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# A REVIEW OF SECONDARY CLARIFIERS AND FILTRATIONS TECHNIQUES USED IN CYANOBACTERIA- MICRO ALGAE

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**Abstract:** In this paper, we propose a new bioremediation approach that extensively uses algae's beneficial properties. Green infrastructure is eco-friendlier and more sustainable than older wastewater treatment methods that use various microorganisms. Using microorganisms like algae and cyanobacteria, bioremediation technology is a novel and promising approach to effectively removing a wide range of organic pollutants. The extensive presence of organic contaminants in aquatic habitats poses a potential threat to a variety of marine creatures. Organic pollutants pose a worldwide threat to aquatic ecosystems because they are dispersed widely as a consequence of human activities such as farming, industry, and waste disposal. It is illegal to dump raw sewage into waterways without first treating it. Algae-based wastewater treatment systems are gaining popularity since they are efficient, safe, and create no harmful byproducts. The amount of organic contaminants that different species of algae and cyanobacteria absorb and retain in their tissues may be affected by the physicochemical properties of the wastewater in which they are cultured. Phytoremediation has a favorable impact on the environment and may save money when compared to traditional treatments for organic pollutant degradation. The phytoremediation-recovered algal biomass may have far-reaching effects on the bioenergy supply chain. This article explores the literature on the degradation of organic contaminants by microalgae and cyanobacteria.

***Keywords:algae;bioremediation;phytoremediation;azodyes;herbicides;pesticides***

## 1. INTRODUCTION

Water pollution has emerged as a significant environmental issue on a worldwide scale as a consequence of the growing urbanization and industrialization of the surrounding areas [1]. Because of their toxicity, tendency for bioaccumulation, persistence, and long-range atmospheric transport and deposit, organic pollutants that come from home and agricultural sewage (raw or processed), urban runoff, and industrial waste have the potential to damage water systems [2]. It is possible for these pollutants to get bioaccumulated and immobilized in sediments [3], and it is also possible for aquatic systems to convert and activate some of them.

A novel approach to the bioremediation of distillery wastewaters is provided by microalgae and cyanobacteria, both of which are capable of surviving on either nitrogen or carbon. It is necessary to first dilute the vividly colored effluents before they can be treated [4]. This is because the photochemical character of these reactions cannot be ignored. Within the scope of this investigation, we investigate the most current methods concerning the treatment of distillery effluent for the elimination of aromatic pollutants and other substances of a similar nature. In order to breakdown melanidins and phenolics like lignin, which are the primary sources of color in slops, it is essential to have the capacity to get rid of them. There is also some data that demonstrates the breakdown of phenol and melanoidin by the action of enzymes. It is widely accepted that the production of microalgae on a large scale has the potential to enhance wastewater treatment technology in a number of different ways. The most significant challenges to commercial manufacturing and the achievement of technoeconomic viability have been conquered by research in genetic engineering. Creating microalgal-based solutions that are relevant to a broad range of situations may be accomplished via the application of biorefinery approaches that mix biology, ecology, and engineering [5].

## 2. ORGANICPOLLUTANTS

### 2.1. *ORGANICHYDROCARBONS*

Polycyclic aromatic hydrocarbons, polychlorinated biphenyls, di-(2-ethylhexyl) phthalate, surfactants, and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) are the most frequent types of organic hydrocarbon pollutants. These hydrophobic compounds are attached to sediments, which allows them to remain in water systems for extended periods of time. Hydrocarbon contamination in aquatic environments is mostly attributable to petroleum products [6]. These pollutants often enter marine ecosystems by rivers, coastal waterways, industrial runoff, and atmospheric deposition [7]. These compounds degrade slowly, with the pace decreasing considerably with increasing molecular weight and the number of aromatic rings [5, 9]. They are also resistant to hydrolysis in aerobic aquatic circumstances. With their carcinogenic properties and long half-lives in the environment, PAHs constitute a major danger to both human health and the ecosystem [4]. The use of personal care products has been related to adverse impacts on human health in addition to the endocrine, developmental, and epigenetic systems of aquatic creatures [5]. Between 2 and 88 parts per billion, phenol is a carcinogenic organic pollutant. Specifically, waste from the petroleum refining industry contains it. Between 5 and 25 parts per trillion, it becomes toxic to marine life. It has been shown that traditional methods of removing phenol compounds from water systems are ineffective. Yet, the excellent eradication efficacy of the organisms utilised suggests that biological approaches have potential [4, 3].

**Natural Dyes**

Adsorption and ultrafiltration are not effective methods for removing organic colors from water since they cannot be decomposed by chemical or electrochemical processes. As a result, organic dyes are a major source of water pollution [2,1]. These poisons are harmful to aquatic photosynthesis as well [1]. The three most popular forms of dyes are anthraquinone, azo, and phthalo-cyanine, which are distinguished by the chromophore groups they use [16]. There are two types of cationic basic dyes, those that are insoluble in ionic solutions and those that are soluble in aqueous (anionic-direct, acidic, or reactive) solutions [1]. Because to its cheap cost and ease of application, adsorption has become the decolonization technique of choice [17]. Adsorption is a cheap and simple method of decolonization.

While there are several thousand distinct azo dyes and a few hundred distinct anthraquinone dyes, they all belong to the same widely-used family [18]. They are used in several production processes, including those involving textiles, plastics, and pharmaceuticals. Several colored effluents are blamed for unfavorable results even when present in minute quantities. The widespread deposition of these dyes contributes to eutrophication and reduces the ability of ecosystems to reoxygenate. A serious issue is the production of toxic amines during the breakdown of azo dyes. Most aquatic organisms cannot survive its toxicity [17].

### 2.2. ORGANOMETALLICCOMPOUNDS

Eventually, a great number of organometallic compounds that are used in industry will make their way into rivers. “Despite the fact that very little is known about the toxicity of organometallic compounds, they are the most lethal poisons that are now accessible [19,20]. There has been a correlation established between exposure to organotin compounds (OTCs) in the workplace and an elevated risk of cancer as well as other disorders. In spite of the fact that they are not very hazardous, they are often used as antifouling agents in aquatic systems. This practice significantly contributes to pollution and puts a broad variety of ecosystems in jeopardy [21]. Both the manufacture of polyurethane foam and silicone foam are dependent on the use of organometallic compounds as catalysts [22]. Currently, tributyltin is the most extensively used poison that can be purchased without a prescription [21]. It is toxic to aquatic creatures”.

### 2.3. PesticidesandHerbicides

There is presently an urgent issue of water pollution caused by pesticides in many developed countries. There are a wide variety of insecticides and herbicides to choose from [23]. Some of the most common pesticides used in agriculture include those that kill insects, rodents, fungus, herbivores, parasitic nematodes, and weeds (vertebrate poisons). Despite pesticides' extensive usage, there are serious concerns about their toxicity, mobility, bioaccumulation, and durability [24]. They are harmful to ecosystems and pose a health risk to humans when found in water [25].

