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State of the art Bioremediation of textile dye in wastewater: A Review

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Wastewater is a major environmental issue that has arisen as a result of various industrial activities, especially in the textile industry. According to the World Bank, water contamination in the textile industry is caused by dyeing and finishing treatments that are applied to the fabric. The textile industry uses a variety of synthetic dyes and produces vast volumes of brightly colored wastewater as a result of the dyes' absorption. The photosynthetic activity of plants is seriously harmed by this brightly colored textile wastewater. Owing to low light penetration and oxygen intake, it also has an effect on marine life. Due to the presence of component metals and chlorine in synthetic dyes, it may also be lethal to certain types of marine life. As a result, before being discharged, this textile wastewater must be treated. In this article, bioremediation or treatment through biological methods (fungi, algae, bacteria, microalgae) in treating textile dyes wastewater will be discussed. This review article will also explain the process of textile production, a common type of dyes being used in textile as well as the harmful effects of textile dyes effluent towards humans and the environment.

Keywords: Textile industry, textile dyes, wastewater, bioremediation, microorganisms

INTRODUCTION

Textiles are one of the largest industries in the world to cater to the basic needs of humans, and have been rapidly growing mainly in developing countries. Cellulose fibers (cotton, rayon, linen, ramie, hemp, and lyocell), protein fibers (wool, angora, mohair, cashmere, and silk), and synthetic fibers (polyester, nylon, spandex, and ace) are the three main categories involved in the textile industry. The classification of the textile industry's dyes and chemicals are discovered to differ depending on the fabrics produced (Yaseen & Scholz et al. 2019). Reactive dyes, direct dyes, naphthol dyes, and indigo dyes are some of the dyes that are commonly used to dye cellulose fibres (Burch, 2013; Robert et al. 2008). Acid dyes and lanaset dyes are used to color protein fibres (Moody & Needles, 2004). Some dyes, such as dispersed dyes, basic dyes and direct dyes, are used to colour synthetic fibres (Burch, 2013).

According to the World Bank, about 17% to 20% of water contamination in the textile industry is caused by dyeing and finishing treatments that are applied to the cloth (Holkar et al. 2016; Rani et al. 2013). Pretreatment of the cloth, dyeing with synthetic dyes, printing, and finally finishing are all phases in the textile printing and dyeing process that led to water pollution. The wastewater released by the textile dyeing industry contains a total of 72 harmful chemicals, 30 of which are resistant to waste treatment (Chen & Burns, 2006). As a result, highly polluted effluents are discharged (Seow & Lim, 2016). These water-soluble textile dyes have had a detrimental impact on the delicate habitats surrounding the industries, and they pose significant environmental issues (Keharia & Madamwar, 2003). Textile effluent, due to its dark colour, normally blocks sunshine, making aquatic organisms' lives at risk of death (Ghaly et al. 2014).

In addition, the textile industry uses a variety of synthetic dyes and produces vast quantities of heavily coloured wastewater due to the low absorption of these dyes by fabrics. The photosynthetic activity of plants is seriously harmed by this brightly coloured textile wastewater. Owing to low light penetration and oxygen intake, it also has an effect on marine life. Owing to the presence of component metals and chlorine in synthetic dyes, it can also be lethal to some types of marine life. During the manufacturing process, the textile industry uses a variety of chemicals as well as a significant volume of water. Water is mostly used to apply chemicals to the fabrics and to rinse the finished products. The wastewater created during this process contains large amount of dyes and chemicals containing trace metals such as Cr, As, Cu and Zn which are capable of harming the environment and human health. Hemorrhage, skin ulceration, nausea, skin irritation, and dermatitis are all possible side effects of textile wastewater. Since the chemicals in the water block sunlight and raise biological oxygen demand, photosynthesis and reoxygenation are inhibited. As a result, before being discharged, this textile wastewater must be treated (Holkar et al. 2016).

