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BIOLOGICAL TREATMENT OF TEXTILE WASTEWATER – AN ECO-FRIENDLY APPROACH: A REVIEW

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Abstract: Since industrialization is essential to a country's economy, development and industrialization are two parallel wheels for every nation. One of the major businesses in the world, the textile sector offers opportunities to those with no specific training and greatly boosts the economy of many nations. Clothing is one way that the textile industry contributes to human civilization. Numerous environmental risks have been connected to textile effluent. The release of coloured wastewater poses a serious risk to both the environment and public health. Since textile wastewater frequently contains a number of contaminants that contaminate the receiving water, it is well-known that it contributes to pollution. Industrial textile processing includes pre-treatment, dyeing, printing, and finishing. A significant by-product of these production processes is chemical pollution. Different organic dyes, chemicals, and auxiliaries are present in textile finishing wastewater, especially dyehouse effluent. In addition to being bright and containing a variety of salts, surfactants, heavy metals, and mineral oils, they also have extreme pH, COD, and BOD values. Therefore, dye bath effluents must be cleaned up before being released into the environment or a municipal wastewater storage facility. There hasn't been a single, cost-effective treatment method that can effectively decolourize textile effluent, which has been a big challenge in recent years. To treat textile wastewater, Physico-chemical and biological (mainly aerobic) systems are frequently employed. In order to reduce COD and BOD, biological processes could be utilised as a pre-treatment decolourization phase in conjunction with conventional treatment methods (such as coagulation-flocculation, and adsorption on activated carbon). This would make them an effective choice for textile dyeing. This study aimed to gain additional knowledge about biological therapy and bioremediation.

Keywords: Bioremediation, Biological Treatment, Textile Wastewater.

Introduction: Textile dyeing and printing, paper printing, cosmetics, pharmaceuticals, and the leather industry are all industries that employ synthetic dyes. These businesses use a lot of energy and water and produce a lot of wastewater that contains many toxins [Babu et al. 2007]. As the demand for textile products has grown, so has the amount of wastewater generated by the industry, polluting receiving water around the world [Andre et al. 2007]. A typical mill discharge in India is roughly 1.5 million litres of contaminated effluent per day, which contains a variety of harmful compounds such as dispersants, levelling agents, acids, alkalis, carriers, and different colours. During various operations, organic dyestuff, chrome dyes, and other chemicals produce a huge amount of solid and liquid waste containing hexavalent chromium [chromium (VI)], zinc salts, and other compounds. It has a high toxicity level in aquatic organisms [Sandhya et al. 2005]. Chromium (VI), zinc, lead, and cadmium concentrations in drinking water should not exceed 0.05, 3.0, 0.015, and 0.005 mg/l, respectively [ISI, 1991]. According to the Central Pollution Control Board's wastewater discharge standard, the discharge concentration of chromium shall not exceed 0.1 mg/l in India [CPCB, 2000-2001]. Chromium, zinc, and copper pollution in ground waterways have been observed as a result of the environmental repercussions of industrial wastewater irrigation from a tanning industrial cluster in Bangalore, India [Shankar, 2009]. This problem changes the pH, raises the biological oxygen demand (BOD) and chemical oxygen demand (COD), and causes the rivers to turn a bright red colour [Dutta et al. 2002]. The usage of these water resources is limited, and microbial populations can be poisonous, mutagenic, and/or carcinogenic to animals, affecting the environment [Gunasekaran et al. 2006].

Textile effluents are treated using a variety of physicochemical processes, including filtration, coagulation, activated carbon, and chemical flocculation [Gogate et al. 2004]. These treatments are costly and generate a secondary disposal issue, whereas microbial breakdown provides a cost-effective and environmentally benign alternative to chemical treatment [Verma et al. 2003].