**Decomposition through macroalgae**

The biological treatment of wastewater is referred to as phycoremediation, and algae are responsible for a significant portion of this process. A wide variety of substances, including radioactive elements, toxic chemical compounds, and inorganic compounds, may be absorbed by algae. Because of this, they are very important to the processes that ensure the safety of drinking water, industrial water, and agricultural water for usage. “The production of algae accounts for a significant portion of the biomass that is found in aquatic ecosystems [26]. Furthermore, several species of algae have developed specific techniques for cleaning contaminated water, including biosorption, bioaccumulation, biotransformation, biomineralization, in situ and/or ex situ biodegradation approaches. There are a number of different physical processes that are included in biosorption. These include sorption, adsorption, surface complexation, ion exchange, and precipitation. The last point to make is that this method of pollution prevention requires a minimal amount of resources and has a limited number of potential adverse impacts on the environment [27]. The elimination of phenolic chemicals and pesticides by biosorption may also include the elimination of chemical colors that are used in textiles. The process of biodegradation has been seen to occur in algae both extracellularly (outside the cell) and intracellularly (inside the cell) [28]. On the other hand, the process often begins outside of the cell, and the further breakdown of the breakdown products takes place within the cell. Depending on the conditions, biodegradation may take place in either anaerobic or aerobic environments after a series of biosorption-related events have taken place in the cell wall. A high level of performance at a reasonable cost, together with exceptional sensitivity and effectiveness. Using biosorbents, which may be either natural materials such as seaweed or weeds or industrial waste such as activated sludge or fermentation waste, is the most efficient approach for the automated removal of biological sludge [29]. Biosorbents can be extracted from a variety of types of materials. There is a significant danger to human health posed by biomass sludge because of the chemicals that it has accumulated. An in-depth investigation on the effectiveness of biosorption in the removal of organic pollutants including pesticides and phenols was carried out by Aksu as part of his research. Getting rid of hazardous and deadly contaminants in the environment may be expensive, but it is definitely something that should be done.

We come to the conclusion that biosorption is not harmful to the environment since it has the capacity to breakdown potentially dangerous chemicals such as azo dyes. Through the release of specialized enzymes such as azo-dye reductase, algae and cyanobacteria are able to facilitate the breakdown of pollutants and the conversion of colors into simple molecules that are not harmful, such as NH2 and CO2. There is a lot of controversy around the question of whether or not phycoremediation can be used to efficiently reduce the amount of nutrients that are present in eutrophic lakes. On the other hand, Razak and Sharip [30] investigated therapies that were based on algae for the treatment of lake eutrophication. Based on the results, wastewater need to be the primary focus of study in the field of phycoremediation. The removal of excess fertilizer, pollutants, and heavy metals from lakes via the use of microalgae has the potential to considerably improve the quality of the water supplied by lakes. The prospects of phycoremediation in lake habitats have not been investigated nearly enough by scientists. Consequently, due to the fact that eutrophication is associated with algae, it is essential to analyze the ecological and physiological properties of the organism. Phycoremediation has to be evaluated in real-world settings, such as lakes and ponds, in order to determine its effectiveness. Because of their capacity to digest toxins via metabolic pathways, organisms such as bacteria, fungi, and algae are used in the process of bioremediation. These are only a few examples of the sorts of organisms that are utilized. Despite the fact that algae may be found in every body of water owing to the enrichment of nutrients, they are a frequent source of annoyance. Microbes that are endemic to the area are quite efficient.

Phycoremediation is a strategy that poses a minimal hazard [36] due to the fact that algae are able to convert sunlight into biomass via the process of digesting nutrients such as phosphorus and nitrogen. The process of biodegradation, which refers to the transformation of organic pollutants into chemicals that are less hazardous, may be accelerated with the assistance of algae, whether they are alive or dead [37]. Recent years have seen a significant increase in the amount of attention that has been paid to research concerning phycoremediation of organic contaminants in aquatic environments [38,39].

Certain species of cyanobacteria stand out for their significant capacity to remove organic pollutants from aquatic environments. This is mostly attributable to the fact that they have a high level of photosynthetic activity, which leads to the creation of vast biomasses. These biomasses include a large number of bioactive chemicals that have the potential to be put to great use in applications that are low-cost [38,39].

Cyanobacteria, in contrast to eukaryotic microalgae, have the ability to quickly reproduce even when the environment is quite strict. Because of the significant amount of polyunsaturated fatty acids that it contains, algal biomass has the potential to be used in a broad range of different ways [40]. This encompasses biodiesel, biogas, and bioethanol, among other things, but is not restricted to these. There are a variety of parameters that influence the rate at which pollutants are taken up and biodegraded. These factors include concentration, molecular weight, algal biomass, species, metabolic activity of algae, growth phase, and environmental variables [1]. The genus Phormidium, which belongs to the Cyanophyta, and the genus Oscillatoria, which includes Oscillatoria limosa, Oscillatoria tenuis, and Nitzschia, which belong to the Bacillariophyta, are some examples of phyla that are characteristic of these groups [41].

It is possible that PAHs and other organic contaminants might be eliminated by algae via one of three different processes. It is via electrostatic repulsion that PAHs first form a compound with the active groups that are present in the algal cell wall. When specific circumstances are fulfilled, there is a possibility that toxins may bioaccumulate in living creatures. For example, hydroxyl, carboxylate, sulfate, phosphate, and amino are all examples of chemical groups that algae have the potential to bioabsorb and accumulate [42].

This is in contrast to the fact that all of the chemical processes that are involved in biosorption take occur at the surface. Examples of this include surface complexation, microprecipitation, and ion exchange with active groups that are located on the surface of the algal cell. An example of this would be the use of redox enzymes in an oxidation-reduction process [44], which would result in the transformation of organic contaminants into carbon dioxide and water. The proteins that bacteria utilize to digest a wide range of chemicals that would otherwise be too much for them to handle and perhaps kill them are called enzymes [45]. The fact that these enzymes are involved in both phase I and phase II activities contributes to the significant complexity of these enzymes. The hydrophilicity of pollutants may be improved by the processes of oxidation, reduction, or hydrolysis by enzymes such as monooxygenases, dioxygenases, hydroxylases, carboxylases, and decarboxylases. Through the process of catalyzing the conjugation of glutathione and glutathione-S-transferases to a wide variety of compounds that possess electrophilic sites, phase II enzymes are able to shield cells from the damaging effects of oxidative stress [47]. Extracellular enzymes known as laccase glycoproteins are of significant assistance to the process of microalgal biodegradation of a wide variety of organic contaminants [48]. In the second hypothesis, the process of algal biodegradation within the framework of an alliance is described. This method is often considered to be a highly promising approach for the removal of a variety of toxins [49]. In order to complete this process, there are two stages: It has been shown that the cells of algae are capable of secreting organic substances like as proteins and extracellular polysaccharides, which have the potential to attach themselves to pollutants in water via a process known as biosorption. The efficiency of this passive method is dependent on a number of factors, including the biosorbents that are used, the environment in which the algae are grown, and the metabolic activity of the algae [50]. In addition to the fact that they are able to bioaccumulate [51] the products of their metabolic activity, algae also perform an essential role in the food chain by eliminating organic contaminants. Among the numerous unexpected effects of pollution is the phenomenon known as eutrophication. Organic debris that has decomposed in water lowers the oxygen levels, which ultimately results in the death of aquatic creatures. One of the most common causes of eutrophication is an increase in the amount of nutrients (particularly NH4+, NO3-, and PO43-) that are present in secondary effluent waste. It has been shown that the presence of these compounds in water may be detrimental to aquatic ecosystems [52,53]. It is for this reason that it is of the utmost importance to process sewage before releasing it into rivers and streams. There are a wide variety of different unit processes that can be used to treat wastewater. Some of these processes include activated sludge, which is used to remove nitrogen and phosphorous; electro flocculation; membrane filtration; electrokinetic coagulation; electrochemical destruction; ion exchange; CatOx treatment (catalytic oxidation); and disinfection (through ozonation, chlorine, or ultraviolet light) [53].

