Mesopotamia Environmental Journal
ISSN 2410-2598
Journal homepage http//:www.mej.uobabylon.edu.iq

DOI: http://dx.doi.org/10.31759/mej.2025.8.32.0050

Potential efficiency of algae and bacteria in bioremoval of toxic industrial dyes: A review

Jasim M. Salman* **Noor S. Naji**

Department of Biology, College of Science, University of Babylon, Iraq

*Corresponding author: jasimsalman@uobabylon.edu.iq
ORCID: orcid.org/0000-0002-2130-7197

To cite this article:

Salman J.M ; Naji,N.S. Potential efficiency of algae and bacteria in bioremoval of toxic industrial dyes: A review . *Mesop. Environ. J*. 2025 Vol.8, No.2, pp:35-50.

Received date: 17/11/2024 accepted date: 10/01/2025 published date:20/01/2025

Abstract:

The use of microorganisms in place of physical and chemical treatments is known as bioremediation. In recent years, there has been a lot of interest in bioremediation. Pesticides, heavy metals, poly aromatic hydrocarbons, and azo dyes can all be broken down or mineralized by bacteria into less dangerous or immobile forms.

The algal Numerous functional groups found in cell wall, such as carboxy, carbonyl, hydroxy, phosphoryl, and amide groups, are crucial for the decolorization of dyes. Some algae have the capacity to take up the pigments of chromophores. Due to the enzymes' capacity to change the dyes into H2O and CO2, algal biomass rises,Since azo dyes are commonly found in aquatic habitats, where textile dye effluents are dumped, algal biomass can therefore be used for the potential treatment of azo dyes.Since bacteria have several advantages from a biotechnological perspective, including being quick-growing, possessing a wealth of degradative enzymes, and having the ability to breakdown a variety of colors, they have been the focus of numerous investigations. In order to decolorize and break down dyes, bacteria must produce azoreductases, an enzyme that can cleave the azo link (-N = N-). Furthermore, bacteria are more adaptable than other organisms because they can further reduce or degrade aromatic amines either aerobically or anaerobically. The biological methods that are currently available to remove such colors from the environment are discussed in this study, with an emphasis on the employment of various microorganisms, in particular bacteria and algae, as well as factors affecting microbial growth.

Keywords: Bioremoval, toxic dyes ,algae , bacteria, bio-sorption **,**azo dyes

Introduction

Microorganisms play a significant part in the delicate biological balance that supports life on our planet. Depending on a variety of factors, microorganisms have developed into a significant influence on biological ecosystems, necessary for maintaining the existence of superior organisms (human, animal, and plant). Microorganisms are used for a number of environmentally and economically significant purposes, including remediation and rehabilitation [1]. In the past several years, there has research on the ability of microbes to break down and change various types of contaminants in various habitats (soil, water, and sediments). Microorganisms can thrive in contaminated environments because they can find niches that are conducive to their survival. The biological breakdown that occurs in the microbial cells that absorb poisons is part of the complex process known as bioremediation[2].

Biotreatment is a method that removes different toxins from environmental media like soil and water. Bioremediation is a technique that, according to the Environmental Protection Agency, "uses naturally occurring organisms to break down hazardous substances into less toxic or nontoxic substances. [3]It works by providing these organisms with various minerals and nutrients, which aid in the rapid breakdown of organic contaminants and aid in the cleanup of oil spills.Numerous factors, including oxygen, nutrients, pH level, composition, bioavailability of the pollutants, physical and chemical characteristics, and the history of the pollution, affect the efficiency of bioremoval. Bioremediation is a non-destructive, low-cost, and effective method of treating pollutants that also occurs naturally [4, 5]. A well-known technology that has been used to successfully treat a number of organic effluents and dye effluents is bioremoval in wastewater treatment. The textile effluents have a high pH [6], a lot of dissolved and suspended particles, and organic compounds. Because the textile industry uses so much water, a lot of industrial waste is daily released into the environment. Textile wastewater ranks first among all industrial sectors in terms of quantity and kind of pollution [7] are numerous physiochemical treatment options for textile wastewater, but their main drawbacks include high capital costs and the creation of secondary effluent. By contrast, The most popular and practical group of colors used in the textile industries are called azo dyes. Therefore, biological decolorization works well in low- to low-oxygen environments [8]

Bioremoval

A regulated biological degradation process called Bioremoval l is used to reduce organic waste to safe state or to concentrations below safe levels or to put it another way, To decompose or detoxify, it makes use of naturally occurring bacteria, fungi, algae, or plants [9]. Additionally, it involves a variety of techniques that lessen the pollutant's impact and mobility as well as stop it from migrating to uncontaminated areas [10].

In spite of the fact that microbiologists have been researching this method The first commercial application of a biotreatment system since the 1940s took place in 1972 to clean up a spilled solar oil pipeline in Ambler., Pennsylvania [11]. It is thought that the ancient Romans used this process to use microorganisms to treat their waste water. This procedure has improved significantly since it was first used to remove various contaminants in 1972. Since 1989, it has developed into a technology that is debated, used, and taken into account in a variety of situations [12].

This method is today referred to as an emerging technology known as therapy based on the use of biological systems for the repair of environmental media is known as environmental biotechnology. [13; 14]. Additionally, It is thought of as a technology that can be utilized anywhere and is thought to be safer, cleaner, more inexpensive, and ecologically friendly. [15], as opposed to the pricey physical-chemical methods that frequently result in toxic, undesirable products that need additional treatment steps [16].

The biotreatment process can be impacted by a variety of variables, including the depletion of preferred substrates, a lack of nutrients, the toxicity and solubility of pollutants, oxidation or reduction potential, and microbial interaction[17]. Each degradation process is influenced by the microorganisms (biomass concentration, population diversity, and enzyme activities), the substrate (physicochemical properties, molecular structure, and concentration), numerous environmental variables (pH, temperature, moisture), the availability of electron acceptors, carbon, and energy sources, as well as the microorganisms' capacity to degrade the substrate[18]. Fig.1 [19]