The removal of dye from textile wastewater can be accomplished using a variety of methods. Physical, chemical, and biological are the three broad categories. These techniques have already been thoroughly examined (Hao et al. 2000; Robinson et al. 2001; Forgacs et al. 2004; Joshi et al. 2004). To extract and/or convert different types of contaminants (heavy metals, dyes, persistent organic pollutants) from the atmosphere, various physico-chemical and biological options and processes were used. Chemical precipitation, ion exchange, adsorption, membrane separation, coagulation, flocculation, flotation, electrochemical methods, and other physico-chemical processes were used. However, although some of these processes produced quick results, they were less effective and costly than bioremediation-based processes. Scientists and stakeholders are becoming increasingly interested in biological applications, which are seen as one of the promising green biotechnologies for ensuring long-term environmental remediation (Azelee et al. 2020). These beneficial microbes have been intensively explored for many applications such as in the food, agriculture, chemical, pharmaceutical, cosmeceutical and for the environment (Dailin et al. 2019; Kepli et al. 2019; Sayyed et al. 2020; Nordin et al. 2020; LuhSuriani et al. 2020; Nithyapriya et al. 2021).

The main disadvantages of physico-chemical methods have been their high cost, low performance, limited mobility, intrusion from other wastewater constituents, and waste disposal. Since microbial decolorization is a cost-effective treatment for textile dye wastewater, it is getting a lot of coverage (Banat et al. 1996; Stolz, 2001; Zee and Villaverde, 2005). Many studies have emphasized bioremediation technology by biosorption and bioaccumulation. These two methods are appealing because of their low cost, abundant biomass, and high productivity (Gavrilescu, 2004). The use of bioremediation strategies that depend on the natural ability of microorganisms (fungi and bacteria), algae, and plants to bind heavy metal ions or, in some cases, facilitate their conversion to less toxic types, through treatment of contaminated effluents, leads to the observation of natural-occurring processes in the ecosystem (Brinza et al. 2009).

Process of textile production

The textile industry can be divided into two categories: dry fabric and wet fabric. The dry process and the wet process were used to categorise these two categories based on the textile production process itself (Ghaly et al. 2014). In the textile industry, drying is critical for removing or reducing water from fibres, yarns, and fabrics after wet processes. Desizing, scouring, bleaching, mercerizing, dying, printing, and finishing are examples of wet fabric manufacturing operations. The amount of wastewater produced by a wet processing textile industry during fabric creation is determined by the operations.

Due to the increased consumption of water for its various wet processing operations, the textile industry is a major source of effluent wastewater. In general, solid waste is produced in the dry fabric industry, while liquid waste is produced in the wet fabric industry. Textile dyeing and finishing treatment produces about 17 to 20% of industrial waste water, according to the World Bank (Kant, 2012). Chemicals such as acids, alkalis, dyes, hydrogen peroxide, surfactants, dispersing agents, and metal soaps can be found in effluent wastewater (Paul et al. 2012). As a result, the textile industry is expected to use more water than any other industry in the world, and almost all wastewater discharged is highly contaminated.

Different type of dyes in industries

In general, cellulose fibres, protein fibres, and synthetic fibres are the three main types of fibres used in textile production (Table 1). The functional classes of these dyes' chemical structures can be used to classify them structurally: anthraquinone, azo, phthalocyanine, sulphur, indigo, nitro, nitroso, and so on (Benkhaya et al. 2020). As a result, dye use varies from industry to industry, depending on the fabrics produced. Different types of dyes are used to dye various types of fibres, which are categorised based on their chemical compositions and properties as shown in Table 2.