What sets algae apart from other organisms is their capacity to convert organic pollutants into metabolites and moistures that are less harmful to the environment. The catabolic genes that are present in some species are responsible for the degradation of pollutants [54]. The production of biosurfactants by algae may be of tremendous assistance to the process of biodegradation in places that are contaminated with hydrocarbons [51]. Some of the components that are used to make these biosurfactants include glycolipids, neutral lipids, phospholipids, and neutral lipids. Fatty acids are also included in this category. The effectiveness of hydrocarbon bioremediation is improved by these amphiphilic biosurfactants [55,56]. This is because they make hydrophobic pollutants more soluble in water." Algae's capability to biodegrade polycyclic aromatic hydrocarbons (PCBs) is influenced by a number of parameters, including the concentration and hydrophobicity of PCBs, the physiological capacity of algae, the algal biomass, and the membrane permeability [57].

### 2.4. BioremediationofOrganicPollutantsbyMicroalgae

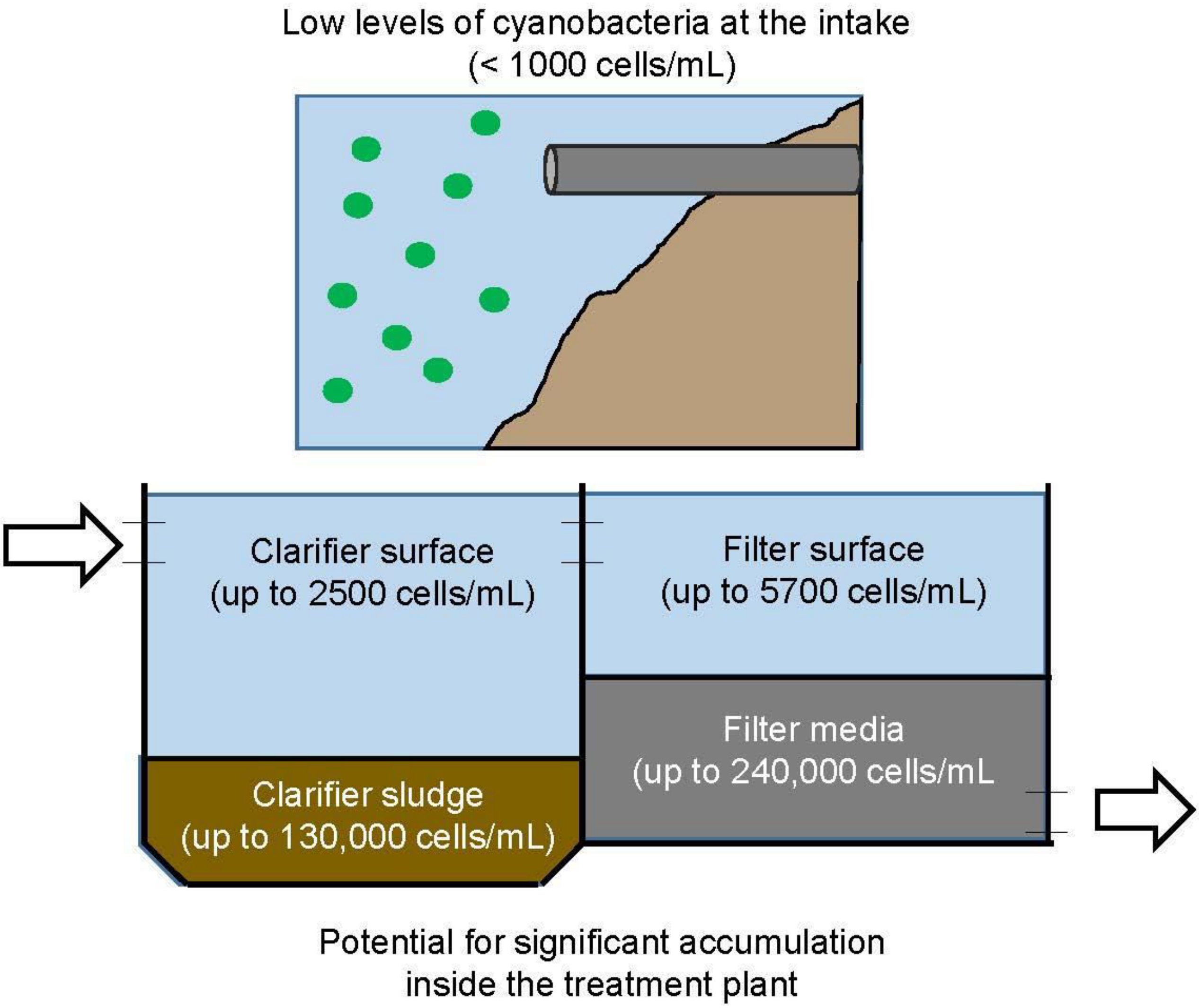
For the reason that microalgae have a high surface area in relation to their volume, rapid metabolism, low cost, and widespread availability, phytoremediation with these organisms is an effective method for ensuring environmental sustainability [58]. This is because microalgae have a high efficiency in degrading a wide range of environmental pollutants. Because of the presence of biological systems, microalgae have the ability to absorb and store these toxins, and the effects of these poisons might possibly be passed on from one organism to another. It is dependent on the lipid content of algae as well as the conditions in which they flourish that they are able to bioaccumulate [60]. As shown in Table 1, some of the taxa that have been suggested for the treatment of wastewater are Botryococcus, Chlamydomonas, Chlorella, Scenedesmus, Nitzschia, and Micractinium. Additionally, the oil that is collected from these plants has the potential to be used in the production of biodiesel [61,62].

***Table1 For an overview of microalgae's effectiveness in removing organic contaminants***

| Pollutants | AlgaeSpecies | OrganicPollutants | DegradationRate% | References |
|---|---|---|---|---|
| Dyes | *Chlorella*spp. | Pyrene | 8.71 | [63] |
| | *Chlorellavulgaris* | Azodye | >90 | [64] |
| | *Sc.Bijugatus* | Tartrazine | 7 | [65] |
| | *Volvoxaureus* | Basiccationic(4ppm) | 2 | 66] |
| Iydrocarbo | *Chlorella*spp. | Pyrene | 8.71 | [63] |
| | *Sc.Obliquus*-acterialconsortium | Oilwastes | 4.2 | 67] |
| 'henols | *ınkistrodesmusbrauni* andSc.*Quadricauda* | phenols | 0 | 68] |
| 'esticides | */annochlorisoculata* | Lindane(0.1mg/L) | 3 | 68] |
| | *'hlamydomonasreinhadtii* | soproturon(50µg/L) | .1 | 69] |

