BIOTECHNOLOGICAL APPROACH FOR BIOREMEDIATION OF TEXTILE AND PESTICIDES INDUSTRIAL POLLUTANTS

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Water has a key role in mediating ecosystem processes at the global scale, connecting the atmosphere, lithosphere, and biosphere by transporting materials across them and facilitating chemical reactions. Natural waters are never completely pure; instead, they are a complex, dynamic blend of suspended particles, dissolved inorganic and organic compounds.

On average, water accounts for 60 to 70 percent of an organism's weight. It fills cells, giving many tissues shape and support. All of life's chemical reactions take place in the medium of water, and water actively participates in many of these events. Water is a solvent that breaks down both the nutrients that cells require for survival and the waste products that cells generate.Water is therefore necessary for the transportation of materials to and from cells.Salts and other substances are dissolved by water, creating solutions that conduct electricity. The energy that powers photosynthesis is also provided by these fluids, which are known as electrolytes.

To prevent communicable diseases and maintain a healthy lifestyle, clean drinking water and basic sanitation are essential. The ongoing use of dirty water remains one of the biggest environmental dangers to health for many of the world's poorest populations. In 2002, the UN projected that 2.4 billion people lacked access to proper sanitation and at least 1.1 billion did not have access to safe drinking water. More than 5 million people every year die as a result of these deficits, which cause hundreds of millions of cases of water-related sickness.

Water shortages are anticipated to worsen as populations increase, more people migrate into cities, and agriculture and industry struggle for dwindling water supplies. Two-thirds of the world's population will reside in water-stressed nations by 2025, as determined by the United Nations as those whose freshwater supplies are consumed at a rate greater than. Reducing the number of people without dependable access to clean water and better sanitation by half was one of the top targets outlined at the UN World Summit in Johannesburg in 2002.

The minimal essential water demands of all of their population cannot be met by 45 countries, the most of which are in Africa or the Middle East. The issue of access to clean water exists in various nations.Accessibility does not necessarily equate to affordability. For instance, a typical low-income household in Lima, Peru, uses one-sixth the amount of water that a middle-class American family does while paying three times as much for it. To buy and purify water, a poor household could spend up to one-third of their income if they followed the government's advice to boil all water to prevent cholera.

Over the past ten years, investments in rural development have resulted in notable advances. Almost 800 million people, or 13% of the world's population, now have access to clean water since 1990. The proportion of rural families that have access to clean water has increased from less than 10% to around 75%.

Bioremediation

Composting and wastewater treatment are well-known examples of traditional environmental biotechnologies. Environmental biotechnology is not a new field. A biotechnological procedure called bioremediation reduces or eliminates environmental contamination. 'Bio' in bioremediation refers to a living thing, and'remediate' means to address an issue. It is a form of waste management strategy that employs living things to either remove or utilize pollutants from a polluted region.

Food, energy, and other necessities of daily life are in greater demand due to the growing global human population. These demands were met by the Industrial Revolution, which led to the mass manufacture of several organic and inorganic compounds. These procedures cause environmental pollution in a variety of ways, whether directly or indirectly.Many various procedures are employed to lessen pollution, one of which is bioremediation, in which noxious chemicals or pollutants with low toxicity are neutralized by biological agents.

Recently, it was thought that bioremediation was a solution for problems with hazardous contaminants that were emerging and involving a variety of microbes, including both aerobic and anaerobic bacteria, fungi, algae, and both.Living things undergo a reaction as a part of their metabolic processes to change contaminants in this process (Kensa *et al*., 2011). In this procedure, naturally occurring bacteria and fungi are occasionally employed to detoxify or breakdown chemicals that are harmful to the environment or human health. The microorganisms may be isolated from another location and delivered to the contaminated locations, or they may be native to the contaminated area.

Bioremediation applications

1. It is an easy and labor-efficient method.

2. It is a natural process that takes some time when bacteria multiply and break down contaminants, but when contaminants are broken down, the population of microbes also declines.

3. Sustainable and eco-friendly.

4. By converting harmful to safe compounds, bioremediation is useful for the total eradication of a wide range of pollutants.

5. Pollutants can be destroyed rather than being transferred from one environmental medium to another, such as from land to water or air.

6. Bioremediation can be done locally, eliminating the need to carry trash elsewhere and reducing risks to both human health and the environment while doing so.