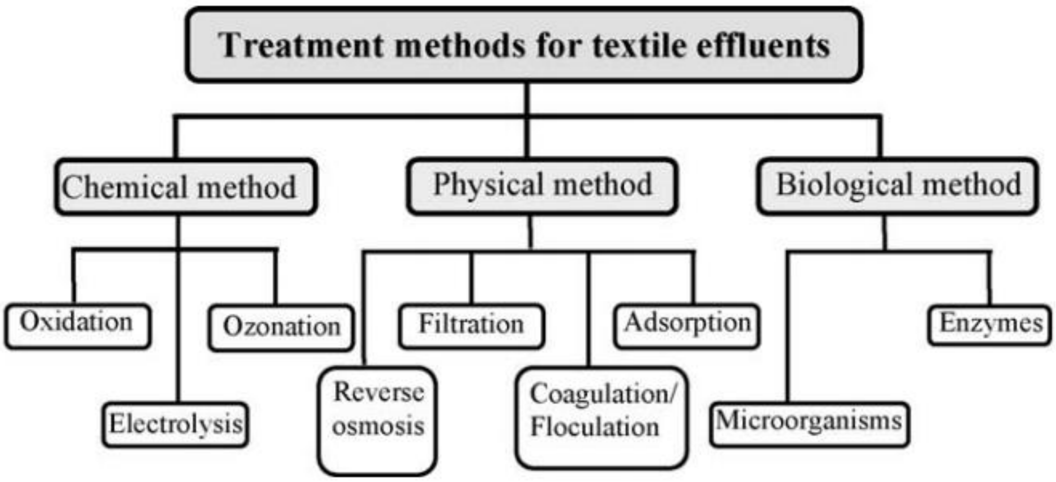


Fig. (1). Techniques for removing colours from wastewater discharge

Toxic dyes (Azo Dyes)

Color is added to materials by dye compounds adhering to them. A chromophore group's presence is what gives a dye its color. They are widely used to tint a wide range of substrates, including textile fiber, paper, leather, hair, fur, plastic material, wax, a foundation for cosmetics, and food items.[20]. There are 20–30 different kinds of dyes, depending on the chromophore's chemical makeup. The most significant types are anthraquinone, triarylmethane, and azo (monoazo, diazo, triazo, polyazo) dyes [21].

The most common family of synthetic aromatic dyes made of sulfonic (-SO3-)groups and one or more N=N groups are called azo dyes, and they have a sizable commercial market[22; 23]. Azo dyes are artificial chemicals that dissolve in water. Typically, phenyl and naphthyl rings are connected by one, two, or three azo linkages in azo dyes.. These rings are typically substituted with triazine amine, chloro, hydroxyl, methyl, nitro, and sulphonate functional groups [24]. They are poisonous to both plants and animals, with a fatal effect, genotoxicity, mutagenicity, and carcinogenicity[25].

Because the metabolic metabolism of benzidine produces carcinogenic amines [26] ,two thirds of the global dyestuff market is accounted for by the textile manufacturing sectors. A byproduct of the textile industry is thought to contain several chemicals used in the industry as major pollutants 10 and 15 percent of the colours used in the dyeing procedure are sent into the wastewater, which causes environmental contamination and health problems. [27].

In watery conditions, azo dyes' hues prevent plant growth by obstructing light, which has an impact on photosynthetic activity [28]. The aquatic biota that is present suffers as a result of the variations in dissolved oxygen content, and the surrounding water's biochemical oxygen demand rises [29]. Additionally, it has been noted that various azo dyes, including Congo red, Direct Blue 15, and Direct Red 2, are poisonous, mutagenic, and carcinogenic to aquatic species [30]

It was discovered that the adsorption of dye may be characterized by a pseudo-second-order rate equation[31]. Farming waste is a cheap, plentiful, and ecologically beneficial material that is used as an incredibly effective adsorbent. Peat bagasse, The most often utilized sources for removing color and heavy metals are coffee powder, pistachio peel, squash coal, rice hull ash, garlic peel, banana peel, pomelo peel, tea waste, coconut shells, orange peel, pomegranate peel, and squash coal.Many dyes, as well as the byproducts of their breakdown, are either fatal, can cause cancer, or both. Little amounts of dyes in the water are quite obvious and have a huge detrimental effect on the marine ecology by purposefully altering the quality and transparency of water bodies including lakes, rivers, and others.Azo dyes are harmful, often causing cancer and mutagenic effects. They are consumed, then broken down by gut microorganisms, causing DNA damage.. [32, 33].

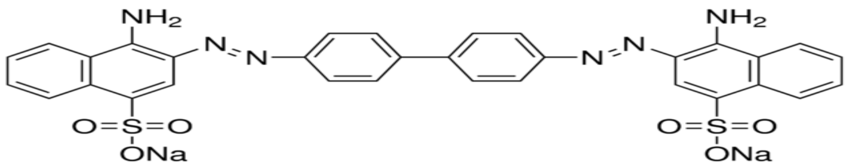
Congo Red

Tetrazotisedbenzidine and two molecules of napthionic acid are combined to create Congo red (CR), a direct, anionic, benzidine-based dye. Table 1 and give its molecular make-up and its physicochemical properties.

The first synthetic azo dye developed that can directly color cotton is congo red. Congo red-containing effluents are produced by a number of industrial processes, including those used in the textile, printing and dyeing, paper, rubber, and plastics sectors [34; 35]. There have been reports of allergic responses following dye exposure. The chemical is regarded as dangerous since it is acutely toxic, cytotoxic, genotoxic, hematotoxic, neurotoxic, and carcinogenic and mutagenic [36]. The CR is included in the list of prohibited azodyes is because it can cleave one or more azo groups to produce carcinogenic amines like benzidine [37]. The presence of aminobiphenyl groups and azo linkages, two characteristics typically regarded as xenobiotics [38], has been implicated in the recalcitrance of CR

 ISSN 2410-2598

Table (1): Congo red's physical-chemical properties . (39)

Name	Characteristic
Chemical structure	
Molecular formula	C32H22N6Na2O6S2
Molecular weight	696.66 g mol-1
Physical form	brounish-red powder
Solubility	ethnol is soluble in water; acetone is just very slightly soluble; ether and xylene are essentially insoluble.
Dye Class	Azo
Melting point	> 360oC
pH range	3.0-5.0
Colour Blue	(pH 3.0) to red (pH 5.0
Absorption wavelength (λmax)	498 nm; 488 nm

Use of Microalgae in Bioremoval

The microalgae are microscopic unicellular or multicellular photosynthetic organisms. Due to their prevalence in various habitats and interactions with a number of biotic and abiotic variables, they face varied nutritional environments [40].

Algae are a diverse range of photosynthetic organisms that have tremendous bioremediation potential as well as industrial uses that can reduce the cost of energy and fuel usage. Algae are used for a variety of things, including fuel, medicine, and wastewater treatment [41].

According to their quality, algae are nonpathogenic, grow quickly, and can recover biomass for industrial output, including biofuel and cattle feed, for the treatment of a variety of wastes [42]Microalgae are the most effective alternative for cleaning up environmental pollutants because algae experience physiological and genetic changes in the presence of high concentrations of contaminants [43] Due to their ability to accumulate plant nutrients, heavy metals, pesticides, toxic organic and inorganic chemicals, and radioactive elements in their cells, algae have recently come to be recognized as essential organisms for the biological treatment of wastewater [44; 45].

