HARMFUL IMPACT ON SOIL & PLANTS:

Dyes, plastic, polyester, fibres, yarns, and other hazardous elements are among the liquid and solid wastes emitted by the textile industry, as indicated in the previous section. Local waste environments and agricultural fields have been contaminated by these polymeric chemicals, particularly in poor countries.

Plant growth is inhibited by soil contamination, which causes oxidative stress and lowers protein content, photosynthesis, and CO₂ absorbing rates [9].

THE HARMFUL IMPACT ON AIR:

Toxic gases such as sulphur, formaldehyde, nitrogen oxides, volatile chemicals, particulate matter, and dust are released by the textile dye industry and have a disagreeable odour.

Humans (workers and customers), animals, the finished product, and the environment may all be affected by this air pollution [9].

THE HARMFUL IMPACT ON WATER:

The main impact of industrial dye effluent is on receiving water bodies (such as seas, rivers, lakes, natural ponds, and streams) and can spread over long distances, causing harm to other types of life. These effluents' dark hue and high turbidity prevent sunlight from passing through the water, lowering the amount of dissolved oxygen and altering the pH level [9].

The presence of tiny numbers of dyes in the water, which are highly visible, has a significant impact on the quality and transparency of water bodies such as lakes, rivers, and others, resulting in environmental damage [52]. In the water and sediments of rivers receiving treated wastewater, the dyes might be partially destroyed or converted [15].

THE HARMFUL IMPACT ON HUMAN:

Dye chemicals and by-products found in wastewater or dust created in the textile sector cause substantial harm and have long-term health consequences for humans. They have an impact on the human body's vital organs (brain, kidney, liver, and heart) as well as systems (respiratory, immunological, and reproductive) [9].

TOXICITY EFFECTS OF DYES:

Basic dyes have a high colour intensity and are highly visible even at low concentrations. The complex dyes are mostly made of chromium, which is a carcinogen. Dyes may reduce photosynthetic activity in aquatic life by reducing light penetration, and they may also be hazardous to some aquatic species owing to metals, aromatics, and other contaminants.

Dyes are also carcinogenic, mutagenic, and teratogenic in a variety of bacterial and fish species. It can also cause significant damage to humans, such as kidney, reproductive system, liver, brain, and central nervous system problems. Azo dyes are poisonous because toxic amines are present in the effluent. Similarly, anthraquinone-based dyes are the most resistant to degradation and maintain their colour in effluents for a long time.

Dyes have sparked a lot of debate about their use due to their harmful consequences. Mutagenesis, chromosomal fractures, carcinogenesis, and pulmonary toxicity have all been reported. As a result, it is desirable to concentrate on specific methods and technology for removing colours from various types of wastewater streams [54].

NOMENCLATURE OF DYES:

Dyes are labelled with either a commercial trade name or a Color Index (C.I.) number. These are cross-referenced in the Colour Index. The names of dyes on the market are usually made up of three components. The first is a trademark used by a certain manufacturer to denote both the manufacturer and the dye class, the second is the colour, and the third is a series of letters and numbers used by the company as a code to describe the hue more precisely and to indicate essential dye qualities.

Different manufacturers use different code letters, which are not standardised. R for reddish, B for bluish, and G for greenish tones are the most common letters used to describe hue. Some of the key significant letters for indicating the dyeing and fastness prop- W is for wash fastness, while E stands for exhaust dyes. The heat fastness of perse dyes is indicated by letters A, B, C, or D, with A being the most heat fast. Heat Fastness is graded from A to D, with A being the least heat fast and D being the most heat fast. M is used in reactive cotton dyes. H denotes a hot-dyeing (ca 80 °C) dye, while denotes a warm-dyeing (ca 40 °C) dye [55].

DYE DEGRADATION METHOD:

- 1]. Physicochemical analysis: Standard methods (UV-visible spectroscopy, atomic absorption spectroscopy, titrimetric method) was used to determine physicochemical parameters (pH, conductivity, BOD, COD, CaCO_3 , potassium, organic matter and carbon, etc.) [56].
- 2]. Isolation of microorganisms: Serial dilution, agar plating, and the enrichment culture technique was used to isolate microorganisms from the contaminated soil and water [56].
- 3]. Characterization and Identification of isolated microorganisms: The morphological (cell shape, colony features, staining, etc.) and biochemical (IMViC, catalase, amylase, etc.) characteristics of isolated microorganisms was determined. properties (e.g., carbon usage, etc.) according to conventional protocols [56].
- 4]. Screening of degradation & decolourization potential of isolated microorganisms: Photometric methods (UV-VIS spectrophotometer) was used to assess the degradation and decolourization capacity of isolated bacteria at various time intervals [56].

LIMITATIONS:

- 1.The effect of isolated dye-degrading bacteria will not be examined in field circumstances due to time constraints.
- 2.Because different dyes include distinct compounds with complex structures, the dye degradation capacity of isolated microorganisms cannot be expected for all types of dyes structures.
- 3.Other contaminants, in addition to dye, are present in contaminated samples and may interfere with the decolourization process.
- 4.Other contaminants that may be present in collected samples will not be degraded in this investigation [56].

V. CONCLUSION

Traditional wastewater treatment is extremely expensive and requires constant chemical input, making it uneconomical and causing pollution more harm to the environment as a result, bacteria-based procedures that are both cost-effective and environmentally acceptable can be used to fine-tune waste water treatment. Biotreatment is a simple, cost-effective, and efficient method of removing textile colours.

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