1.1 Bioremediation: Bioremediation is a technique for utilizing innate biological activity to eliminate or render harmless certain contaminants. As a result, it uses low-tech, low-cost methods that are widely used by people and are frequently done on-site. It won't always be appropriate though because the range of contaminants on which it is effective is constrained, the time periods needed are lengthy, and the residual contamination levels reached might not always be enough. A successful bioremediation programme may require a significant amount of experience and expertise even though the methodologies used are not technically complex. This is because it is necessary to thoroughly assess a site for suitability and optimize conditions in order to produce a satisfactory result. Research in this area is rapidly growing, especially in the United States, because bioremediation seems to be a workable substitute for conventional clean-up technology. Various parts of the world, including Europe, have tried bioremediation with varying degrees of success. Biodegradation offers a lot of potential for handling various forms of site contamination, and techniques are getting better as more information and experience are gathered. Unfortunately, there is a lack of understanding of bioremediation's concepts, methods, advantages, and disadvantages, especially among those who will have to deal with it directly, such as site operators and inspectors. We hoped to help by offering a clear, practical understanding of the processes involved in bioremediation, the benefits and drawbacks of the approach, and the concerns to consider when dealing with a bioremediation proposal [King et al.1997].

1.2 Principle of Bioremediation: Composting and wastewater treatment are two well-known examples of old environmental biotechnologies. Recent research in molecular biology and ecology, on the other hand, suggests that biological processes can be made more efficient. The clean-up of polluted water and land areas is one of these studies' notable accomplishments. Bioremediation is the biological decomposition of organic wastes in a controlled environment. controlled conditions to a benign state, or concentrations below regulatory agencies' concentration limits [Mueller et al.1996].

The method of bioremediation involves employing living organisms, usually bacteria, to transform environmental contaminants into less dangerous forms. Using naturally occurring bacteria, fungus, or plants, it destroys or detoxifies toxins that are hazardous to human health or the environment. The microbes could have been isolated somewhere else and then brought to the polluted site, or they might be local to the contaminated area. Through reactions that take place as part of their metabolic processes, living organisms alter contaminating compounds. A chemical is often biodegraded as a result of the activity of several organisms. Bringing microorganisms to a polluted location to help with deterioration is a process known as bioaugmentation.

For bioremediation to be successful, pollutants must be attacked enzymatically by microorganisms and converted into innocuous chemicals. Since environmental circumstances must be favourable for microbial growth and activity for bioremediation to be effective, environmental parameters are regularly changed to hasten microbial growth and breakdown. Like all other methods, bioremediation has its own inherent constraints. Some contaminants, such as chlorinated organics and highly aromatic hydrocarbons, are resistant to microbial attack. There are no rules for determining if a contaminant can be removed; they degrade slowly or not at all, making it challenging to forecast the rates of bioremediation clean-up. Bioremediation procedures are often less expensive than traditional methods like cremation, and some contaminants can be treated on-site, lowering exposure hazards for clean-up workers and potentially wider exposure due to transportation mishaps. Bioremediation is more widely accepted than other approaches because it is based on natural attenuation [Vidali 2001].

1.3 Bioremediation Strategies: Several strategies are used depending on the degree of saturation and aeration of an area. The term "in situ" refers to treatments that are applied to soil and groundwater on-site with minimal disturbance. Ex-situ procedures are those that are used on soil and groundwater that has been removed from a place through excavation (soil) or pumping (groundwater) (water). Microorganisms with the potential to break down contaminants are added to bioaugmentation processes.

1.3.1 In Situ Bioremediation: In situ bioremediation: These methods are the most prevalent since they are cheaper and cause less disturbance because toxins are treated on-site rather than excavated and relocated. In situ treatment is limited by the layer of the soil that must be adequately treated. In many soils, optimum diffusion of oxygen for optimum biodegradation rates ranges from a few centimetres to around 30 cm, but depths of 60 cm and more have been treated effectively in other cases.