Algae, a type of microorganism, have been tested as a biosorbent for the removal of color. Tests on various algae species for bio-decolorization of dyes have been conducted [46]. Malachite green dye removal tests on

Chlorella sp., Cosmorium sp., and Euglena sp. revealed removal efficiencies of 92%, 91%, and 87%, respectively [47].

The benefits of using algae in biotreatment may be quickly identified as being abundant, inexpensive to operate, producing little sludge, not requiring additional nourishment [48], straightforward and adaptable in use, and requiring little upkeep [49]. Agriculture waste can be cleaned up by growing algae biomass, which can be done using relatively simple and affordable methods [50; 51].figure(2)

Algae are capable of absorbing and eliminating organic contaminants through biosorption and/or metabolization [52, 53]. In addition to detoxifying and mineralizing the pollutants, they can employ a variety of organic contaminants, such as pesticides, as an energy source for growth [54].

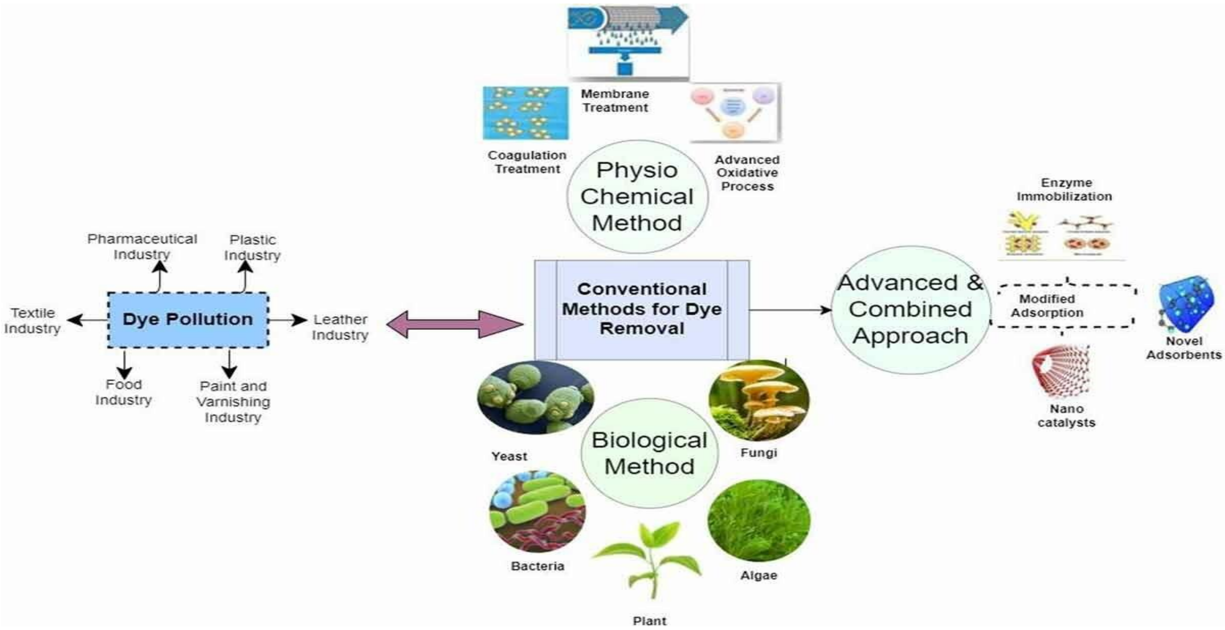


figure **2**: Biological methods for dye removal from environment [55].

Use of *Chlorella vulgaris* in Bioremoval.

Chlorella vulgaris is a photosynthetic microorganism and a eukaryotic member of the chlorellaceae family. It is a unicellular green microalgae and one of the important species because of its rapid growth and resistance to cultivation systems' manipulation technologies, as well as its production process's ease and low cost [56; 57].

C. vulgaris presents enormous potentials for creating future industrial bioenergy and bioremoval of diverse effluent quality due to its robustness, high oil content, mixotrophic culturing environment, rapid growth rate in various demanding settings, and tolerance to high amounts of heavy metals..[58; 59].

The photoautotrophic growth of *C. vulgaris* is typically constrained by carbon limitation, light attenuation, pH shift, nutritional depletion, and oxygen buildup from photosynthetic processes [60;61].

In autotrophic, heterotrophic, and mixotrophic environments, C. vulgaris can be cultivated. It makes use of energy from the sun or other external sources, nutrients (nitrogen and phosphorus) from wastewater, and carbon dioxide during autotrophic development to boost its algal density [62].

Mesopotamia Environmental Journal
Mesop. environ. j. 2025, Vol.8 No.2 :35-50.
ISSN 2410-2598

The reason *Chlorella vulgaris* was chosen above other species was because it is highly powerful, performs well in wastewater, and has the ability to eliminate contaminants. Additionally, it can withstand a variety of temperatures, nutrient concentrations, and making it versatile for wastewater remediation [63].

C. vulgaris can increase the effectiveness of nitrogen and total organic carbon removal as well as water reuse in urban wastewater [64].

Efficiency was something to build on, and the heavy metals and red color from the textile wastewater were removed [65]. *Chlorella vulgaris, Chlorella pyrenoidosa, and Oscillatoriatenuis* were able to biodegrade and decolorize over 30 azo compounds, converting azo dyes into less complicated aromatic amines. [66]

The ability of the species Chlorella, Ankistrodesmus, and Scenedesmus to biodegrade harmful organic pollutants is well recognized, and they have already been utilized successfully for the treatment of wastewaters .[67]

Decolorization and Degradation of AzoDyes by Algae .

Using an induced version of an azo reductase, algae can degrade azodyes, according to a review of the literature [68]. The three main methods by which algae lose color are chromophores adsorption on algal biomass, CO2 and H2O transformation of colored molecules, and CO2 and H2O conversion of colored molecules into non-colored ones. A few species of Chlorella and Oscillatoria may break down azo dyes into their aromatic amines, which can subsequently be broken down into simpler chemical compounds or CO2 [69]

Mohan *et al*. [70]claim that biosorption, followed by bioconversion and biocoagulation employing algae, are the main causes of the decolorization. It has been shown that more than 30 azo compounds are subject to biodegradation and decolorization by *Chlorella pyrenoidosa, Chlorella vulgaris, and Oscillateri atenuis*, resulting in the conversion of the azo dyes into less complex aromatic amines [71]. According to the aforementioned findings, algae may be crucial for eliminating azo dyes and aromatic amines from stabilizing ponds. In addition to being a viable alternative to more expensive materials, the biosorption approach may also be utilized to decolorize effluents in an economical and efficient manner[72; 73].