7. Compared to other approaches for hazardous waste cleanup, bioremediation is less expensive.

8. Bioremediation preserves aesthetic qualities by keeping industry out of the environment.

9. Contaminants are eliminated, not just distributed throughout various environmental media.

10. Comparably simple implementation.

11. Non-intrusive, possibly enabling continuous site use.

Types of Bioremediation

Microbial bioremediation

For the removal of harmful pollutants, bacteria and fungi are used as microorganisms. When a dangerous substance is present and the temperature is below zero, microbes can proliferate. The key contributing elements for the degradation of pollutants are the microbial population, the accessibility of contaminants to the microbial population, and environmental conditions such soil type, pH, temperature, oxygen content, and nutrition levels (Sharma, 2020).

Phytoremediation

Green plants and the related microorganism are used in this procedure to purge harmful environmental contaminants from the environment. A number of processes, including phytodegradation, phytovolatilization, phytoaccumulation, and phytoextraction, are used in phytoremediation. The health and yield of soil can be improved via phytoremediation, which is more affordable than other traditional methods (Singh *et al*., 2017).

Mycoremediation

In terms of mycoremediation, the method of employing fungi to degrade harmful compounds in the environment. Fungi have non-specific enzymes that can break down a wide variety of substances. 'White rot fungi' is the mycoremediationbranch that has seen the highest development (Tomer *et al.,* 2021).

Bio- Stimulation

The ability to send the stimulus to the environment is known as bio-stimulation. One of the most established methods of bio-remediation of hydrocarbons is bio-stimulation, which has lately made advancements in geophysics, stable isotope studies, and molecular microbiology. By first providing fertilizers, growth aids, and trace minerals, then by providing other environmental factors like pH, specific nutrients are injected at the site (soil/ground water) to stimulate the activity of native microorganisms, which include naturally existing bacteria and fungus communities.Secondly, oxygen and temperature to boost their metabolism. Pollutants that are present in modest amounts also act as stimulants by activating the bioremediation enzymes. The majority of the time, nutrients and oxygen assist these routes to continue by supporting local microbes (Kensa *et al*., 2011).

Bio-attenuation

The contaminants are changed to a less hazardous form during bioattenuation. These transformational processes are mostly brought on by biodegradation by microorganisms, to some extent by reactions with naturally occurring chemicals, and to some amount by sorption on geologic media. Natural attenuation is a method for treating fuel compounds that is specifically acknowledged as polluted, but not for many other groups.

Many polluted locations might not need an aggressive repair strategy. According to Maitra (2018), bioattenuation is effective and economical.Bioattenuation is dependent on natural degradation processes. In order to make sure that the concentration of contaminants at important sampling points declines over time, a technique of tracking the natural progression of degradation has been developed (Sharma *et al.*, 2020).

Bio-pile

Because of its cost-effectiveness, this ex-situ technique enables for the effective management of operational biodegradation variables like PH, Nutrients, Temperature, and Aeration. The usage of biopiles, sometimes referred to as bio-cells, bio-heaps, bio-compounds, and compost piles, helps to lower petroleum pollutant concentrations in excavated soils while promoting biodegradation. This method includes leachate collection, bed systems for treating leachate, nutrients, irrigation, and aeration.

It is also possible to remediate volatile low molecular weight contaminants with the biopile.In order to facilitate constant air circulation in contaminated piled soil through air pump, biopile systems were connected to additional field ex-situ bioremediation techniques, such as land farming, bioventing, biosparging, robust engineering, maintenance and operation cost, and lack of power supply at remote sites.

Extreme air temperatures can cause soil to dry out and undergo bioremediation, which inhibits microbial activity and promotes volatilization rather than biodegradation.The breakdown of adsorbed petroleum pollutants increased as a result of the increased microbial activity brought on by microbial respiration (Sharma *et al.*, 2020).

Bioventing

In order to increase the activities of native microbes for bioremediation, the bioventing technique involves controlled airflow stimulation by delivering oxygen to unsaturated zones. Amendments are made by adding nutrients and moisture to increase bioremediation, which achieves microbial transformation of pollutants to harmless state.

Bioventing is used for efficient bioremediation of petroleum-contaminated soil. In unsaturated soils, bioventing can considerably lower the concentration of a variety of hydrocarbons and other organic pollutants. Systems for bioventing remediation should be planned to reduce constituent volatilization. By eliminating the requirement for off-gas treatment, it lowers remediation costs (LEE *et al.*, 1993).