Table 1: Type of textile dyes according to type of fibers

Type of fibers	Source of fibers	Type of dyes	References
Cellulose fibers	Originated from plant sources (Example: cotton, linen)	Reactive dyes Direct dyes Vat dyes Napthol dyes Indigo dyes	Burch, 2013; Robert et al. 2008
Protein fibers	Originated from animals (Example: wool, silk)	Reactive dyes Acid dyes Lanaset dyes	Moody & Needles, 2004
Synthetic fibers	Artificially synthesized fibres (Example: polyester, nylon, spandex)	Disperse dyes Basic dyes Direct dyes	Burch, 2013

Table 2: Types of dyes and its characteristics (Benkhaya et al. 2020; Holkar et al. 2016)

Dyes classification	Type of dyes	Characteristics
Reactive dyes	**Triazine derivatives:** Procion MX	-Procion MX is a non-reactive cold-water dye that can be used at room temperature. -Lightfastness and wash fastness. **-**When fabrics are not exposed to alkaline conditions, they become inactive.
	Quinoxaline derivatives: Levafix E	-Suitable used forcold dyeing -A dye molecule that can form a covalent bond with a cellulose molecule.
	Vinyl sulphone: Remazol	-Have a masking community that keeps them from reacting with water, allowing them to last longer in water.
Direct dyes	Direct red 81	-Do not form tight bonds with the fibre molecules and are only loosely connected with them -Lack of the ability to dry quickly after being applied to fabrics.
Indigo dyes	Dark blue	-A dark blue crystalline powder that is water-insoluble.
Naptholdyes	Napthol AS	-The diazo salts and the naphthol are a mixture of two distinct chemicals (which determine the colour of the dye). -Compared to other reactive dyes, they contain more hazardous chemicals.
Acid dyes	Azo dyes Triarylmethane dyes Anthraquinone dyes	-Azo dyes, which account for 60-70 percent of all dye classes, are known for producing vibrant, high-intensity colours as compared to other dye classes. -Wool and silk fibers are dyed with acidic triarylmethane dyes containing at least two sulfonic acid groups. -The sulfonic acid group in anthraquinone dyes makes them water-soluble.

Dyes for cellulose fibres

Cellulose is made up of glucose units that repeat. Reactive dyes are the most widely used dye for cellulose textiles. Direct dyes, vat dyes, sulphur dyes, indigo dyes, and napthol dyes are the other types of dyes used.

Dyes for protein fibres

Both animal-derived fibres (such as wool and silk) are classified as protein fibres. Twenty basic amino acids make up proteins. They are more complex than cellulose, which is made up of sugar units that are replicated. Acid dyes are used to dye wool, angora, cashmere, and silk since high pH denatures proteins. The dye and the fibre react chemically, resulting in the creation of an insoluble dye molecule on the fibre. Azo dyes, triarylmethane dyes, and anthraquinone are the three most common acid dyes.

Dyes for synthetic fibres

Dispersed dyes are the most widely used dyes for synthetic fibres. Polyesters, nylon, and acetates are commonly printed with these dyes. In the printing industry, some dispersed dyes are used as ink.

Treatment of textile dye wastewater

The removal of dye from textile wastewater is accomplished using a variety of methods. Physical, chemical, and biological are the three broad categories. These techniques have already been thoroughly examined (Hao et al. 2000; Robinson et al. 2001; Forgacs et al. 2004; Joshi et al. 2004). The main disadvantages of physico-chemical methods have been their high cost, low performance, limited mobility, intrusion from other wastewater constituents, and waste disposal. Biological treatments, also known as bioremediation, are a less costly choice for removing dyes from wastewater (Chen, 2006). Several microorganisms have been tested for their ability to absorb heavy metals and dyes, including bacteria, fungi, and microalgae (Dönmez, 2002; Malik, 2004; Sadettin and Dönmez, 2007).

Bioremediation is a method that uses naturally occurring or intentionally introduced microorganisms to treat a contaminated or polluted site, as well as changing environmental conditions to promote the growth of microorganisms and degrade the target pollutants, in order to clean a polluted site and maintain environmental quality. Bioremediation is generally divided into three categories: biosorption, biodegradation, and bioaccumulation. The elimination of toxins from wastewaters can be accomplished using biological methods such as bioaccumulation and biosorption. Biosorption is the process of inert, dead biological materials removing substances from solution, while bioaccumulation is the process of pollutant accumulation within cells (Gadd, 2009; Wang and Chen, 2009).In nature, biomass plays a critical role in the detoxification of a wide range of waste streams. Soluble chemicals bind with biological materials and are attached to cellular surfaces in a process known as biosorption, or they accumulate within the cells in a process known as bioaccumulation (Kadukova and Vircikova, 2005).