The most crucial land treatments are as follows:

1.3.1.1 Bioventing: The most well-known kind of in situ treatment is called Bioventing, which involves injecting air and nutrients into polluted soil through wells to encourage the growth of local microorganisms. Bioventing reduces volatilization and pollutant release into the environment by using low airflow rates and only supplying the amount of oxygen needed for biodegradation. It may be used in contaminated areas that are deep below the surface and is effective for simple hydrocarbons. Circulating aqueous solutions through contaminated soils to feed naturally existing microorganisms that degrade organic contaminants with oxygen and nutrients is referred to as in situ biodegradation.

Both soil and groundwater may use it. This approach often includes scenarios like the penetration of water carrying nutrients, oxygen, or other electron acceptors for groundwater remediation.

1.3.1.2 Bio Sparging: By infusing pressurized air beneath the water table, a technique known as "bio sparging," pollutants may be biologically broken down by naturally existing microbes more quickly. By boosting mixing in the saturated zone, bio-sparging improves the interaction between soil and groundwater. Small-diameter air injection sites may be easily and inexpensively inserted, which gives designers and builders of the system a great lot of flexibility.

1.3.1.3 Bioaugmentation: The addition of microorganisms, either native or exogenous, to contaminated locations is a common part of bioremediation. The utilization of additional microbial cultures in a land treatment unit is limited by two factors: 1) Nonindigenous cultures seldom compete effectively enough with indigenous cultures to develop and sustain viable population levels, and 2) most soils with long-term exposure to biodegradable waste have indigenous microbes that are good degraders if the land treatment unit is adequately managed [EPA, U. 1990].

1.3.2 Ex-Situ Bioremediation: These methods entail excavating or removing contaminated dirt from the ground.

1.3.2.1 Land Farming: Landfarming is a basic approach that involves excavating polluted soil, spreading it over a prepared bed, and tilling it periodically until contaminants have degraded. The goal is to encourage indigenous biodegradative bacteria and make it easier for them to degrade pollutants aerobically. The procedure is often limited to the treatment of the top 10–35 cm of soil. Landfarming has gotten a lot of attention as a disposal option since it has the potential to reduce monitoring and maintenance costs as well as clean-up obligations.

1.3.2.2 Composting: Composting is the process of mixing polluted soil with non-hazardous organic amendments like manure or agricultural waste. The presence of these organic materials encourages the growth of a diverse microbial population and the high temperatures associated with composting.

1.3.2.3 Bio Piles: Bio heaps are a combination of landfarming and composting. Engineered cells are aerated composted piles that have been aerated. They're a more sophisticated form of landfarming that focuses on limiting physical contamination losses through leaching and volatilization. They are commonly used to address surface contamination caused by petroleum hydrocarbons. The optimal environment for aerobic and anaerobic bacteria to thrive is found in bio heaps.

1.3.2.4 Bioreactors: Ex-situ treatment of contaminated soil and water pumped up from a contaminated plume is done with slurry reactors or aqueous reactors. In reactor bioremediation, polluted solid material (soil, sediment, sludge) or water is processed using a designed containment system. A slurry bioreactor is a containment vessel and apparatus used to create a three-phase (solid, liquid, and gas) mixing condition to increase the bioremediation rate of soil-bound and water-soluble pollutants as a water slurry of contaminated soil and biomass (usually indigenous microorganisms) capable of degrading target contaminants as a water slurry of contaminated soil and biomass (usually indigenous microorganisms) capable of degrading target contaminants [von Fahnestock et al.1998].