Bioremediation of water waste of textile and dye industry

Textile dye

Commercial synthetic dyes are also use in various types of industries such as paper, printing, plastic and pharmaceutical industry, different type of paint and textile industry. The textile industry plays important role in the economic development of different countries, as China is the largest exporter of textile products, followed by India, European Union, The USA and Turkey(Sudarshan *et al*., 2023).

Textile Waste Toxicity

Adverse effect of Textile dyes on human health such as, some dyes cause allergic skin reaction, Numerous respiratory tract irritations, skin and mucous membrane ulceration and mental disorientation when inhaled.
Improperly disposed textile dye effluent affecting photosynthetic activity, so it increases heterotrophic activity, which result lowers dissolved oxygen levels affects water Ecosystem(Sudarshan *et al.*, 2023*).*

Types

Bioremediation of textile water waste by Bacteria

Most effective degraders of synthetic dye are Bacteria and Cyanobacteria, because of their short life cycles plays important role in secondary waste generation and adaptability to variety of substrates. Microorganism reduces hazardous chemicals and transform toxic chemicals into less harmful. Some bacterial strains, such as *Bacillus cereus*, *Pseudomonas putida*, *Pseudomonas fluorescence*, *Pseudomonas desmolyticum* and *Bacillus sp*. have been used in the biodegradation of azo dyes (Sudarshan *et al*., 2023).

Table 1: Summary of decolorization of various dyes by pure and mixed bacterial Culture

Sr. No.	Dye	Bacteria	Decolorization of textile dye (in %)	References
1.	Methyl Red	*Staphylococcus saprophyticus AUCA SVE3*	94 & 97% Decolorization within 24 & 48 hrs. Resp.	Hakim*et al*., (2014)
2.	Reactive Violet 5	*Paracoccus sp. GSM2*	70% decolorization within 38 Hrs.	Bheemaraddi*et al*., (2014)
3.	Acid Orange	*Bacillus megaterium PM582*	73% Decolorization within 38 hrs.	Shah*et al*., (2014)
4.	Reactive Red 198	*Acinetobacter baumannii*	96.20% removal after 72hrs.	Unnikrishnan *et al*., (2018)
5.	Reactive Yellow 145	*Thiosphaera pantothropha ATCC 35512*	50% decolorization within 96 hrs.	Garg*et al*., (2020)
6.	Reactive Red HE8B	*Pseudomonas aeruginosa*	86% decolorization within 48 hrs.	Patel*et al*., (2016)
7.	Reactive Black 5	*Aeromonas hydrophila*	76% decolorization within 24 hrs.	El Bouraie*et al*., (2016)
8.	Reactive Red 120	*Shewanella haliotis*	99% decolorization	Birmole*et al*., (2019)

			in 2.5 hrs.	
9.	Congo Red, Reactive Black 5	*Enterococcus faecalis R1107*	65.57% & 72.64 % decolorization Resp. within 48 hrs.	Wang*et al*., (2022)
10.	Malachite Green	*Pandoraea pulmonicola*	85.2% decolorization	Chen*et al*., (2009)
11.	Reactive Blue 59	*Bacillus odyssey SUK3, Morganella morganii SUK5 & Proteus sp. SUK7*	100% decolorization within 60h, 30h. & 24h resp.	Patil*et al*., (2008)
12.	Reactive Orange 16	*Pseudomonas sp.*	100% decolorization within 48 hrs.	Jadhav*et al*., (2010)
13.	Reactive Green 19A	*Micrococcus glutamicus NCIM-2168*	100% decolorization within 42hrs.	Saratale*et al*., (2009)
14.	Direct Black 22	*Bacterial consortium*	100% decolorization within 12 hrs.	Mohana *et al*., (2008)
15.	Metanil Yellow	*Bacillus sp. AK1 & Lysinibacillus sp. AK2*	100% decolorization within 27 hrs.& 12 hrs. Resp.	Anjaneya *et al*., (2011)
16.	Methyl Red, Tartrazine, Ponceaus, Rea Red 35, Evans Blue, Acid Red 3R, Acid red, Methyl Orange, Reactive violet, Red AG	*Nesterenkonia lacusekhoensis EMLA3*	<90% decolorization within 72 -192 hrs.	Prabhakar*et al*., (2022)
17.	Acid Black, Congo red, Acid red 27,	*Bacillus*	51.2%, 1.9%, 32.05%, 36.2%	Kesebir *et al*., (2021)