The two methods used by microorganisms for the bioremoval of azo dye are adsorption and/or biodegradation. Colors are absorbed by using the biomass of microbial cells, both living and dead. This technique keeps the dye's original structure intact. To the contrary, biodegradation happens when bacteria alter the dye's natural structure, occasionally mineralizing it into water and carbon dioxide [74].

Depending on the azo dyes' molecular structure and the kind of algae utilized, algae like Chlorella and Oscillatoria can remove them [75]A review of several investigations on the removal of dyes by algae is provided in Table 2..

Table (2) Different dyes are discolored by algae.

Strain	Species	Dye	Reference
Algae	*Spirogyra rhizopus*	Acid red 247	Ozer *et al*, 2006
	Cosmarium sp	Triphenylmethane dye & Malachite green	Daneshvar *et.al*,2007
	Chlorella vulgaris	tectilon yellow 2G	Acuner and Dilek.2004)
	Scenedesmus bijugatus	Tartrazine	Omar (2008)

ISSN 2410-2598

Bacterial azo dye decolorization and degradation

Numerous bacterial species frequently decolorize azo dyes when they are subjected to facultative anaerobic, conventional anaerobic, and aerobic conditions. Azo dyes are broken down by bacteria in anaerobic environments, and azo.bonds (-N=N-) are reductively cleaved by azoreductase enzymes. This process produces colorless solutions with potentially dangerous aromatic amines.[77; 78].

Following that, either aerobically or anaerobically, the resulting intermediate metabolites are further broken down [79]. Microbial biocatalysts are the focus of numerous recent investigations [80–81] that aim to extract dye from wastewater.

The bacterial decolorization and degradation of these dyes has garnered a lot of interest because it is economical, environmentally benign, and works with a variety of azo dyes while also producing less sludge. It might also speed up mineralization and biodegradation, there has been considerable interest in the bacterial decolorization and degradation of these dyes. [82]

The emission of textile and dye-house effluent, which may cause an abnormal coloring of the surface water, is the most pressing environmental issue with regard to water quality. This has an immediate effect on water wildlife and flora. The impact of azo dyes on human health as well as the occupational exposure of personnel in the dye production and use industries have received attention for many years. Apparently has drawn a lot of interest, especially from people who work in the dye-making and dye-consuming industries. In their pure forms, many azo dyes have been shown to exhibit direct mutagenic and carcinogenic characteristics [83]. Three methods by which azo dyes made by bacteria decay are as follows: (i) Azo dyes that only become toxic after the azo bond is reduced and broken down to produce aromatic amines, typically by intestine anaerobic bacteria. Because of metabolic oxidation, reactive electrophilic species formed from aromatic amines covalently bind DNA;

(ii) Metabolic oxidation for azo dyes with structures comprising free aromaticamine groups without azo reduction; and

(iii) Direct oxidation of the azo bond linkage to electrophilic diazonium dyes that are extremely reactive.
Since each pathway could be compound-specific, azo toxicity is likely brought on by a number of different mechanisms. It has been noted that the azo dyes' converted intermediates are extremely poisonous and mutagenic in nature [84]. Mechanisms of bioremoval of dyes by bacteria [85].

Factors affecting microbial decolorization

The ability of microorganisms to decolorize azo dyes is directly impacted by physico-chemical operational parameters in biological treatment processes, including temperature, pH, dye structure, dye concentration, carbon and nitrogen sources, oxygen concentration, electron donor, and redox mediator. Therefore, to improve the process's viability, speed, and efficiency, it's crucial to predict how each element would affect the decolorization of azo dyes [86].

1. Temperature

Bacteria are directly impacted by the temperature of their surroundings because microbial cells use metabolic or enzymatic processes to adapt to temperature fluctuations. Temperature must be considered in any microbial life-related activity, such as remediation of soil and water. The extremely complex bacterial consortia living in active sludge require restricted temperature ranges in order to decolorize azo dyes, according to several studies looking at the activation energy of microbial decolorization of azo dyes [87; 88]. Furthermore, temperature variations have been shown to abruptly alter the activation energy of microorganisms' physiology [89].Additionally, reports on the effects of temperature on response mechanism, biomass output, and growth rate have been published [90]. It was found that up to the optimal temperature, the rate of azo dye decolorization increases; beyond that, the decolorization activity somewhat declines. This decrease at higher temperatures can be explained by either lower cell viability or denaturation of an azo reductase enzyme [91;92].

2. pH

In decolorization, the pH the medium is another crucial component. For color removal, the pH range between 6.0 to 10.0 is usually the most successful. A dye's ability to be decolored is greatly influenced by pH[93]. The optimal pH causes color fading to happen more quickly, whereas strongly acidic or extremely alkaline pH tend to cause it to happen more slowly. It is suspected that pH affects the passage of dye molecules across cell membranes, the rate-limiting step in the decolorization process [94]. pH variations between 7.0 and 9.5 often don't affect the dye breakdown process much.[95]. The pH may increase when the azo link is physiologically removed because the metabolites of aromatic amines are more basic than the parent azo molecule. [96]. The dye degradation process is typically not significantly affected by pH changes between 7.0 and 9.5. Although Chang *et al* [97] discovered that the dye reduction rate became insensitive in the pH range of 7.0 to 9.5 [98], it increased roughly 2.5 times as the pH was raised from 5.0 to 7.0.
When using adsorptive treatment for colored wastewater, pH must be taken into account. The structural stability of CR and, consequently, the intensity of its color, are known to be influenced by pH, as well [99].

3. Dye Concentration

The inability of the dyes to obstruct the active sites of the enzyme azo reductase with molecules of different structures, their toxicity to specific bacteria, low biomass concentrations, or an incorrect cell-to-dye ratio are likely the reasons for the decreased decolorization rate when the dye concentration is gradually increased [100]. Additional investigation demonstrated that reactive group azo dyes containing sulfonic acid (SO3H) groups on their aromatic rings significantly limit microbial growth at greater dye concentrations. [101; 102].Reactive group azo dyes containing sulfonic acid (SO3H) groups on their aromatic rings were also discovered to significantly suppress microbial growth at greater dye concentrations. [103; 104]discovered that employing bacterial co-culture instead of pure culture lessened the effect of concentration increases, which could be connected to the two microorganisms' mutually beneficial interactions. The rate of decline was also unaffected by dye concentration [105].This outcome is consistent with a reduction mechanism that is not

ISSN 2410-2598

enzymatic and is governed by factors independent of dye concentration. A thorough kinetic study and the relationship between the equilibrium conversion and the substrate-dependent specific decolorization rate have been the focus of many investigations [106].