Surface complexation, ion exchange, electrostatic attraction, and microprecipitation are all examples of nondirected physicochemical mechanisms (Gavrilescu, 2010). Biosorption is a metabolically passive process (made mainly by nonliving microorganisms or biological materials (e.g., agricultural waste), while bioaccumulation necessitates the presence of living organisms and is accomplished in the later stages of biosorption. As a result, biosorption is the first stage in bioaccumulation; after that, the pollutant is transported within cells primarily through energy-intensive active transport systems (Chojnacka, 2010). Biodegradation, on the other hand, is the biologically mediated breakdown of chemical compounds. It is an energy-intensive process that involves the breakdown of dye into a variety of by-products through the action of enzymes. The mechanism of treating wastewater textile dyes via bioremediation was shown in figure 2. These approaches have many advantages, including low running costs, reduced pollutant concentrations, and high efficacy in detoxifying very dilute effluents. Algae, fungi, and bacteria are three readily accessible classes that can be used as biosorbent products, with the first two potentially providing more options (Ahluwalia and Goyal 2007; Wang and Chen 2006; Zeng et al. 2013). Along with their biosorption ability, algae have gotten a lot of attention from scientists. Micro- and macro-multifunctional algae's use in food, cosmetics, medicine, energy, and other fields demonstrates their wide availability for other applications, such as bioremediation. Algae can be used in a biosorption system either alive or dead, with the dead form being more realistic because it does not require nutrients and is not exposed to pollutants' toxicity (Bilal et al. 2018). Brinza et al. (2007) supported a thorough examination of the functional aspects of using algal biomass to biosorb heavy metals from wastewater. The authors focused on the possibility of reusing algal biomass in multiple adsorption/desorption cycles, as well as the impact of morphology and environmental factors on algal tissue reusability.

Use of different microorganisms

Biosorption, biodegradation, and bioaccumulation are the most popular methods for microorganisms to bioremediate pollutants (Dursun et al. 2003;Igiri et al. 2018).Microorganisms and biocatalysts may be used to bioremediate textile dyes, but each has its own set of advantages and disadvantages in terms of decolorizing performance, suitability, and working capability (pH, temperature, and concentration of dye).Microorganisms of various strains may absorb or release enzymes that can eliminate or neutralize harmful contaminants from polluted sites. Both bacteria alone and bacteria in combination with fungi and algae have been extensively used in the decolorization process (Raouf et al. 2012; Ito et al. 2016).

Different microorganisms (bacteria, algae, fungi, yeast, and so on) have been confirmed to remove different heavy metals and dyes from aqueous solutions separately (Mehta and Gaur, 2001; Wang and Chen, 2006; Yadav et al. 2015). The function of fungi in wastewater treatment has been extensively studied (Azmi et al. 1998; Ito et al. 2016). The fungus has proven to be an effective organism for treating clothing effluent and removing dyes. By producing extracellular enzymes, fungal mycelia have an additive benefit over single-cell organisms in that they can solubilize insoluble substrates. Fungi have a higher physical and enzymatic interaction with the environment due to their increased cell-to-surface ratio. The extracellular presence of fungal enzymes is also beneficial in tolerating high toxicant concentrations. Microalgae organisms such as *Chlorella vulagris*, *Chlorella pyrenoidosa*, and *Spirulina platensis* have also been found to degrade azo dyes into simple aromatic amines and decolorize dye wastewater in previous studies.A variety of microorganisms (bacteria, fungi, microalgae, and yeast) have been confirmed to be capable of handling textile dye wastewater in several studies as shown in Table 3.