	Reactive black, Methylene Blue	*licheniformis*	decolorization resp.	
18.	Congo red, brilliant blue& Bromophenol blue, Crystal violet	*Staphylococcus haemolyticus*	80% and 40% decolorization resp. within 3 hrs.	Li *et al.,* (2020)
19.	Malachite Green	*Dietzia sp.*	72.05% decolorization	Bera*et al.,* (2016)
20.	Amido Black 10B	*Chroococcus minutus*	55% decolorization	Parikh *et al.,* (2005)
21.	Reactive Dark blue	*Exiguobacterium sp.*	97% decolorization within 24 hrs.	Qu *et al.,* (2010)

Utilizing microalgae for textile waste water bioremediation

If discharged without adequate treatment, waste water from the textile industry contains a variety of pollutants, the majority of which are dyes and have negative effects on aesthetics, eutrophication, a reduction in photosynthetic activity, and bioaccumulation of toxins in aquatic ecosystems.

A viable alternative to the current standard method of waste water treatment is the growing of microalgae in the textile dye effluent. The conventional treatment process by using microalgae for bioremediation of textile effluents provided valuable biomass that can be processed into bioproducts, biofuels, and bioenergy. The treatment using microalgae reduces color and nutrient load of textile effluent, which reduces numerous negative environmental impacts caused by its discharge into natural environment (Premarathe *et al.*, 2021).

Table 2: Summary of some recent studies on Phycoremediation of textile dye wastewater using microalgae

Sr. No	Textile dye	Decolorizing Microalgae	Decolorization Removal percentage	References
1.	Indigo Blue	Scenedesmus quadricauda ABU12	100% decolorization within 4 days	Chia*et al.,* (2014)
2.	Congo Red	Chlorella	98%	Mahalakshmi *et al.*, (2015)

		vulgaris	Decolorization	
3.	Direct Red 5B	Comamonas sp. UVS	100% decolorization	Jadhav *et al*., (2008)
4.	Congo Red	Haematococcu s sp.	98% Decolorization	Mahalakshmi*et al*., (2015)
5.	Azo dyes	Nostoc muscourm	68% Decolorization in 6 days	Omar *et al*., (2008)
6.	Methylene Blue & Malachite Green	Desmodesmus sp.	98.6% decolorization in 6 days	Bera *et al*., (2016)
7.	Direct Red 31	Chlorella pyrenoidosa	80.12 % decolorization within 180 min	Behl *et al*., (2019)
8.	Indigo Blue	Chlorella vulgaris	49.03 % decolorization within 24 hrs.	Revathi *et al*., (2017)
9.	Disperse orange 2RL	Scenedesmus obliquus	98.14% Decolorization	Hamouda *et al*., (2022)
10.	CI Reactive Red 66	Shewanella algae B29	91.04% Decolorization	Chaieb*et al*., (2008)
11.	Remazol Black 5, Reactive Blue	Chlamydomon areinhardtii	72.97% Decolorization	San *et al*., (2015)
12.	Remazol Black B	Phormidiuman imale	99.96 % decolorization	Bayazit *et al*., (2020)

Utilizing fungi for bioremediation of textile waste water

The biological method—which employs a variety of microorganisms and fungi—is thought to be the most efficient and least energy-intensive way to remove the majority of pollutants from water.

Industrial dyes are removed by fungus through an adsorption mechanism, however in some fungi, such as White Rot fungus, both adsorption and degradation can take place at the same time. The decolorization of textile colors using Funaliatrogii pellets, a white rot fungus. The dye concentration, amount of pellet, temperature, and media agitation all had a substantial impact on the decolorization activity.

White rot fungus, which can release ligninolytic enzymes that bind to non-specific substrates and then degrade a wide range of refractory compounds (i.e., pollutants including dyes), can deculturate dyes (Jebapriya *et al.*, 2013).