1.4 Sources of pollutants in textile industries: In a typical textile processing business, desizing, scouring, mercerizing, bleaching, neutralizing, dyeing, printing, and finishing are among the main processes used. During the production of textiles, solid waste, air pollutants, and liquid effluents are all created. Liquid effluents, on the other hand, are a significant source of worry because of their vast volume and contamination potential. The amount and kind of waste produced are influenced by a variety of factors, including the fabric being processed, the chemicals used, the technique utilized, and others. Colour, biological oxygen demand (BOD), chemical oxygen demand (COD), toxic heavy metals, lingering chlorine, dissolving particles, and non-biodegradable organics known as refractory compounds are among the significant contaminants in a typical textile waste discharge. Utility wastewater and domestic wastewater are produced by textile units that have amenities such as cooling towers, labs, workshops, fuel storage facilities, residential colonies, administrative buildings, canteens, and so on. Boilers, thermotanks, and diesel generators are the main sources of air pollution. These devices emit gaseous pollutants such as suspended particulate matter (SPM), sulphur dioxide gas, and nitrogen oxide gas, among others [Tiwari et al. 2013].

1.4.1 Air pollutants: The majority of textile mill processes emit pollutants into the atmosphere. Gaseous emissions have been identified as the second most significant source of pollution (after solid waste for the textile industry's effluent quality) There has been some speculation about the amount and type of pollutants released into the atmosphere by textiles even though operations have been extensive, air pollution has been a problem. Data about textile manufacturing operations is difficult to come by. Dust, oil mists, acid vapours, and other pollutants are all released into the atmosphere. smells and exhaust from the boiler Changes in production and cleaning Sludges from tanks and discarded process chemicals are the result. It could be contaminated with hazardous organics and metals. The introduction of chemicals, particulates, or biological material into the atmosphere that causes injury or discomfort to humans or other living organisms, or affects the natural environment, is referred to as air pollution [Tiwari et al. 2013].

1.4.2 Water pollutants: The importance of water to all living things cannot be overstated, as it accounts for the majority of all biomass. Water is also a valuable resource that human activities such as agriculture, industry, transportation, and residential use rely on. Water, on the other hand, represents the resource that men and their activities have mistreated, mismanaged, and contaminated the most. The principal water contaminants are still industrial effluents, urban runoff, waste discharged directly into bodies of water, agricultural fertiliser, and animal faeces. Water quality is frequently harmed as a result of these procedures, which raise Physico-chemical parameters above allowed levels. Water pollution is a key source of concern in developing countries all over the world. Many industries dump industrial effluents directly into drainage systems without treatment. Drainage systems lead to canals, from which the contents are dumped into rivers and lagoons. As a result, surface water pollution occurs, endangering human health. In poor countries, industrial effluents have been found to contaminate water, land, and air, resulting in a high disease burden and shorter life expectancy. Industrial effluent contains poisonous compounds that can injure humans and animals, as well as contaminate water supplies [Awomeso et al. 2010].

1.5 Types of Characteristics of Hazardous waste: The largest and most powerful industrial sector is the textile sector. Given that it consumes a sizable amount of textile industry processing water and generates discharge water that is extremely polluted, it is rather significant in terms of environmental problems. Water is used extensively in the garment business, from the cleaning of textiles through the wet processing, colouring, stamping, and washing of finished products. The process effluents were characterized in terms of their treatability and reusability after process data had been gathered and merged. It is now clear that environmental contamination generated by textile waste has a substantial impact on the health of the flora as well as the general health of the residents of the area or those who consume marine delicacies. Inorganic heavy metals in ionic salts, such as Cd, Cu, Cr, Fe, Mn, Ni, and Zn, are directly absorbed by marine and freshwater biota or incorporated in groundwater in both cases, i.e., polluted groundwater and marine foods, which are widely consumed by humans, may cause diseases such as cancer, tumours, brain diseases, psychiatric diseases, sexual diseases, and so on.

Salt, acid, alkalis, bleaching, and finishing agents are also extremely damaging to biota and have a significant impact on their health. Pollutants' impacts may not be immediately apparent, but with time, their invisible consequences become lethal [Imtiazuddin et al. 2012].