Table 3: Different types of microorganisms capable of dye removal

Strain	Dye	Mechanism	References
Chlorella vulgaris UMACC 001 (green microalgae)	Supranol Red 3BW	Biosorption	Lim et al. 2010
Spirulina platensis (microalgae)	Reactive Red 120	Biosorption	Cardoso et al. 2012
Desmodesmus sp. (microalgae)	Methylene Blue and Malachite Green	Biosorption	Fawwaz& Abdullah, 2016
Chlorella pyrenoidosa (microalgae)	Diazo dye Direct Red 31, Methylene blue dye	Biodegradation, Biosorption	Sinha et al. 2016; Pathak et. al., 2015
Candida tropicalis (yeast)	Remazol Blue, Reactive Black and Reactive Red	Bioaccumulation	Donmez, 2002
Phormidium sp. (cyanobacteria/photosynthetic bacteria)	Black B or Remazol Blue	Bioaccumulation	Sadettin&Donmez, 2007
Pseudomonas entomophila (bacteria)	Azo dye RB 5	Biodegradation	Khan & Malik, 2016
Irpexlacteus (white rot lignolytic fungus)	Dark Blue 2SGL-01	Biodegradation	Kalpana et al. 2011
Aspergillus tamarii (fungus)	chromium complex dyes	Biosorption, bioaccumulation, biodegradation	Ghosh et al. 2017
Aspergillus versicolor (fungus)	reactive dyes	Bioaccumulation	Tastan et al. 2010
Aspergillus niger, Rhizopus arrhizus, Trametes versicolor (fungus)	Gryfalan black RL	Biosorption	Aksu&Karabayir, 2008
Schizophyllum commune, Ganoderma lucidum (fungus)	Solar golden yellow R	Biodegradation	Asgher et al. 2008
Trametes versicolor (fungus)	Direct blue 1, direct red 128	Biosorption	Bayramoglu& Arica, 2007

Health impact of dyes on humans and environment

Textile effluent not only causes significant degradation in the environment but also in human health. Approximately 40% of the world's colorants contain organically bound chlorine, which is a known carcinogen (Kant, 2011). Harmful chemicals can be entered into the human body through digestion, skin or bronchially (Daugherty, 1997) that is carcinogenic, mutagenic and can cause allergic reactions (Akarslan and Demiralay, 2015). Because of the harmful existence of textile dyeing effluent, the normal functioning of cells is disrupted, which can result in alterations in biochemical and physiological processes of humans, which lead to the injury of the main function such as osmoregulation, respiration, reproduction and even mortality (Islam and Mostafa, 2018). The most commonly recognized peril of the textile dye is related to the respiratory problems due to the inward breath of dye particles. They can also influence the individual's immune system and in outrageous cases, the individual's body can respond dramatically when the individual inhales the dye again. This is known as respiratory sensitization and symptoms encompass sniffling, watery eyes, itching, tingling, sneezing while symptoms of asthma include wheezing and coughing. Asthma usually occurs in human during occupational exposure. Occupational asthma is caused by the particular causative agents that are present in the workplace (Bernstein et al. 2006). Reactive dye, which includes a chromogen linked to a reactive group that allows covalent attachment of the dye to hydroxyl groups on cellulose fibres, has been found to be one of the causative agents of occupational asthma (Koh et al. 2008; Park et al. 2001). These fibres function as haptens and can trigger the immune system. (Park et al. 2007).

Besides, textile dyes also stimulate allergic reactions. According to some studies, some textile dyes can move from fabrics to the human skin during perspiration (Osawa et al. 1997) as clothing encourages textile dyes to come into direct contact with the human skin. This may cause urticaria, allergies or dermatitis (Ramchandani et al. 1996; Teschke et al. 1997; Zuskin et al. 1997). Individuals that are affected are frequently erythrodermic and suffer from intractable pruritus that can be debilitating. It was found that workers who have prolonged exposure to reactive dyes will acquire asthma, rhinitis, nasal problems, and dermatitis (Islam and Mostafa, 2018). Irritant contact dermatitis (ICD), allergic contact dermatitis (ACD), atopic dermatitis (AD), and mimics of textile pattern dermatitis are the four categories of dermatitis associated with textiles. The key source of sensitization associated with textile-related ACD is rarely caused by textiles but is frequently because of occupational exposure to chemicals that cross-react with allergens found in the textile (Tang et al. 2018).