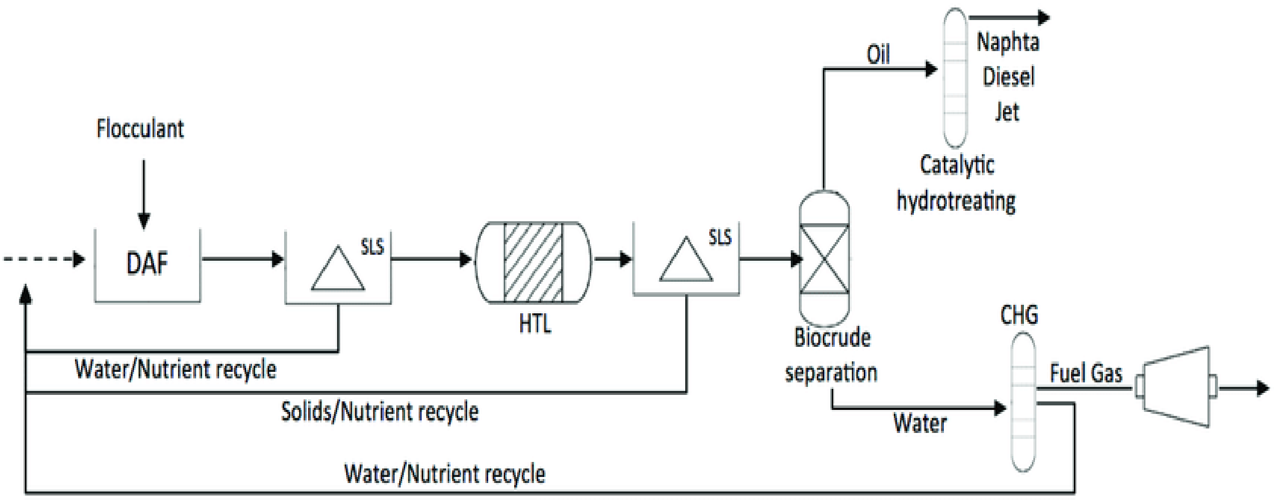
#### 2.4.1. Dyes

It has been shown that microalgae are capable of degrading a wide variety of colors into carbon and nitrogen sources in an effective manner. This enables the dyes to be removed from water, which in turn reduces the amount of eutrophication that occurs. However, this is reliant on the molecular geometry of the dye, the algal species, and the metabolism azo-reductase enzymes [65,70]. Numerous studies have shown that different microalgal species, such as Chlorella spp., Scenedesmus spp., and Aphanocapsa spp., are capable of biodegrading a wide range of colors. Biosorption, bioconversion, and biodegradation are the three processes that have been shown to be capable of eliminating dye from microalgae. Laccase glycoproteins were discovered to be present in a number of various phenols and synthetic colors [48]. There is a possibility that nitrogen-hungry algal cells are responsible for the degradation of these pigments, which might be the reason why eutrophication is reduced in aquatic settings [71]. It has been proven that a variety of Chlorella species are capable of metabolizing aromatic amines and degrading the azo link, which results in the transformation of azo dyes into either simple organic molecules or carbon dioxide [72]. It is possible that Chlorella vulgaris is capable of degrading more than ninety percent of azo dyes [64]. In the course of their biological research, Chlorella pyrenoidosa and Chlorella vulgaris were shown to be capable of biodegrading more than thirty azo compounds, therefore transforming them into aromatic amines or carbon dioxide that are less hazardous to human health (Figure 1). It is [73]. In the article [74], the effectiveness of Scenedesmus quadricauda in degrading Reactive Blue 19 and Remazol Brilliant Blue R (RBBR) in a range of aquatic habitats is addressed. Sc. ellipsoidea, Sc. kessleri, Sc. vulgaris, Sc. bijuga, Sc. bijugatus, and Sc. obliquus were the organisms that were responsible for the breakdown of tartrazine [60,75]. The removal of toxins from water and soil, as well as the sequestration of carbon dioxide from the atmosphere, are all examples of phytoremediation, which involves the use of plants such as microalgae and cyanobacteria [53,76]. The use of photoautotrophic bacteria is recommended since they do not contribute to the contamination of the environment [77]. Cyanobacteria, which are photoautotrophic microorganisms, have been used in a number of studies for the purpose of phycoremediation [36,78–80]. This is owing to the fact that they proliferate quickly, have the capacity to thrive in infertile environments, and have minimal requirements for both water and land. It is possible for blue-green algae to generate oxygen for the atmosphere because they are able to convert carbon dioxide into biomass. It is possible that these techniques will result in the production of beneficial byproducts such as biogas, biofuels, and a great deal of other things [50]. In addition, the enzymes that are released by algae and cyanobacteria have the potential to have the ability to convert contaminants into chemicals that are simple and harmless. In the article [74], the effectiveness of Scenedesmus quadricauda in degrading Reactive Blue 19 and Remazol Brilliant Blue R (RBBR) in a range of aquatic habitats is addressed. It is because of algae's adaptability and ability to photosynthesise that they have become well-known. They are essential to the maintenance of many ecosystems because they cycle nutrients and generate oxygen. Without them, many ecosystems would be unable to function properly. The biomass of microalgae is a popular kind of adsorbent. Regarding the process of biosorption, Scenedesmus quadricauda is a relatively novel species. They are able to thrive in circumstances where there is a scarcity of organic carbon because they get their energy from light rather than from carbon sources like bacteria and fungus. Because of this, it could be simpler to develop microalgal systems that have a high metabolic rate [74]. In recent times, immobilized algae have been used as a method to alleviate this problem. [65] The bacteria C. ellipsoidea, C. kessleri, C. vulgaris, Sc. bijuga, Sc. bijugatus, and Sc. obliquus are capable of degrading both mono- and di-azo tartrazine with equal efficiency.




2.4.2. **Organic Hydrocarbon**

The levels of organic pollutants in the water column are regulated by a number of different types of phytoplankton, which are essential regulators. "The potential to take in significant amounts of contaminants and maybe store certain chlorinated hydrocarbons is possessed by them [69]. According to research [51], it was shown that Nitzschia sp., as opposed to Skeletonemacostatum, was more effective in bioremediation of phenanthrene (PHE) and fluoranthene (FLA). Skeletonemacostatum was found to be less effective than Nitzschia sp. when it came to the bioremediation of phenanthrene (PHE) and fluoranthene [51]. It is a FLA. It is possible that some of the microalgae found in crude oil might have remedial activity due to the fact that they are able to break down hydrocarbons into components that are less complicated without receiving any harm [52]. Chlorella vulgaris, Sceletiumquadricauda, Sceletiumplatydiscus, and Selenastrumcapricornutum are examples of microalgae that have the ability to degrade the carcinogenic polycyclic aromatic hydrocarbon (PAH) benzo[a]pyrene (BaP) [61]. However, the extent to which they are able to do so is contingent upon a number of factors, including the composition of their cell walls, the presence of oxidation-reduction enzymes, and some density. By using a dioxygenase mechanism, Selenastrumcapricornutum has been shown to be responsible for the oxidation of benzo[a]pyrene, which results in the formation of sulfate ester and glucoside conjugates [53-86]. It has been suggested by El-Sheekh [52] that under heterotrophic conditions, N. punctiforme and S. platensis may be able to develop in a healthy manner if they are fed crude oil. According to study that was published by Subashchandrabose [61], it has been shown that the enzyme named Chlorella sp. dihydrolipoamide acetyltransferase, which is produced by microalgae, is capable of detoxifying soil that has been polluted with pyrene. According to the findings presented in [55,86], the rate of pyrene biodegradation increases or decreases depending on the quantity of algal biomass that is present. The researchers hypothesized that the anti-algal growth actions of pyrene were due to its ability to inhibit the production of proteins. On the other hand, pyrene metabolites that are created by bacteria have the potential to promote the development of algae by increasing the rate of DNA replication as well as protein synthesis. The purpose of this research is to investigate the relationship between algae and bacteria in order to break down organic contaminants and make life simpler for algae. The rapid growth of C. vulgaris and Sc. obliquus, as well as their ability to biodegrade oil in heterotrophic environments with waste oil serving as the only carbon source, have led to their recognition as prospective biosystems for the degradation of crude oil [57-89]. The ability of S. obliquus and C. vulgaris to flourish in heterotrophic environments was examined by El-Sheekh et al. [58] via the use of crude oil as the only source of carbon. A demonstration was made that both types of algae had the capability to breakdown PAHs and n-alkanes. The idea was considered to be an original one, and it was thought practical for wider use." According to the findings of Ghasemi's study, algae may contribute to the breakdown of pollution in two different ways: either they may modify the pollutants themselves, or they can improve the ability of the microbial population to degrade the pollutants directly. As a result of its ability to flourish in the presence of organic pollutants, chlorella is now often discovered in wastewater treatment plants. Algal cells not only possess a method for recycling, but they also have the ability to make commodities in a selective manner. Enzymes that might be of potentially beneficial use could be created by modifying their DNA in order to act in unique ways. The green alga Prototheca zopfii has been shown to be capable of degrading around 49.3 percent of saturated aliphatic hydrocarbons and between 26.5 and 1.5 percent of aromatic compounds that are present in crude oil, as shown by prior study [40]. It has been shown in the laboratory that Prototheca zopfii is capable of breaking down oils and other petroleum compounds.