Conclusion

Azo dyes are now crucial in a variety of businesses, particularly as consumers' preferences are heavily influenced by color. However, as azo dye use has increased, a number of health and environmental issues have surfaced, some of which are brought on by azo dyes and their metabolites. Bioremediation should be utilized since contemporary civilizations strive for environmentally friendly solutions. Algae and bacteria are examples of microorganisms that have demonstrated versatility in both environmental application and the biomedical area. Through biosorption and/or metabolization, algae can absorb and eliminate organic contaminants.They can both detoxify and mineralize a variety of organic contaminants, including colors, while also using them as an energy source for growth. an infection

Author Contributions Statement

All authors was doing the laboratory work, collection and analysis of data, and writing and final editing .

Declaration of competing interest

The author confirms that there was no competing interest.

Acknowledgment

Authors was thank to department of biology ,college of science to all help and support .

References

[1]Zadeh M. Evaluation of oil removal efficiency and enzymatic activity in some fungal strains for bioremediation of petroleum-polluted soils. *Ira J of Enviro Heal Sci&Eng* 9:26-2012.

[2]Malik, P. India's Universal Service for telecom: Policy and Regulatory Gaps. Forthcoming in Connectivity: Beyond Technology, Samarjiva, R. and Zainudeen (eds.), *Sage Publication, India*. 2006.

[3]Chehregani, A., Noori, M. and Yazdi, L. H): Phytoremediation of heavy metal polluted soils: screening for new accumulator plants and evaluation of removal ability. *Ecotoxicol Environ Safety*. 72:1349–1353. 2009

[4]Vidyarthi, A.S. and Singh, J. (Enhancement of *Chlorella vulgaris* cell density: shake flask and bench-top photobioreactor studies to identify and control limiting factors. *Korean J of ChemEng*, 33 (8) : 2396-2405-2016.

[5]Allard, A. S. and Neilson, A. H. Bioremediation of organic wastes sites: a critical review of microbiological aspects. *Inter Biodeter and biodegrade.* 39: 253 – 285. 1997.

[6]Alexander M Biodegradation and Bioremediation. 2nd *ed*. San Diego, CA: Academic Press, 325–7. 1999.

[7]Chia MA, Lombardi AT and Melao MGG Growth and biochemical composition of *Chlorella vulgaris* in different growth media. Anais da Academia Brasileira de Ciências, 85(4): 1427-1438.DOI 10.1007/s11356-015-4277-12013

[8]Abo-State .M. A. M., Y. E. Saleh and H. A. Hazaa. Decolorization of Congo Red dye by bacterial isolates ,*J of Eco of Heal &Enviro An Inter* J Vol. 5, No. 2, 41-48.2017.

[9]Ranjan, R.; Siddhnath, and Bavitha, M.). Bioremediation - A potential tool for management of aquatic pollution. *International J of Multidisci Res and Develot,* 1 (7): 335-340. 2014

[10]Mittal, A., Thakur, V., Mittal, J., &Vardhan, H.. Process development for the removal of hazardous anionic azo dye Congo red from wastewater by using hen feather as potential dsorbent. *Desalination and Water Treatment, 52*(1-3), 227-237.Jain et al., 2011

[11]Raymond, J.; Rogers, T.; Shonnard, D. and Kline, A.A. Review of structure-based biodegradation estimation methods. *J of Hazar Materials,* 84: 189-215. . 2001)

[12]Hoff, R.Z. Bioremediation: an overview of its development and use for oil spill cleanup. *Marine Pollution Bulletin*, 26 (9): 476-481.1993..

[**13]Prasad, K.S.; Kumar, N.S. and Sharma, S.** Bioremediation: Developments, current practices and perspectives. *Gen Eng and Biotec J*, 1-20. 2010.

[14]Juwarkar, A.; Singh, S. and Mudhoo, AX A comprehensive overview of elements in bioremediation. *Reviews in Enviro Science and Biotec*, 9: 215-288.V

[15]Bhatnagar, S. and Kumari, R. Bioremediation: A Sustainable Tool for Environmental Management – A Review. *Annual Review and Rese in Bio*, 3 (4): 974-993. 2013.

[16]Sridevi, V., Lakshmi, M. C., Swamy, A. V. N., &Rao, M. N. Implementation of response surface methodology for phenol degradation using Pseudomonas putida (NCIM 2102). *J of Bioremed and Biodegrad, 2*(2). 2011.

[17]M'sakni,N.H. and Alsufyani ,TRemoval of Cationic Organic Dye from Aqueous Solution by Chemical and Pyrolysis Activated Ulva lactuca. Water 2021, 13, 1154. https://doi.org/10.3390/w13091154. 2021.

[18]Dos Santos, A. B., F. J. Cervantes, and J. B. van Lier, Review Paper on Current Technologies for Decolourisation of Textile Wastewaters: Perspectives for Anaer-obic Biotechnology, *Bioresour. Technol*, 98, 2369 . 2007

[19]Yaseen D.A., Scholz,M. Shallow pond systems planted with Lemna minor treating azo dyes. Ecological Engineering 94 (2016) 295–305. http://dx.doi.org/10.1016/j.ecoleng.2016.05.081-2016.

[**20]Pearce, C., Lloyd, J., Guthrie, J.,.** The removal of colour from textile wastewater using whole bacterial cells: a review. Dyes Pigm. 58, 179–196. 2003

[21]Vandevivere.P.,Bianchi.R.,Verstraete.W.J.,(The effects of reductant and carbon source on the microbial decolorization of azo dyes in an anaerobic sludge process .*Chem. Technol.Biotechnol*.,72:289-302. 1998.

[22]Bell, J., Plumb, JJ., Buckley, C A., Stuckey, D CTreatment and decolorization of dyes in an anaerobic baffled reactors. *J. Environ Eng*126: 1026-32. 2000.

[23]Puvaneswari, N., Muthukrishnan, J., and Gunasekaran, P. . Toxicity assessment and microbial degradation of azo dyes. *Indian J Exp Biol*.44, 618626. 2006

[24]Sponza .D. T, Isik. M, Toxicity and intermediates of C.I. Direct Red 28 dye through sequential anaerobic/aerobic treatment, *Process Biochem*. 40-2735–2744.v

[25]Verma R.K, Sankhla M.S., Rathod N.V., Sonone S.S., Parihar K., Singh G.K. . Eradication of Fatal Textile Industrial Dyes by Wastewater Treatment . Biointerface Research in Applied Chemistry , 12(1) : 567 - 587 https://doi.org/10.33263/BRIAC121.567587(2022)

[26]Golka. K, Kopps. S, Myslak. WZ, Carcinogenicity of azocolorants:influence of solubility and bioavailability. *Toxicol Lett* 15:203–210(2004)

[27]Annuar, M.S.M., Adnan, S., Vikineswary, S., Chisti, Y Kinetics and energetics of azo dye decolorization by Pycnoporussanguineus. *Water Air Soil Pollut*. 202,179–188. .(2009).