Textile dyes often cause diseases ranging from dermatitis to central nervous system disorders or are linked to the substitution of enzyme cofactors, resulting in the inactivation of enzyme activities (Copaciu et al. 2013). The acute toxicity of textile dyes is caused by inhalation and oral ingestion, particularly by dust exposure (Clark, 2011), which irritates the skin and eyes (Christie, 2007). Chemicals that act as irritants include ammonia, bleach, acetic acids, soda ash, some shrink-resist chemicals, caustic soda, some optical whiteners and formaldehyde-based resins (Hassaan and El Nemr, 2017). Since 1926, formaldehyde-containing resins have been used as wrinkle-resistant fabrics in the garment industry. In the 1950s and 1960s, allergic contact dermatitis caused by formaldehyde in textiles was widely published in the literature. However, since the textile industry has attempted to reduce the amount of free formaldehyde in bedding fabrics as well as wearing textiles, reports of contact allergies to textiles caused by formaldehyde have become less frequent (Akarslan and Demiralay, 2015).

On the other hand, another category of dyes - complexed metal dyes, which have half-lives of 2-13 years and are commonly used in the textile industry (Copaciu et al. 2013). Generally, metals used to form a complex include copper, chromium, cobalt and nickel (Chavan, 2011). Once discharged to the water bodies, the heavy metal cations can be assimilated by the fish gills, due to the presence of negative charges, allowing them to accumulate in certain tissues (Vargas et al. 2009). Consequently, cations travel up the food chain and finally enter human organs, and cause a variety of pathologies (Khan and Malik, 2018).

Chemical chlorine reacts with organic matter to form trihalomethanes (THM) chlorination by-products during the removal of pathogenic microorganisms. Prolonged exposure to these compounds has significant health consequences, including carcinogenic effects (colorectal, bladder, colon, etc.) as well as affecting the reproductive and immune systems carcinogenic and genotoxic properties. In terms of toxicity, azo dyes, especially cationic and diazo dyes, are the most toxic synthetic organic dyes, causing cancer in both animals and humans. The electron-withdrawing nature of azo groups, which induces electron deficiencies, causes azo compounds unstable in aerobic oxidative catabolism (Berradi et al. 2019).

The textile industry is among the most water, energy as well as chemical-consuming industries (Akarslan and Demiralay, 2015). This industrial sector considers as an anthropogenic activity which is one of the world's most polluting industries and consumes vast amounts of fuels. Special attention is the emphasis on the large use of drinking water in numerous operations of its production chain, such as dyeing, cleaning, and bleaching (Hossain et al. 2018). Apart from its huge input, textile industries also produce an enormous number of effluents, solid waste ingredients and dirt slurry daily (Islam and Mostafa, 2018) and because of inefficiency in the dying process, expected 200000 tonnes of dyestuff are discharged into the environment per year during dyeing and finishing operations (Manzoor and Sharma, 2020). The primary solid wastes are constituting discarded packaging, scraps of textile yarns and fabrics while textile sludge reveals problems associated with the unwanted composition and surplus volumes, frequently presenting large amounts of micronutrients, heavy metal cations, pathogenic microorganisms and organic matter (Bhatia, 2017).

Moreover, 80% of the untreated effluents discharged into the water bodies are produced by this industry which is the main damage to the environment (Bhatia, 2017; Wang, 2016). The majority of the textile industry residual waters have relatively high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) (Setiadi et al. 2006). The huge amount of non-biodegradable organic compounds, particularly textile dyes, should be prioritized (Orts et al. 2018). Based on Kant (2012), the World Bank estimates that textile dyeing and finishing treatment is given to fabric have contributed approximately 17% - 20% of industrial water pollution. 72 toxic chemicals have been recognized in water that is solely derived from textile dyeing, 30 of which cannot be removed.