1.6 Biological Treatment: Decolorization of dyes by bacterial strains began with anaerobic reduction or breakdown of the azo bonds catalyzed by azo-reductase, followed by aerobic or anaerobic degradation of the resultant aromatic amines by a mixed bacterial community [Singh et al. 2017]. Other biological approaches for treating textile effluents include:

1.6.1 Aerobic Treatment: There are limited reports on the utilisation of bacterial degradation of azo dyes, though it has been discovered that some organisms can diminish the presence of colours. In the presence of glucose under aerobic conditions, *Pseudomonas aeruginosa* was able to decolourize Navitan Fast Blue SSR, a commercial tannery and textile dye [Garg et al. 2017].

1.6.2 Anaerobic Treatment: Azo reduction is achieved in anaerobic conditions by breaking the azo bond, but poisonous amines are generated. Dyes are easily cleaved under anaerobic conditions, creating aromatic amines, which are persistent biotransformation products of metabolism [Bhatt et al. 2005].

1.6.3 Anoxic Treatment: Various researchers have described anoxic decolourization of various colours using mixing aerobic and facilitating anaerobic bacteria [Chen et al. 2003]. Although numerous bacteria may grow aerobically, decolourization can only be achieved in an anoxic environment. Under anoxic conditions, pure bacterial strains such as *Pseudomonas luteola*, *Aeromonas hydrophila, Bacillus subtilis,* and *Proteus mirabilis* destroyed azo dyes [Sandhya et al. 2005].

1.6.4 Sequential Degradation: Aromatic amines produced during the anaerobic degradation of azo dyes have been hypothesised to be furtherdestroyed by aerobic action. Mordant Yellow, a sulfonated azo dye, was the first to demonstrate the feasibility of this method. The microbes completely mineralized the amines produced afteraeration [Sandhya et al. 2005].

1.6.5 Photocatalytic Degradation Techniques: Traditional treatment procedures like ozonisation, chlorination, and filtering have their own set of constraints in terms of energy sources and waste generation. Organic dye photocatalytic degradation techniques should be appealingfor the treatment of textile effluents due to their high oxidation capabilities, low cost, high effectiveness, broad applicability, and ease of use [Saravanan et al.2015]. Semiconductor photocatalysis is a new and effective way to treat dyehouse effluent, with the ability to decolourize and dissolute dye molecules into simple inorganic components like CO2 and water. This decreases the risk of harmful by-products and sludge being produced, which frequently cause further treatment and disposal concerns [Mamba et al.2015].

1.7 Agents of Bioremediation

1.7.1 Treatment of Textile Wastewater by Bacteria: In comparison to fungal decolourization, bacterial decolourization is usually faster. There have been numerous reports of bacteria that can destroy colours. Efforts to find bacteria capable of degrading azo dyes began in the 1970s, with reports of Bacillus subtilis, Aeromonas hydrophila, and then Bacillus cereus. According to recent findings, some bacterial strains can mineralize different colours under aerobic circumstances. Sulphate-reducing bacteria have also been used by certain researchers to aid colour breakdown. Many bacterial strains that can aerobically decolourize azo dyes have been discovered in recent years. Because dye cannot be used as a growth substrate, many of these strains require organic carbon sources. Many bacterial strains have been identified as dye decolourizes or dye degraders, including *Bacillus megaterium, Alcaligenes faecalis* 6132, *Rhodococcus erythropolis* 24, *Bacillus licheniformis* LS04, *Rahnella aquatilis*68, *Acinetobacter guillouiae*, *Microvirgula aerodenitrificans*, and *Pseudomonas desmolyticum* NCIM 2112 [Naresh et al. 2013].