[28]**Bafana, A., Krishnamurthi, K., Devi, S., Chakrabarti, T.).** Biological decolouriza-tion of C. I. Direct Black 38 by E. gallinarum. J. *Hazard. Mater*. 157 (1), 187–193. 2008

[29] Nielsen B.V. , Maneein S., Anghan J.D. , Anghan R.M. , Al Farid Md.M. and Milledge J.J Biosorption Potential of Sargassum for Removal of Aqueous Dye Solutions. Appl. Sci. 2022, 12, 4173. https://doi.org/10.3390/app12094173. 2022.

[30]Saratale, R. G., Saratale, G. D., Chang, J. S., &Govindwar, S. PBacterial decolorization and degradation of azo dyes: a review. *Journal of the Taiwan Institute of ChemilEng*, *42*(1), 138-157. 2011.

[31]Kumar, R., Sankhla, M. S., Kumar, R., & Sonone, S. S.. Impact of Pesticide Toxicity in Aquatic Environment. *Biointerface Research in Applied Chemistry, 11*(3), 10131-10140., http://dx.doi.org/10.33263/BRIAC113.1013110140. 2021

[32]VimonsesVS, Lei B, Jin CWK, Chow C and Saint Kinetic study and equilibrium isotherm analysis of Congo Red adsorption by clay materials, *Chem. Eng*. J. 148:354–364. 2009.

[33]Purkait MK, Maiti A DasGupta S and De S Removal of congo red using activated carbon and its regeneration, *J. Hazard. Mater.* 145 :287–295.2007.

[34]Sabnis RW Handbook of Biological Dyesand Stains. Synthesis and Industrial Applications(John Wiley & Sons, New Jersey, Canada, Springer, 106-107). (2010)

[35]Pielesz .A, The process of the reduction of azo dyes used in dyeing textiles on the basis of infrared spectroscopy analysis, *J. Mol. Struct*. 511-512.337–44. 1999.

[36]Sanmuga Priya, E., Senthamil Selvan, P. Water hyacinth (*Eichhornia crassipes*) – An efficient and economic adsorbent for textile effluent treatment – A review. Arabian Journal of Chemistry 2014, ttp://dx.doi.org/10.1016/j.arabjc.2014.03.002

[37]Edwards, K. F.; Litchman, E. and Klausmeier, C. A. (Functional traits explain phytoplankton community structure and seasonal dynamics in a marine ecosystem. *Eco Letters*, 16(1): 56-63. 2013.

[38]Bansal ,A. ; Shinde, O. and Sarkar, S., Industrial Wastewater Treatment Using Phycoremediation Technologies and Co-Production of Value-Added Products. *J of Bioremed&Biodegrad*, 9(1) : 1-10(2018)

[39]Rawat, I.; Kumar, R.R.; Mutanda, T. and Bux, F. Dual role of microalgae: Phycoremediation of domestic wastewater and biomass production for sustainable biofuels production. *Applied Energy*, 88 (10): 3411–3424.2010.

[40] Fogg, G.E. Algal Adaptation to Stress — Some General Remarks. Algal Adaptation to Environmental Stresses, 1-19. 2001.

[41] Gonzalez, R.; Garcia-Balboa, C.; Rouco, M.; López-Rodas, V. and Costas, E. Adaptation of microalgae to lindane: a new approach for bioremediation. *Aquatic Toxico*, 109: 25-32. 2012.

[42] Kalesh, N.S. and Nair, S.M. The Accumulation Levels of Heavy Metals (Ni, Cr, Sr, & Ag) in Marine Algae from Southwest Coast of İndia. *Toxil and EnviroChemy*, 87 (2): 135-146-2005.

[43]lp, M.T.; Ozbay, O. and Sungur, M.A. Determination of Heavy Metal Levels in Sediment and Macroalgae (*Ulva* sp. and *Enteromorpha* sp.) on the Mersin Coast. *Ekoloji*, 21 (82): 47-55. 2012.

[44]Khataee AR, Dehghan G, Ebadi A, Zarei M, Pourhassan M. Biological treatment of a dye solution by macro algae *Chara* sp.: Effect of operational parameter intermediates, Identification and artificial neural network modelling. Bioresource Technology. 2009; 101(7):2252–58.

[45]Soeprobowati, T.R. and Hariyati, R Bioaccumulation of Pb, Cd, Cu, and Cr by Porphyridium cruentum (S.F. Gray)Nägeli. International Journal of Marine Science, 3 (27): 212-218.Solutions by Biogas Waste Slurry,*J. Chem. Tech. Biotechnol*., 53, 153-157. 2013.

[46]Chojnacka, K. Biosorption and Bioaccumulation in Practice. *Nova Science Publishers*, 149-2009.

[47]Emienour, M.M.; Phang, S.M. and Chu, W.L.. Use of an algal consortium of five algae in the treatment of landfill leachate using the high-rate algal pond system. *Jl of Appl Phyco,* 24 (4): 953-963-2012.

[48]Priyadarshani, I.; Sahu, D. and Rath, B.. Microalgal bioremediation: Current practices and perspectives. *J of BiochemTechn,* 3 (3): 299-304. 2011.

[49]Ghasemi, Y.; Rasoul-Amini, S. and Fotooh-Abadi, E. Review: The Biotransformation, Biodegradation, and Bioremediation of Organic Compounds by Microalgae. *J of Phycoy,* 47: 969–980**.** 2011.

[50]Salman J.M. ,Omran A. R., Baiee M. A., Juda S. A. Removal of Congo red dye from aqueous solution using a new adsorbent surface developed from aquatic plant ,Inter *J of ChemTech Res*. 9(4) : 334-342, 2016.

[51]Gayathiri E., Prakash P., Selvam K., Awasthi M.K., Gobinath R., Karri R.R., Ragunathan M.G., Jayanthi J., Mani V., Poudineh M.A., Chang S.W.& Ravindran B. Plant microbe based remediation approaches in dye removal: A review, Bioengineered, 13:3, 7798-7828. DOI: 10.1080/21655979.2022.2049100-2022.

[52]Ortiz, M. E.Y.; Casazza, A.A.; Aliakbarian, B.; Perego, P.; Converti, A. and Carvalho, J.C.M. Production of *Chlorella vulgaris* as a source of essential fatty acids in a tubular photobioreactor continuously fed with air enriched with CO2 at different concentrations. *BiotechnolProg.*, 30(4): 916-922-2014.

[53] Kabir, M.; Hoseini, S. A.; Ghorbani, R. and Kashiri, H. Performance of microalgae *Chlorella vulgaris* and *Scenedesmusobliquus*in wastewater treatment of Gomishan (Golestan-Iran) shrimp farms. *AACL Bioflux,* 10(3):622-632-2017.