2.4.3. **PhenolicCompounds**

Using two inducible intracellular enzymes, polyphenol oxidase and laccase, it has been proven that microalgae are capable of breaking down phenolic substances [56]. Chlamydomonas moewusii is responsible for the production of laccase enzymes, which play a significant role in the process of biodegradation [41]. It is possible that some bacteria, such as Pseudochlorococcum sp., Chlorella sp., and Chlamydomonas sp. [42, 93], are capable of effectively decomposing phenol in wastewater. The findings of these studies indicate that the green microalga Monoraphidiumbraunii is the most promising candidate for the conversion of bisphenol into monoglucoside [43]. In order to show the biodegradability of phenolic compounds, the green microalgae Chlorella sp. and S. obliquus were able to destroy a large number of phenolic compounds, including those that are considered to be priority pollutants by the Environmental Protection Agency (EPA) of the United States of America [44]. Phenols such as catechol, hydroxytyrosol, p-hydroxy, tyrosol, benzoic acid, ferulic acid, synaptic acid, caffeic acid, and vanillic acid were all decomposed by Ankistrodesmusbraunii and Scenedesmus quadricauda at concentrations of 400 mg/mL or less [68]. In the process of converting naphthalene into 1-naphthol, microalgae have been shown to be among the organisms that function with the highest efficiency [45]. It has been shown that the marine microalga Dunaliella sp. is more efficient than C. pyrenoidosa in the process of degrading dimethyl phthalate (DMP) [46].

2.4.4. **PesticidesandHerbicides**

Recently, there has been an increase in the commercial use of low-cost algal-based systems for the treatment of wastewater or effluents from agrochemical businesses [47]. Although this capacity varies depending on the lipid content of the microalgae strain, the chemical composition of the pesticide, and the strain itself, many microalgae have the potential to biosorb and bioaccumulate various pesticides [67,98]. There is a possibility that insecticides and cyanide might provide microalgae with a supply of nitrogen and carbon [49].

With the assistance of enzymes that they make themselves, many microalgae are able to degrade potentially hazardous substances such as hydrocarbons in order to maintain their own survival [40,40,41]. There are several advantages to pretreatment of wastewater using C. vulgaris and biosurfactants [42], particularly for the removal of nutrients from wastewaters produced by petrochemical industries. Organic xenobiotics, which include those that are utilized in herbicides, insecticides, and medications, pose a rising risk to water systems [43]. There are a few different kinds of green algae that have been shown to be particularly effective in degrading these pollutants. Diazinon, a popular pesticide, is hazardous to a wide variety of animals when it is taken in via the mouth at high concentrations. To a lesser degree, chlorella vulgaris may be able to convert diazinon [44], a pesticide that is very toxic, into a metabolite that is less hazardous. Scenedesmus and Chlorococcum microalgae are the organisms that are accountable for the conversion of the cyclodiene insecticide endosulfan into sulfate [45].

Several studies have shown that both C. vulgaris and S. bijugatus are capable of acquiring phosphorus from organophosphorus pesticides [46]. The family of enzymes known as cytochrome P450 monooxygenase is very important to the process of bioremediation of pesticides [47].

The removal of the herbicide prometryne from water systems is accomplished by the use of bioremediation, which makes use of green microalgae such as Chlamydomonas reinhardtii [43]. Certain microalgae have the potential to breakdown the pesticide fluroxypyr in a short amount of time [48]. The triazine group herbicides were absorbed by C. vulgaris over the course of three hours [49]. During the process of degrading pesticides, algae activate an enzyme known as cytochrome P450, which is accountable for dealkylation [30]. In order for the cleaning process to be successful, monooxygenase enzymes, such as those produced by C. fusca and C. sorokiniana in response to the herbicide metflurazon [31], are essential.

Algal nitrate reductases have the potential to breakdown nitroaromatic chemicals, such as TNT and a resistant xenobiotic that is used in explosives [13].

It has been established in recent studies that immobilized cells are superior than free cells when it comes to the biodegradation of a broad variety of pollutants found in wastewater products. Considering that this procedure may be used several times at a minimal cost, there is no need to be concerned about the viability of the cells that have been preserved throughout the course of time [3]. Because of the limits imposed by diffusion, immobilization reduces the sub-strata inhibition and microbial toxicity when it occurs. Over the course of almost four decades, researchers have been using immobilization for a variety of biotechnological purposes. After three hours, C. vulgaris was able to decrease the amount of organic matter in industrial wastewater, according to tests that included the immobilization of ca-alginate [3]. Tributyltin (TBT), a component of biocide, was degraded by it in a period of time that was shorter than twenty-four hours. In order to convert TBT into DBT and MBT in C. vulgaris that was immobilized in alginate, it was necessary to perform six cycles of high TBT concentration [3]. In the process of decomposing tri-, di-, and monobutyltin chlorides, chlorella emersonii that had been immobilized in alginate was shown to be more effective than free cells [36]. Several pieces of evidence have been provided that demonstrate the effectiveness of Sc. quadricauda immobilized in alginate for the breakdown of dyes (see [74,3]). (this was described in [74,3]).

It is possible to clear wastewater of organic contaminants at no cost by using the symbiotic relationship that exists between bacteria and algae. Microalgae contribute to the improvement of bacterial biodegradation by creating oxygen, which is an essential electron acceptor for the aerobic bacterial breakdown of organic contaminants using aerobic bacteria. On the other hand, the production of carbon dioxide by bacteria is essential for the process of photosynthesis in microalgae [37]. As a result of its ability to increase the efficiency with which pollutants are removed, increase the amount of algal biomass and lipids produced, and decrease the cost of harvesting microalgae, this technology shows potential for wider use [38].

A group of microalgae lead by bacteria belonging to the genus Sc. obliquus was found to be capable of decomposing oil waste by 84.2%, according to the findings of researchers [39]. Under autotrophic circumstances, it was reported that the algal-bacterial combination of Cyanobacteria sorokiniana and Pseudomonas migulae was able to breakdown around 350 4 mgL1 of phenanthrene from tetradecane or silicone oil without the addition of any oxygen from the outside [30]. Furthermore, the C. vulgaris and Coenochlorispyrenoidosa consortium was able to absorb fifty milligrams of pentachlorophenol (PCP) L1 over the course of five days while being exposed to light [31].

It was shown that Scenedesmus spp. are capable of breaking down contaminants at a faster rate than other species [44], and both Chlorella spp. and Scenedesmus spp. are widely considered to be promising species for phycoremediation efforts.

### 2.5. BioremediationofOrganicPollutantsbyCyanobacteria

Cyanobacteria, which are also known as blue-green algae, are responsible for increasing water productivity [32]. They do this by converting atmospheric nitrogen and carbon dioxide into forms that may be used. Because of their extensive distribution, ease of culture, metabolic flexibility, and high absorption capacity, the biomass of the majority of cyanobacterial species is considered to be one of the most useful bioaccumulators [33,34]. According to Table 2, a number of different species of cyanobacteria have the ability to convert aromatic hydrocarbons and xenobiotics into nutrients via the process of metabolism. Laccase, azo reductase, and polyphenol oxidase [35] are some of the enzymes that are produced in order to change the metabolic processes and assist in cleaning activities. It is the cyanobacterium Phormidiumvalderianum that is responsible for the production of laccase and polyphenol oxidase [36]. These enzymes are responsible for the great majority of the biodegradation and degradation of phenol.