1.7.2 Treatment of Textile Wastewater by Fungi: The white-rot fungus (WRF) is the most proficient class of microorganisms in nature at degrading manmade colours. WRF are a type of bacterium that produces effective enzymes that degrade dyes in aerobic circumstances. Lignin modifying enzymes (LME) from WRF, such as Manganese Peroxisade (MnP), Lignin Peroxidase (LiP), and laccases, are directly engaged in the degradation of lignin in its natural lignocellulosic substrates, as well as a variety of resistant xenobiotic chemicals, such as dyes. WRF's peroxidases and laccases are oxidative enzymes that don't require any other biological components to function. The lignin-degrading white-rot fungus *Phanerochaete chrysosporium* has been extensively explored in the last decade due to its capacity to digest a variety of resistant pollutants such as chlorophenols, nitrotoluenes, and polycyclic aromatic hydrocarbons. It has also been demonstrated that it can decolourize a wide range of dyes. Under aerobic conditions, *Phanerochaete chrysosporium* was found to be able to decolourize several azo dyes, including orange II, Congo red, and tropaeolin O. Various extracellular peroxidases (lignin peroxidase and Mn-dependent peroxidase) or laccases are thought to be involved in the dye decolourization process. The findings also revealed that a high rate of dye breakdown can only be accomplished by careful selection of fungi and cultural conditions.

Various *Trametes sp., Trametes versicolor, Irpex lacteus, Pleurotus ostreatus, Pycnoporus sanguineus, Pycnoporus cinnabarinus, Phlebia tremellosa, Ischnoderma resinosum, Funalia trogii, Aspergillus flavus, Aspergillus fumigat* Penicillium has been demonstrated to breakdown a variety of polymeric colours. In the literature, it has been reported that *Trametes versicolor, Pleurotus ostreatus, Phanerochaete chrysosporium, Piptoporus betulinus, Laetiporus sulphureus*, and *numerous Cyathus* species breakdown triphenylmethane dyes [Naresh et al. 2013].

1.7.3 Treatment of Textile Wastewater by Algae: Because algae are common in both salt and freshwater, they could be used as long-term bio sorbents. In recent years, algae have received a lot of attention for their capacity to degrade colours in textile effluent due to their abundant availability. Algae have a high biosorption and bio coagulant capacity due to their comparatively high binding affinity and wide surface area. Algal species have superior cell-wall properties that help with biosorption, complexation (which is said to happen during the biosorption process), and electrostatic attraction. Phosphate, hydroxyl, amino, and carboxylate functional groups linked to the algal cell surface are thought to play a role in eliminating contaminants from textile effluent. PH, temperature, and the presence of functional groups such as phosphate, hydroxyl, amino, and carboxylate are all factors that affect the algal remediation of textile effluent [Ihsanullah et al. 2020].

1.8 Advantages of Bioremediation:

- Because bioremediation is a natural process, the general public views it as a suitable method of handling waste from polluted materials like soil. As the contamination is present, the number of microbes that can break down the pollutant rises; when the contaminant is broken down, the biodegradative population falls. The treatment's leftovers, which comprise carbon dioxide, water, and cell biomass, are often safe byproducts.
- In theory, bioremediation may be used to completely eliminate a range of pollutants. Many substances that are deemed harmful by law can be converted into safe goods. By doing this, all potential future responsibility for the handling and disposal of tainted material is eliminated.
- Target pollutants can be completely destroyed rather than being transferred from one environmental medium to another, for as from land to water or air.

- Significantly less costly than other technologies used for hazardous waste cleanup, according to Bioremediation.

1.9 Disadvantages of Bioremediation:

- Many biological processes are quite specialized. The availability of metabolically competent microbial populations, proper environmental growth conditions, and optimum quantities of nutrients and pollutants are crucial site requirements for success.
- Some people worry that the byproducts of biodegradation may be more hazardous or persistent than the original chemical.
- Bioremediation is only possible with biodegradable substances. Not all substances are capable of full and quick degradation.
- Research is required to design and build bioremediation methods that are suitable for sites with complex mixes of pollutants that are not equally disseminated in the environment. It is challenging to extrapolate from the bench and pilot-scale research to full-scale field operations.
- Bioremediation sometimes takes longer than other treatment alternatives, such as excavation and removal of soil or cremation. Contaminants may be present as solids, liquids, or gases [Vidali, M. (2001)].

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