Table 3: Summary of decolorization of various dyes by Fungi

Sr. No.	Species	Dye	Percentage Removal	References
1.	*Aspergillus versicolar*	Reactive Black 5	98% decolorization within 420 min	Huang *et al*., (2016)
2.	*Pleurotus eryngii*	Reactive Black 5	93.57 % decolorization within 72 hrs.	Hadibarata*et al*., (2013)
3.	*Funalia trogii*	Reactive Black 5	100% decolorization within 48 hrs.	Mazmanci*et al*., (2005)
4.	*Pleurotus eryngii*	Methyl Orange	43% decolorizatiom with 5 min treatment.	Akpinar*et al*., (2017)
5.	*Coriolopsis gallica*	Reactive Black 5	82% decolorization within 120min	Ben *etal*., (2022)
6.	*Penicillium sp. QQ*	Reactive dark blue	97% decolorization within 24 hrs	Qu *et al*., (2010)
7.	*Penicillium oxalicum*	Methylene Blue	99.17% decolorization within 6hrs	Mathur *et al*., (2021)
8.	*Penicillium simplicissimum*	Reactive Black 5	92% decolorization	Muthukumaran *et al*., (2017)
9.	*Penicillium chrysosporium*	Reactive lack 5 & Direct red 81	88% decolorization	Muthukumaran *et al*., (2017)
10.	*Penicillium sp. YW01*	Malachite Green	98.23 % decolorization within 6 days	Yang *et al*., (2011)
11.	*Umbelopsis isabellinna & Penicillium geastrivorous*	Reactive Black 5	100% decolorization within 16-48 hrs.	Yang *et al*., (2003)
12.	*Aspergillus niger*	Cibacron Black	33%	Biyik *et al*., (2012)

		W-NN	decolorization	
13.	*Cyathus bulleri*	Reactive Red 198, Reactive Orange	80 % decolorization	Chhabra *et al*., (2008)

Various dyes like Malachite Green, Commercial Xanthene, Rhodamine B, Brilliant Green, Azo dyes, Metanil Yellow and Methyl Orange leads to Carcinogenic, Genotoxic, Mutagenic and Neurotoxic against humanhealth and other living organism, also affect immune system and reproductive as well as respiratory system of living organism (Sudarshan *et al.*, 2023).

Pesticide bioremediation

In agriculture, the use of pesticides boosts agricultural output and lowers crop loss. Agricultural discharges of pesticides into water increase their toxicity and harm aquatic life (Singhal *et al.*, 2021). According to the FAO (2018), Asia uses 52.8% of the world's pesticides, followed by the USA (30.0%), Europe (13.7%), Africa (2.2%), and Oceania (1.3%).

Pesticide removal is influenced by two factors: the first is the biome's ideal conditions for survival and activity, and the second is the pesticide's chemical composition and factors related to organisms (microalgae), such as the quantity of suitable organisms, the biological substrate, the availability of water, oxygen tension and redox potential, surface bonding, the presence of substitute carbon substrates, and other electron acceptors. (Nie*et al.*,2020).

Pesticides have significantly increased crop yields from agriculture by helping to manage pests on a global scale, yet applying pesticides heavily to agricultural land has negative effects on the environment, the human body, and human health. For this reason, the development of a quick method of pesticide detoxification is particularly crucial.

The detoxification of environmental pesticide residues is greatly aided by bioremediation. Pesticides can be detoxified or degraded by a variety of microorganisms, including fungi, bacteria, and algae.

The composition of pesticides in contaminated wastewater, treatment costs, and ease of use are the main factors influencing pesticide treatment methods. In order to construct treatment facilities that are intended to remove emerging pollutants like pesticides from wastewater, a thorough investigation of influent characteristics and the coupling of the best treatment technology are necessary. For the elimination of pesticide degradation in aqueous medium, physical, chemical, and biological approaches have been widely applied (Nie*et al.*, 2020).

Effects of pesticides and heavy metals on human health

Organophorus (op), Carbamate (CB), and OC pesticides are among the most harmful because they work by interfering with the nervous system's normal operation (Riodolfi*et al.,* 2014). These pesticides lead to plenty of hazardous effects on human, animals, plants and environment. Table 4 depicts examples of some pesticides with their adverse effects on human health.

Table 4: Harmful effect of pesticides on human health

Sr no.	Pesticides	Health effects	
1.	Aldrin	Nervous system effects. Probable carcinogen.	Green *et al*., (2004)
2.	Dichlorodiphenyltrichloroethane (DDT)	Nervous system effects (tremors, seizures). Probable carcinogen	
3.	Chlordane	Nervous system, digestive system, liver effects, Headaches, irritability, confusion, weakness, vision problems, vomiting, stomach cramps, diarrhoea, and jaundice for lower doses.	
4.	Dieldrin	Nervous system effects. Probable carcinogen. Uncontrolled muscle movement.	
5.	Heptachlor	Nervous system damage, liver and adrenal gland damage, tremors.	