***Table 2 The efficiency of cyanobacteria in eliminating organic contaminants in a controlled environment.***

| Pollutants | Algae Species | OrganicPollutants | Degradation Rate % | References |
|---|---|---|---|---|
| Dyes | *Nostoclinckia*HA46 | Toxicreactivered198 dye | 94 | [44] |
| | *N.muscorum* | Tartrazine | 70 | [65] |
| | *Nostoclinckia* | Azodye | 81.97 | [66] |
| | *Oscillatoriarubescens* | BasicFuchsin(5ppm) | 94 | [66] |
| | *Phormidiumceylanicum* | AcidRed97 | 89 | [37] |
| | *Ph.animale* | RemazolBlackB(RBB) | 99.66 | [38] |
| | *Chroococcusminutus* | AmidoBlack4B($40mgL^{-1}$) | 55 | [37] |
| | *Gloeocapsapleurocapsoides* | FFSkyBlue($40mgL^{-1}$) | 90 | [37] |
| Hydrocarbon | *Protothecazopfii* | Saturatedaliphatichydrocarbons | 49±3 | [90] |
| | *Protothecazopfii* | Aromaticcompounds | 26.5±1.5 | [90] |
| | *Oscillatoria*sp. | Pyrene | 95 | [63] |
| Phenol | *Anabeanavariabilis* | O-nitrophenol(ONP) | 0 | [39] |
| Pesticides&herbicides | *Oscillatoriaquadripunctulata* | Biocides | 0 | [20] |

It is possible to culture cyanobacteria in wastewater in order to increase their output [21], since wastewater already contains the biogenic components that are necessary for the development of these organisms. There are three species of cyanobacteria that are used the most often for the purpose of cleaning up industrial effluent: Westiellopsis sp., Spirulina sp., and Oscillatoria sp. [22-25].

### 2.5.1. **Dyes**

*There is evidence that the rate of biodegradation of basic fuchsin may be improved by the presence of Hydrocoleumoligotrichum, Oscillatoria oligotrichum, Oscillatoria limnetica, and Spirulina spp. [1]. By degrading Remazol Black B (RBB) dye in wastewater in a way that is both safe and effective, Phormidiumanimale has been shown to be successful [38]. [26] Arthrospira platensis was able to successfully remove reactive red 30 (RR-30) from aqueous solutions at a concentration of 482.2 mg g1. There is a possibility that the cyanobacterium known as Nostoc linckia might be used to extract pigments from wastewater from industrial processes [44].*

*Anabaena flos-aquae (UTCC64), Synechococcus sp. (PCC7942), and P. autumnale (UTEX180) were shown to be capable of biodegrading three individual colors in an effective manner [27]. Nostoc linckia was able to degrade azo dye by 81.97 percent when it was exposed to it for just seven days [66]. The use of Spirogyra rhizopus resulted in the degradation of acid blue with remarkable effectiveness [28]. The dyes FF Sky Blue and Acid Red 97 lost eighty percent of their original color after being subjected to Gloeocapsapleurocapsoides and P. ceylanicum over a period of twenty-six days [31].*

*At a pH of 2.0 and a temperature of 30 degrees Celsius [44], Nostoc linckia HA 46 on calcium alginate is able to destroy hazardous reactive red 198 dye in an effective manner by 94%.*

### 2.5.2. OrganicHydrocarbon

High amounts of the chemical compounds known as di-n-butyl phthalate (DBP), diethyl phthalate (DEP), and dimethyl phthalate (DMP) may be discovered in the natural environment. Microcystis aeruginosa (Kutz.) (strain 2396, and SM) exhibited a lower absorption rate for these compounds compared to Anabaena flos-aquae, which had a greater absorption rate for these substances [27]. It is a first that PAHs with a high molecular weight have been found in pyrene. After thirty days of incubation, the rate of pyrene bioremediation by Oscillatoria sp. was 95% greater than the rate achieved by Chlorella sp., a green microalga, which was 787.4% [63]. A number of different species of cyanobacteria have the potential to degrade petroleum and compounds derived from petroleum [28].

The degradation of several petroleum hydrocarbons was accomplished by Anabaena sp., Aphanothececonferta, Phormidium sp., Nostoc sp., and Synechocystisaquatilis [29]. The degradation of these hydrocarbons was dependent on the species of cyanobacteria that were employed and the chemical structure of the hydrocarbon compounds. Cyanophyta species play a significant part in the process of hydrocarbon breakdown as well as the elimination of oil pollutants from waste [4]. As a result of their effectiveness in removing crude oil, mixed cultures or individual species of cyanobacteria, such as O. salina, Plectonematerebrans, and Aphanocapsa sp., are used in the process of reducing oil pollution [3]. A Phormidiumanimale mat that has been immobilized is responsible for the breakdown of crude oil. This mat was mostly degraded by other bacteria that were associated with it, with Ph. animale only acting as a matrix [3]. [2] It was said that the use of phormidium sp. immobilized on synthetic capron fibers was an effective method for cleaning up oil and phenol spills. A. variabilis was able to breakdown o-nitrophenol (ONP) at a rate of forty percent when it was exposed to light, but this rate was only fifty percent when it was grown in the dark [37,39].

It is possible for a number of different species of cyanobacteria to convert naphthalene (PAH) into non-toxic quantities of four primary compounds, as seen in Figure 2 [45]: 1-naphthol, cis-naphthalene dihydrodiol, 4-hydroxy-4-tetralone, and trans-naphthalene dihydrodiol. In an environment that is heterotrophic, it has been shown that N. punctiforme and Arthrospira platensis have the potential to breakdown crude oil and transform aliphatic molecules into aromatic ones [52,14]. It has been shown that Oscillatoria species are capable of decomposing biphenyl and naphthalene, which are two frequent byproducts of petroleum production [45].

During the heterotrophic process, oil is emulsified and transformed into minute droplets by the polysaccharides that are generated by cyanobacteria. This makes the oil more vulnerable to assault [15]. The cyanobacteria have the ability to degrade the components of oil [16]. Consortiums of aerobic heterotrophic bacteria and cyanobacteria were found to be of tremendous assistance in the process of biodegradation in an oil-polluted environment, as described by Abed [28].

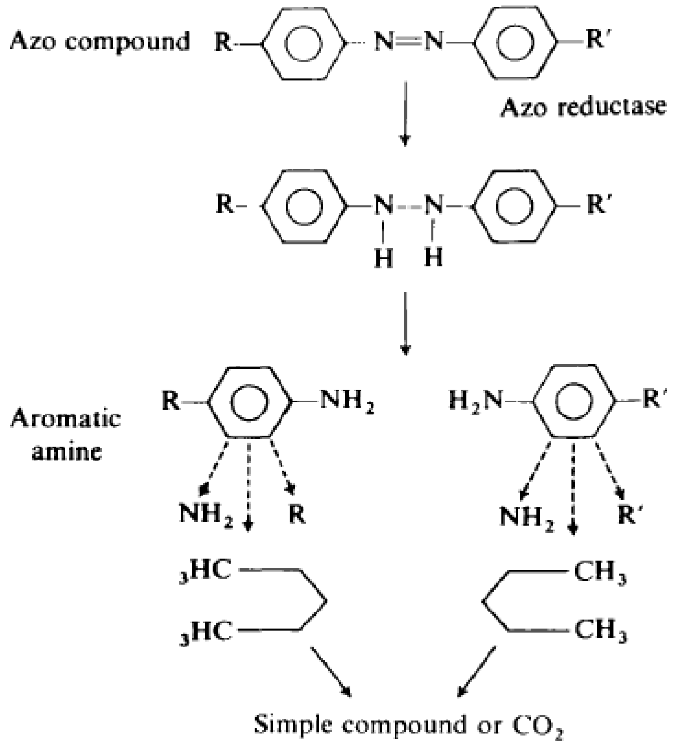



**Figure 2.** Degradation mechanism of azo dyes by microalgae.Reprinted with permission fromref. [73]. Copyright 1992 Elsevier.