[54] Ge. Z, Zhang. H, Zhang.Y,Yan, C. and Zhao, Y. (2013)Purifying synthetic high-strength wastewater by microalgae *chlorella vulgaris* under various light emitting diode wavelengths and intensities. *J of Enviro Health Science and Eng,* 11: 1-8.

[55] Znad, H., Al Ketife, A. M., Judd, S., AlMomani, F., &Vuthaluru, H. B.. Bioremediation and nutrient removal from wastewater by *Chlorella vulgaris. Ecoloeng, 110,* 1-7(2018).

[**56]Vidyarthi, A.S. and Singh, J.** Enhancement of *Chlorella vulgaris* cell density: shake flask and bench-top photobioreactor studies to identify and control limiting factors. *Korean J of ChemEng,* 33 (8) : 2396-2405. (2016)

[57]Chalivendra, S. Bioremediation of Wastewater using Microalgae. Ph.D thesis, University of Dayton, pp, 188. **.** 2014.

[58]Patino, R. ; Janssen, M. and Stockar, U.V. A study of the growth for the microalga *Chlorella vulgaris* by photo-bio-calorimetry and other on-line and off-line techniques. *Biotechnology and Bioengineering*, 96 (4): 757-767. 2007.

[59]Yaseen DA, Scholz M. Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review. Int J Environ Sci Technol (Tehran). 2019;16(2):1193–1226.

[60]Ghazal, F. M. ; Mahdy, E. M. ; Abd EL- Fattah, M. S. ; EL-Sadany, A. Y. and Doha, N.M. E. The Use of Microalgae in Bioremediation of the Textile Wastewater Effluent. *Nature and Science,* 16(3): 98-104-2018.

[61]Zhang, Z. B,Liu, C. Y, Wu, Z. Z, Xing, L. and Li, P.F Detection of nitric oxide in culture media and studies on nitric oxide formation by marine microalgae. *Med. Sci. Monit*., 12 (2): 75-85**.** 2006.

[62]Rauf MA and Salman A. S. Survey of recent trends in biochemically assisted degradation of dyes. Chem Eng J. 2021; 209:520–530.

[63]Abou-ElSouod, G.W. and El-Sheekh , M.M Biodegradation of basic fuchsin and methyl red by the blue green algae *Hydrocoleum oligotrichum* and *Oscillatoria limnetica*. *Environ. Engin. Manage. J.* 15(2), 279-286. **.** 2016.

[64]Mohan SV, Rao CN, Prasad KK and Karthikeyan J (Treatment of Simulated Reactive Yellow 22 (azo) Dye Effluents Using Spirogyra Species ,V*Waste Manage*.,22, 575 . 2002).

[65]Yan, H. and G. Pan, Increase in Biodegradation of Dimethyl Phthalate by*Closteriumlunula* Using Inorganic Carbon, *Chemosphere*, 55, 1281-2004.

[66]Jahir Khan M, Rai A, Ahirwar A, et al. Diatom microalgae as smart nanocontainers for biosensing wastewater pollutants: recent trends and innovations. Bioengineered. 2021;12(2):9531–9549.

[67]Fazal, T. *et al.* Bioremediation of textile wastewater and successive biodiesel production using microalgae. *Renew. Sustain. Energy Rev.* 82, 3107–3126 -2018.

[68]El-Sheekh MM, Gharieb MM, Abou-El-Souod GW. Biodegradation of dyes by some green algae and cyanobacteria. *Int Biodeterior Biodegrad* 63:699–704-2009.

[69]El-Naggar, N. E. A., Rabei, N. H. & El-Malkey, S. E Eco-friendly approach for biosorption of Pb2+ and carcinogenic Congo red dye from binary solution onto sustainable *Ulva lactuca* biomass. *Sci. Rep.* 10(1), 1–22 -2020.

[70]El-Naggar, N. E. A. & Rabei, N. H. Bioprocessing optimization for efficient simultaneous removal of methylene blue and nickel by *Gracilaria* seaweed biomass. *Sci. Rep.* 10(1), 1–21 -2020.

[71]Abou-El-Souod, G., Hamouda, R. A. & El-Sheekh, M. Influence of heavy metal as cocontamination on biodegradation of dyes by free and immobilized *Scenedesmus obliquus*. *Desalin. Water Treat.* 182, 351–358 2020.

[72]Maniyam, M. N., Ibrahim, A. L. & Cass, A. E Decolorization and biodegradation of azo dye methyl red by *Rhodococcus* strain UCC 0016. *Environ. Technol.* 41(1), 71–85. 2020 .

[73]Chen, K. C., J. Y. Wu, D. J. Liou, and S. C. J. Hwang,. Decolorization of the Textile Dyes by Newly Isolated Bacterial Strains, *J. Biotechnol.*, 101, 57 2003 .

[74]An, Y., L. Jiang, J. Cao, C. Geng, and L. Zhong Sudan I Induces 4 Genotoxic Effects and Oxidative DNA Damage in HepG2 Cells,*' Mutat. Res*., 627, 164 . , 2007

[75]Milledge, J.J.; Thompson, E.P.; Sauvêtre, A.; Schroeder, P.; Harvey, P.J.)Novel developments in biological technologies for wastewater processing. In Sustainable Water and Wastewater Processing; Galanakis, C.M., Agrafioti, E., Eds.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 239–278.

[**76]Theng, M.L.; Tan, L.S.; Siaw,W.C.** Adsorption of Methylene Blue and Congo Red Dye fromWater onto Cassava Leaf Powder.Prog. Energy Environ. 2020, 12, 11–21.

[77]Kloareg, B.; Badis, Y.; Cock, J.M.; Michel, G. Role and Evolution of the Extracellular Matrix in the Acquisition of Complex Multicellularity in Eukaryotes: A Macroalgal Perspective. Genes 2021, 12, 1059.

[78]Saratale, R. G., Saratale, G. D., Chang, J. S., &Govindwar, S. P Bacterial decolorization and degradation of azo dyes: a review. *J.of the Taiwan Instit of Chem Eng*, *42*(1), 138-157**.** 2011..

[79]Arumugam, N.; Chelliapan, S.; Kamyab, H.; Thirugnana, S.; Othman, N.; Nasri, N. Treatment of Wastewater Using Seaweed: A Review. Int. J. Environ. Res. Public Health 2018, 15, 2851.

[80]Dos Santos, A. B., F. J. Cervantes, and J. B. van Lier. Review Paper on Current Technologies for Decolourisation of Textile Wastewaters: Perspectives for Anaer-obic Biotechnology, *Bioresour. Technol*, 98, 2369**,** 2007 .