Dyes are organic compounds that are soluble, particularly those classified as acids, basic, direct and reactive. They have a high solubility in water, making them difficult to eliminate using traditional methods (Hassan and Carr, 2018). Due to the presence of chromophoric groups in the molecular structure of dyes, it has the capability to impart colour on a substrate (Shamey and Zhao, 2014). Nonetheless, the ability to fix the colour to the material is associated with the auxotrophic groups that are polar and can bind to the polar groups of textile fibres (Wardman, 2017).

During the dyeing process, the dyeing of textiles needs vast amounts of water (approximately 200 tons of water per ton of product) and more than 10000 types of dyes are used. It is estimated that about 10% - 50% of the dyes are lost during the dyeing process due to the incomplete fixation of the dye during the textile fiber dyeing step, and end up in the effluent (Akarslan and Demiralay, 2015; Mansour et al. 2012; Rajaguru et al. 1999; Vaidya, 1982). The textile effluents discharged contain a complex mixture of numerous pollutants including dyes, pesticides, naphthol, soaps, nitrates, sulphur, acetic acid, vat dyes, and a trace amount of heavy metals for instance arsenic, nickel, mercury, cobalt iron, zinc, lead, copper, chromium and certain auxiliary chemicals all combine to make the effluent extremely toxic. Non-biodegradable dyeing chemicals, formaldehyde-based dye fixing agents and hydrocarbon-based softenersmay also present in the water. These dyeing effluents are being quitted into the farming fields, adjacent waterways, exterior water, irrigation channel and finally flow into the water bodies such as sea, river and etc. When this effluent is discharged to the field, it obstructs the pore soil and causes loss in soil productivity. In addition, the effluent also causes the soil texture to become hardened and subsequently roots penetration is inhibited (Islam and Mostafa, 2018).

Other than that, if the effluent is discharged into the water bodies, it causes variation in biological, chemical and physical nature in the aquatic atmosphere. In terms of physical impact, textile effluents cause aesthetic damage to the water bodies. In terms of chemical impacts, it causes the fluctuation in turbidity, odour, pH and temperature which seriously affect the community health, aquatic life, biodiversity, livestock and wildlife (Islam and Mostafa, 2018; McMullan et al. 2001). Besides, the textile dye effluent also leads to the change in the biological cycle of aquatic biota especially obstructing the oxygen transfer mechanism at the air-water interface and photosynthesis process of aquatic life in the water bodies by blocking the sunlight passing through the water (Pereira and Freire, 2005). Furthermore, due to the high thermal and photostability to resist biodegradation, textile dyes can last for a long time in the environment (Shaikh, 2009). The non-biodegradability of dyes makes them keep on accumulating in the sediments, fishes or other forms of aquatic life and eventually this agent crosses the entire food chains providing biomagnification for example the organisms at higher trophic levels exhibit higher contamination compared to their prey (Lellis et al. 2019; Saini, 2017). Moreover, depending on the concentration and duration of exposure, dyes may have chronic or acute effects on organisms (Pereira and Alves, 2012).

CONCLUSION

Textile dye wastewater seems to affect the environment and human health drastically. Therefore, this review has discussed suitable bioremediation through the application of various types of microorganisms (bacteria, fungus, and microalgae) to treat the dye in textile wastewater and to reduce the pollution load. This bioremediation technique is acknowledged as a fitting candidate for the removal of dyes, because of its advantages such as economical operation, eco-friendly approach, straightforward and safe operation, and no production of sludge.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

DJD, NZN, LTT, SR, YMMJ and DNAZ were involved in data collection and writing the manuscript. LFC, NS, DS and HAE reviewed the manuscript. All authors read and approved the final version.

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