Microalgal bioremediation of contaminated by pesticides

Algae likely make up to 27% of the total microbial biomass in the soil, making them a significant part of the soil microflora. It is crucial for the nitrogen economy of soils and helps sustain soil fertility and oxygen generation. Algae increase BOD by fixing carbon dioxide (CO_2) and releasing oxygen (O_2) during photosynthesis. Algae are used as biofertilizers or soil conditioners. contribute significantly to the biomonitoring and regulation of organic pollutants in aquatic ecosystems (Nie *et al.*, 2020).There are several pesticide elimination mechanisms used in bioremediation, including bio adsorption, bioaccumulation, and biodegradation. 2020 (Nie *et al*).

The method of bio adsorption is passive (Ardal *et al.*, 2014). According to a recent study (Mishaqa *et al*., 2017), grown algae were able to remove 87-96% of a variety of pesticides from aqueous phase, including atrazine, simazine, molinate, isoproturn, carbofuran, propanil, dimethoate, metolachlor, pendimethalin, and pyriproxin.

According to Ardal*et al*. (2014), bioaccumulation is an active process that can be expressed by the bio-concentration factor (BCF). According to Wang *et al.* (2014), variations in the bioconcentration mechanism, bioavailability of chemicals, physical barriers, methods of determining the BCF, dissolved organic matter, metabolism, ionization of ionizable compounds, and environmental conditions have a significant impact on the values of the BCF. According to additional data, BCF values vary depending on the concentration. Additionally, pyrometryne BCF values at 2.5 (or 5.0) g/L concentrations were higher than those at 10.0 (or 12.5) g/L concentrations in green algae (Jin*et al*., 2012).

Pesticides in the environment undergo biodegradation as a result of different enzymes' metabolism. Pesticide degradation is a multi-step process that involves enzyme metabolism. Steps include (i) activating pesticides without functional groups by cytochrome P450 through oxidation, reduction, and hydroxylation reactions to produce more hydrophilic, soluble, degradable, and less toxic compounds; (ii) transferring enzymes in the cytosol to pesticides that are activated functional groups forming conjugation with glutathione, glucose, and malonate; and (iii)Glutathione transporters are responsible for moving these conjugates into vacuoles (Ghasemi *et al*., 2011; Kumar and Singh, 2017; Laura *et al*., 2013; Mau *et al.*, 2017).

Studies have been done on the co-culture of microalgae and beneficial bacteria for pollutant removal. The ability of microalgae to produce oxygen for photosynthesis to support bacterial development and microalgae to use carbon dioxide produced by bacterial metabolism as,

Table 5: Summary of bioremediation potential of pesticides by algae

Sr. No.	Microorganism	Pesticides	Percentage of removal	References
1.	*Streptomyces sp. ML* *Streptomyces sp. OV*	Sole carbon thiamethoxam Dichlorophenol	84% o 40%	Bouferach *et al.*, (2022)
2.	*Monoraphidium braunii*	Bisphenol	48%	Gattulla*et al.*, (2012)
3.	*Scenedemusa quadricauda*	Dimethomorph pyrimethanil Isoproturon	24% 10%	Olette*et al.*, (2010)

			58%	
4.	*Selenastrum capricornutum* *Scenedesmus acutus*	benzo(a)pyrene	99% 95%	Lasera*et al.*, (2016)
5.	*Nannochloris oculate*	Lindane	73% -68.2%	Perez-legaspi*et al.*, (2016)
6.	*Chlamydomonas reinhardtii*	OrganophosphrusTrichloforn	100%	Wan*et al.*,(2020)
7.	*Chalamydomonas reinhardtii*	Fluroxypyr	57%	Zhang *et al.*, (2011)
8.	*Chlamydomonas reinharditi*	Trichlorforn	51.3%	Wan e*t al.*,(2020)
9.	*Chlorella vulgaris* *Scenedesmus quadricuda* *Spirulina platensis*	Malathion Nickle Lead Cadmium	99% 95% 89% 88%	Abdel-razek *et al.*, (2019)
10.	*Nostoc muscorum* *S. platensis*	Malathion	91%	Ibrahim *et al.*,(2014)
11.	*Serratia marcescens*	Chlorpyrifos Fenitrothion Parathion	58.9% 70.5% 82.5%	Cycon*et al.*, (2013)
12.	*Serratia liquefaciens* *Serratia marcescens* *Pseudomonas sp.*	Diazin	80%-92%	Cycon*et al.*,(2009)

Different pesticides can be broken down by bacteria in both liquid and soil environments.