2.5.3. **PhenolicCompounds**

It was the marine cyanobacterium "Phormidiumvalderianum [36] that was the first to discover polyphenol oxidase and laccase enzymes. These enzymes enable cyanobacterial species to tolerate and remove phenol from a variety of environments within a matter of days. It has been shown that Lyngbalagerlerimi, N. linkia, and O. rubescens are capable of effectively removing the phenolic pollutants which are indicated in Table 1 [17]. Spirulina maxima was shown to be capable of degrading a variety of phenolic compounds that are regarded to be priority pollutants in the United States, as can be seen in Figure 3. This was discovered by Klekner and Kosaric [44]. The freshwater cyanobacteria Anabaena cyalindrica and Phormidumfoveolarum were the first organisms to be shown to be capable of bioremediating phenolic chemicals [18]. Not a single one of these creatures experiences ring fracture or the production of metabolites".

2.5.4. **Pesticides and Herbicides**

According to one theory, some cyanobacteria have the ability to break down the potentially hazardous chemical known as fenamiphos [19]. An alternative to the usage of inorganic phosphate, the Aulosirafertilissima ARM 68 used a mixture of compounds in order to battle pests. One of the medications that was used was phosphamidon, along with dichlorvos, quinalphos, malathion, and monocrotophos. Through an increase in acid-phosphatase activity, these compounds were able to compensate for the reduced amount of inorganic phosphate [4]. There is a correlation between the availability of phosphorus in the cell and the levels of glyphosate that are absorbed by Spirulina species [3]. Less than a day may be all that is required for A. cylindrica and M. aeruginosa to eliminate the potentially hazardous phenyl-lurea herbicides [57,38]. lindane, a highly chlorinated aliphatic insecticide, was dechlorinated by both N. ellipsosporum and Anabaena sp. together. Oscillatoria quadripunctulata was able to reduce the total dissolved salts by forty percent when it was put to petrochemical waste [20]. There were no more phenols, aromatic compounds, biocides, or sulfides available to be obtained. The fact that cyanobacteria are able to fix nitrogen and carbon [32,34] brings forth the possibility that they are involved in the generation of more water. As a result of its abundance, cheap cost, and high absorption capacity, biomass that is formed from cyanobacteria and microalgae is considered to be one of the most exceptional bioaccumulators

[33]. Xenobiotics and aromatic hydrocarbons must be broken down by cyanobacteria in order for them to continue as living organisms.

Each and every one of them should be eradicated. Cyanobacteria are responsible for the production of enzymes that mimic laccase, such as azo reductase and polyphenol oxidase. Among the enzymes that are engaged in the biodegradation of phenol, the most important ones are laccase and polyphenol oxidase [36] from Phormidiumvalderianum. In sewage sludge, it has been shown that cultivating cyanobacteria may increase output while simultaneously reducing waste [21]. Some of the protozoa that have been associated to the biodegradation of basic fuchsin include Hydrocoleumoligotrichum, Oscillatoria oligotrichum, Osc. limnetica, and an assortment of Spirulina species [63]. In wastewater, it has been shown that the breakdown of Remazol Black B (RBB) is both time-consuming and cost-effective [53]. Arthrospira platensis has been studied and shown to be capable of effectively removing RR-30 (482.2 mg g-1) from water [77]. Besides its ability to eliminate unpleasant odors, Nostoc linckia may also be applied to neutralize colors that are present in industrial effluent [78]. In order to evaluate the degradative capabilities of Anabaena flos-aquae (UTCC64), Synechococcus sp. (PCC7942), and P. autumnale, Remazol Brilliant Blue R (RBBR), sulphur black, and indigo (UTEX180) were used in the laboratory. It took Nostoc linckia seven days to totally breakdown an azo-dye in the majority of those instances [6]. [50] The acid blue was swiftly degraded by the bacteria known as Spirogyra rhizopus. G. pleurocapsoides had removed 80% of FF Sky Blue and 95% of Acid Red 97 after a period of 26 days [39], while P. ceylanicum had completed the removal of Acid Red 97. The content of the potentially harmful reactive red 198 dye was dramatically reduced by 94% when the Nostoc linckia HA 46 strain was cultured on calcium alginate at a pH of 2.0 and a temperature of 30 degrees Celsius [76]. Some examples of phthalates that are used extensively are di-n-butyl phthalate, diethyl phthalate, and dimethyl phthalate (also known as DMP). Anabaena flos-aquae had a higher proportion of absorption for these compounds compared to Microcystis aeruginosa (Kutz.). This was seen in the study. 78.71% of pyrene was bioremediated by the green microalgae Chlorella sp., whereas the red microalgae Oscillatoria sp. accomplished the same thing. Numerous species of Cyanobacteria have been suggested as potential catalysts for the breakdown of petroleum and chemical derivatives of petroleum [32,28]. Synechocystisaquatilis and Anabaena sp. have the potential to degrade petrochemicals using their enzymes [3, 4]. [78] The hydrocarbon breakdown and oil refining industries make extensive use of cyanophyta's capabilities. Aphanocapsa species or mixed cultures of O. salina and Plectonematerebrans have the potential to reduce the amount of oil pollution that occurs [36]. [79] Mats of Phormidiumanimale have the potential to digest crude oil. This alga was mixed with synthetic capron fibers in order to have the ability to remove phenols and oil spills. It is shown in Figure 2 [77] that the PAH molecules that are most often eliminated by cyanobacteria are 1-naphthol, cis- and trans-naphthalene dihydrodiol, 4-hydroxy-4-tetralone, and 4-hydroxy-4-tetralone. On account of a metabolic transition, it is possible that some bacteria are able to transform aliphatic compounds into aromatic ones [36,77]. Oscillatoria species were able to breakdown naphthalene, which is a waste product of petroleum as well as biphenyl, which is a polycyclic aromatic hydrocarbon [3, 4]. Abed [28] conducted research that led to the discovery of symbiotic relationships between cyanobacteria and aerobic heterotrophic bacteria. By using Lyngbalagerlerimi, N. linkia, or O. rubescens, it is possible to successfully remove the phenolic contaminants that are mentioned in Table 1. According to Klekner and Kosaric [44], despite the fact that the Environmental Protection Agency (EPA) deems phenolic compounds to be pollutants, Spirulina maxima has the capability of breaking down these chemicals. This is despite the fact that the United States considers them to be pollutants. Because of their poor water solubility, hydrophobic petroleum molecules may remain stable in a wide variety of environments and resist the degradation of microorganisms. [4] The blue-green algae that fixes nitrogen often blooms. These photoautotrophic algae are typical and may be found in a wide variety of environments. [32,33,53] Research on the cyanobacteria's ability to tolerate toxins was driven by the discovery of cyanobacteria in polluted water.

The use of genetic engineering (GE) to modify microalgae and cyanobacteria for bioremediation is quite common. The number of active groups in the algal cell wall is increased as a result of GE, in addition to the fact that it accelerates the production of polysaccharides and draws in pollutants [50]. Engineered organisms have the potential to decompose a wide variety of natural and manufactured aromatic and xenobiotic compounds, as well as explosives and polycyclic aromatic hydrocarbons (PAHs). Genome-modified algae are not only immune to a broad variety of pollutants, but they also degrade toxins more rapidly in a variety of environments [38]. This is because they have been genetically modified. It has been shown by Kuritz and Peter [3] that GE increases the biodegradation ability of Anabaena varieties. There is evidence that Anabaena species that has the pRL634 gene is more efficient than the wild type in the degradation of lindane. GE adoption is hampered by a number of challenges, including regulatory restrictions and environmental concerns. The four most important strategies that should be implemented when employing genetic engineering for biodegradation applications are modifications to enzyme specificity and affinity, the design and monitoring of bioprocesses, the management of biodegradation pathways, and the use of bioreporter sensors and analytical endpoints [2].