[81]Dutta, S.; Gupta, B.; Srivastava, S.K.; Gupta, A.K. Recent advances on the removal of dyes from wastewater using various adsorbents: A critical review. Mater. Adv. 2021, 2, 4497–4531

[82]Saratale, R. G., Saratale, G. D., Chang, J. S., &Govindwar, S. P Ecofriendly degradation of sulfonateddiazo dye CI Reactive Green 19A using Micrococcus glutamicus NCIM-2168. *Bioresource technology*, *100*(17), 3897-3905. **.** 2009c.

[83] Kilic, N. K., J. L. Nielsen, M. Yuce, andG. Donmez Characterization of a Simple Bacterial Consortium for Effective Treatment of Wastewaters with Reactive Dyes and Cr(VI), *Chemosphere*, 67, 826**,** 2007 .

[84]Chandanshive VV, Rane NR, Tamboli AS, et al. Govindwar SP Co-plantation of aquatic macrophytes *Typha angustifolia* and *Paspalum scrobiculatum* for effective treatment of textile industry effluent. J Hazard Mater. 2017;338:47–56.

[85]Sarkar S, Banerjee A, Halder U, Biswas R,Bandopadhyay R Degradation ofsynthetic azo dyes of textile industry: asustainable approach using microbial enzymes.Water Conserv Sci Eng 2(4):121–131 2017.

[**86]Jadhav, S. U., M. U. Jadhav, A. N. Kagalkar, and S. P**. Govindwar,.Decolorization of Brilliant Blue G Dye Mediated by Degradation of the Microbial Consortium of GalactomycesgeotrichumandBacillu ssp., *J. Chin. Inst. Chem. Engrs.,* 39, 563. 2008

[87]Mall, I. D., Srivastava, V. C., Agarwal, N. K., & Mishra, I. M. Removal of congo red from aqueous solution by bagasse fly ash and activated carbon: kinetic study and equilibrium isotherm analyses. *Chemosphere* 2005., *61*(4), 492-501.

[88] Garg SK, Tripathi M Microbialstrategies for discoloration and detoxificationof azo dyes from textile effluents. Res JMicrobiol 2017 12:1–19

[89] Sghaier I, Guembri M, Chouchane H .Recent advances in textile wastewatertreatment using microbial consortia. J TextEng Fashion Technol 2019 5(3):134–146

[90] Akansha K, Chakraborty D, Sachan SG Decolorization and degradation of methylorange by *Bacillus stratosphericus* SCA1007.Biocatal Agric Biotechno 2019 l 18:101044 .

[91] Sandesh K, Kumar G, Chidananda B, Ujwal P Optimization of Direct Blue-14 dyedegradation by *Bacillus fermus* (Kx898362)an alkaliphilic plant endophyte andassessment of degraded metabolite toxicity. JHazard Mater 2019 364:742–751

[92] Bankole PO, Adekunle AA, Obidi OF,Chandanshive VV, Govindwar SP Biodegradation and detoxification of ScarletRR dye by a newly isolated filamentousfungus, *Peyronellaea prosopidis.* SustainEnviron Res (2018)28(5):214–222

[93] Shang N, Ding M, Dai M, Si H, Li S, Zhao GBiodegradation of malachite green byan endophytic bacterium *Klebsiella aerogenes*S27 involving a novel oxidoreductase. ApplMicrobiol Biotechnol 2019 103(5):2141–2153.

[94] Riva V, Mapelli F, Syranidou E, Crotti E,Choukrallah R, Kalogerakis N, Borin S Root bacteria recruited by *Phragmitesaustralis* in constructed wetlands have thepotential to enhance azo-dye phytodepuration.Microorganisms 2019 7(10):384

[95] Masarbo RS, Niranjana S, Monisha T, NayakAS, Karegoudar T .Efficientdecolorization and detoxification ofsulphonated azo dye Ponceau 4R by usingsingle and mixed bacterial consortia. BiocatalBiotransform 37(5):367–376 2019

[06] Athab ZH, Halbus AF, Abbas, AS, Salman J M ,Lafta ,AJ. Enhanced Macroporous Cationic Chitosan Hydrogel by Freezing and Thawing Method with Super adsorption Capacity for Anionic Dyes. J Polym Environ ,2022. https://doi.org/10.1007/s10924-022-02462-w

[97] Ngo A.C.R. and Tischler D Microbial Degradation of Azo Dyes: Approaches and Prospects for a Hazard-Free Conversion by Microorganisms. Int. J. Environ. Res. Public Health 2022, 19, 4740. https://doi.org/10.3390/ijerph19084740

[98]. Singh, P.K.; Singh, R.L. Bio-removal of azo dyes: A review. Int. J. Appl. Sci. Biotechnol. 2017, 5, 108–126.

[99] Ali, M.Y.; Hassan, G.M.; Hassan, A.M.S.; Mohamed, Z.A.; Ramadan, M.F. In vivo genotoxicity assessment of sunset yellow and sodium benzoate in female rats. Drug Chem. Toxicol. 2020, 43, 504–513.

[100]. Das, S.; Singh, S.; Garg, S. Agri-residual waste, wheat bran as a biosorbent for mitigation of dye pollution in industrial wastewaters. J. Basic Microbiology 2022, 62, 465–479.

[101]. Akansha, K.; Chakraborty, D.; Sachan, S.G. Decolorization and degradation of methyl orange by Bacillus stratosphericus SCA1007. Biocatal. Agric. Biotechnol. 2019, 18, 101044.

[102]. Barathi, S.; Aruljothi, K.N.; Karthik, C.; Padikasan, I.A. Optimization for enhanced ecofriendly decolorization and detoxification of Reactive Blue160 textile dye by Bacillus subtilis. Biotechnol. Rep. 2020, 28, e00522.

[103]. Yang, C.; Luo, H.; Cheng, W.; Jiang, K.; Lu, L.; Ling, L. Decolorization characteristics and mechanism of methyl orange dye by using Stenotrophomonas acidaminiphila EFS1. Int. J. Environ. Sci. Technol. 2022, 1–10.

[104]. Kyzas, G.Z.; Fu, J.; Matis, K.A. The change from past to future for adsorbent materials in treatment of dyeing wastewaters. Materials 2013, 6, 5131–5158.

.

[105]. Jeon, S.J.; Lim, S.J. Purification and characterization of the laccase involved in dye decolorization by the white-rot fungus Marasmius scorodonius. J. Microbiol. Biotechnol. 2017, 27, 1120–1127.

[106]Suzuki, H. Remarkable diversification of bacterial azoreductases: Primary sequences, structures, substrates, physiological roles, and biotechnological applications. Appl. Microbiol. Biotechnol. 2019, 103, 3965–3978.