Potentials for bacterial bioremediation are advantageous from an environmental and financial standpoint. The parent ingredient of a pesticide must be completely oxidized in order to produce carbon dioxide and water, which gives microorganisms energy. Pesticides are discovered to be degraded by Bacterium Raoultella sp. (Uquab*et al*., 2016).Group of bacteria are present in high concentration in soils called actinobacteria(Alvarez*et al.*, 2017). Most representative pesticide-degrading genera of actinobacteria such as, Arthrobacter, *Rhodococcus*, *Streptomyces*, *Frankia*, *Janibacter, Kokuria, Mycobacterium, Nocardia,* and *Psuedonocardia* (Alvarez *et al*., 2017).

Table 6: Summary of bioremediation potential of pesticides by Microoraganism

Sr. No.	Microorganism	Pesticides	Percentage of removal	References
1.	White rot fungi	Aldicarb Atrazine Alacholar	47% 98% 62%	Haie*et al.*, (2011)
2.	*Pseudomonas*	Crude oil	73.7%	Magan*et al.*, (2010)
3.	*B. cereus* *B. safensis*	Methomyl	88.25% 77.5%	Roy *et al.*, (2017)
4.	*Bacillus sefensis*	Diazinon	63%	Aly *et al.*,(2017)
5.	*Phanerochaete velutina*	Polyaromatic Hydrocarbons PHAs	96%	Winquist *et al.*, (2014)
6.	*Pleurotus ostreatus*	Polychlorinatrd biphenyls (PCBs)	50.5%	Stella *et al.*, (2017)
7.	*Rhizopus sp.* *Pencilliumfuniculosm* *Aspergillus sydowi*	Petroleum hydrocarbon (TPH) Aliphatic hydrocarbons(AH) Polycyclic aromatic hydrocarbon(PAH)	36% 30% 17%	Lopez *et al.*,(2008)
8.	*T. versicolar (*R26 and R101) *P. ostreatus*	Dieldrin Trifluralin Simazine	80%	Fragoeiro*et al.*,(2005)

9.	*Pleurotus cystidious* *Pleurotus sajor-caju* *Trametes socotrana* *Polystictus sanguime aus* *Trametes veriscolar* *Phanerochaete chrysosporium*	Simazine Trifluranin Dieldrin	50%	Magan*et al.*,(2010)
10.	*Novosphingobium Strain* DY4	2,4-dichlorophenoxyacetic acid	50and 95%	Dia*et al.*,(2005)
11.	*Pseudomonas*	Atrazine Carbofuran Glyphosate	90%	Echeverria *et al.*, (2020)
12.	*Trichoderma*	Dichlorvos Glyophosate	100%	Poveda *et al*., (2022)
13.	*Aspergillus oryzae* *Penicillium* *Trichoderma*	Glycophosate	60%	Correa *et al.*, (2019)
14.	*Stenotrophomonas sp.*	DDT DDE	81% 55%	Xie *et al*., (2022)
15.	*Sphingomonas trueperi CW3*	Allethrin	93%	Bhatt *et al.*,(2020)
16.	*Brucella spp.*	Dimethoate	83%	Ahmad *et al.*,(2022)

In comparison to other bacteria, fungi are more significant to pollution because they can quickly colonize and their hyphae can penetrate soil to access contaminants faster (Readdy and Mathew 2002; Harms *et al*., 2011).

Fungal enzymes like lignin, degrading enzymes, laccase, oxidoreductases, and peroxidases have the notable ability to remove the pesticides and insecticides residue from contaminated soil. Fungi are eukaryotic organisms that are diverse throughout the world in any environmental condition. They also have a high bioremediation potential to degrade pesticide residue. Pesticide degradation is influenced by soil's physical and chemical characteristics, contaminated microorganism kinds, and concentration levels(Khatoon *et al.*,2021).

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