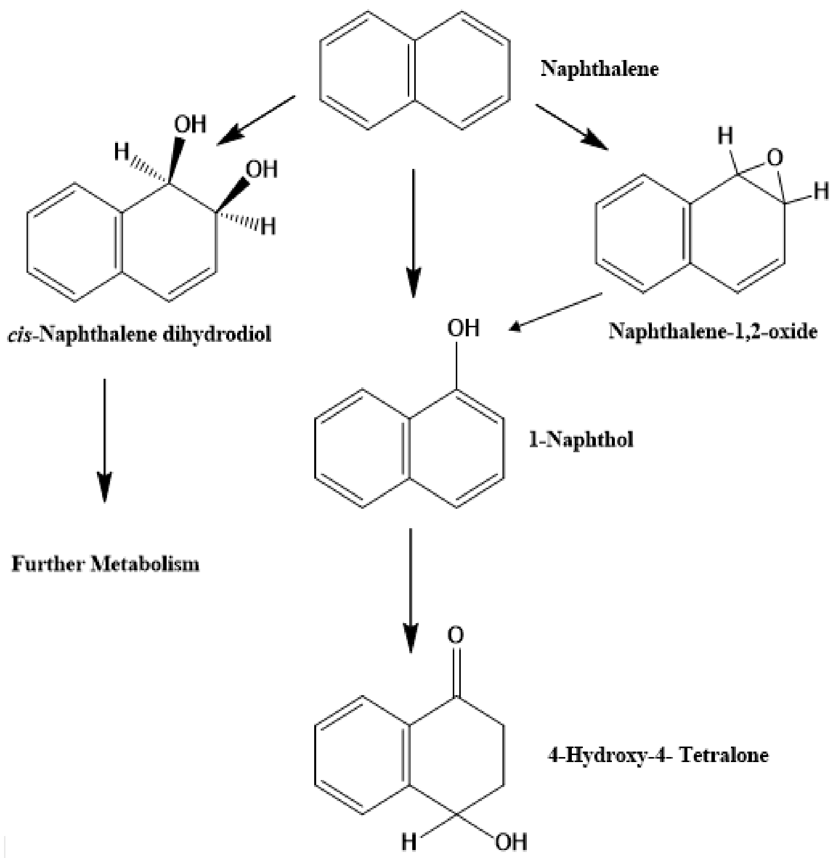



**Figure 3.** Cyanobacterial transformation mechanisms of naphthalene.Reproduced with permission from ref. [94]. Copyright 1992 Informa UK Limited.

## 3. Advantages of Phycoremediation Treatment

Precipitation, adsorption, coagulation, and advanced oxidation processes including ozonation, UV radiation, ultraviolet radiation mixed with hydrogen peroxide, and the photo-Fenton reaction are often used to treat wastewater. These methods have been shown to be effective in ridding ecosystems of organic contaminants; nevertheless, they may be rather costly and even harmful (Table 3) [1,15]. Nevertheless, activated sludge is one of the most recommended procedures because it employs a dense microbial culture under sus- cation to biodegrade organic material in aerobic conditions [16]. In order to remove the soluble and suspended organic components from wastewater, this approach is used [17]. Nevertheless, this procedure results in a great deal of waste and sludge. TiO2 nanoparticles' ability to effectively oxidize and mineralize hazardous organic pollutants has piqued the attention of a number of researchers and practitioners [1].

Phytoremediation, sometimes known as "green" remediation, is a method of cleaning up polluted areas that is gentle on the environment (sludge). Nevertheless, phycoremediation is not a perfect solution for more costly and inefficient physical and chemical techniques because of its limited application and inability to address carbon sequestration, sludge generation, and the avoidance of carcinogenic intermediates (Figure 4). The upfront cost for biological methods is five to twenty times lower than that of standard chemical treatments. Costs associated with running the system are far lower than those of more traditional techniques [18]. Since it has the potential to lead to the full mineralization of pollutants and the development of a blue and circular economy [4,19], phycoremediation may be thought of as a kind of permanent bioremediation.

***Table 3 Comparison between removal techniques utilized for waste water treatment***

| Disadvantages | Advantages | Process |
|---|---|---|
| Phycoremediation pollutants<br>Fungiandbacteria<br>Activatedsludge<br>Cost-effective<br>Low energy requirements<br>Effectivemethodforremovalofsolubleand suspended organic material<br>Chemicalprecipitation<br>Pollution<br>Simpleprocess<br>UV/H2O2<br>Effective method for mineralization and oxidation of most organic pollutants<br>Improvesbiodegradability<br>Electrochemical oxidation<br>Ozonation<br>Effectivemethodformineralizationand oxidation of most organic pollutants | Ecofriendly,lowcost<br>Adaptedtohighlevelsof<br>Doesnotrequirechemicalsorhightemperatures<br>Applicable for a wide range of pollutants simple process<br>Does not require chemicals or high temperatures<br>Appilication for a high range of pollutants TiO2<br>Formationaharmfulbyproduct | Noteffectiveforsome<br>LimitingpHtolerance<br>Sludgeproduction<br>Productionoftoxicsecondarypollutants<br>Productionofsludge<br>Chemicalconsumption<br>Costlytechnique<br>Lesseffective<br>Lowreactionratesandselectivity<br>•High initial cost of the equipment<br>Formation of sludge<br>Highcost<br>Complex technology |

As opposed to bacteria and fungi, which need carbon input, energy, nutritional supplies, and other supplements to remove pollutants, microalgae and cyanobacteria are viewed as promising biodegradation microorganism choices for a range of toxins [70]. This is because they have the potential to clean the air without contributing to the pool of carbon in the atmosphere, which is growing at an alarming rate due to human activities utilizing fossil fuels [65], [80]. High pollutant absorption and accumulation due to high algal biomass production is another economical advantage of phycoremediation made possible by organic pollutants. Moreover, it was shown that the biodegradation efficiency of the green algae Chlorella and Scenedesmus was superior to that of Rhodococcus sp. and other bacterial strains. S. obliquus outperforms other bacteria in desulfonating naphthalene monosulfonicacids . Mixotrophy.

## 4. Conclusions and Future Perspectives

One of the most significant environmental issues that the world is now facing is the growing popularity of technologies that produce trash that is composed of hydrocarbons and many other organic contaminants. Bioremediation, which makes use of microalgae and cyanobacteria rather than other microorganisms or more traditional methods, is an environmentally friendly method that is both sustainable and ecologically acceptable for the purpose of cleansing polluted water. These toxins also boost the biomass of algae, which has the potential to be used in a number of different ways in the not too distant future. Two potential solutions to this issue are the screening of novel algae strains for the purpose of phycoremediation and the use of genetic engineering to enhance the biodegradation capabilities of algae and their tolerance to various organic contaminants. The introduction of novel bacterial genes that are specifically intended to degrade various organic pollutants into algae will be done in order to hasten the process of degradation. It may be possible to speed up the process of phycoremediation of organic contaminants and reduce the amount of time needed for decontamination if the physicochemical properties of aquatic systems are modified. You will need a growing system that has been carefully considered if you want to get the most out of your crop while having the lowest possible expenditures.

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