**Biotechnological Approach for Bioremediation of Textile and Pesticides Industrial pollutants**

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Water has the central role in mediating global-scale ecosystem processes, linking atmosphere, lithosphere and biosphere by moving substances between them and enabling chemical reactions to occur. Natural waters are never pure water but a complex and ever-changing mixture of dissolved inorganic and organic molecules and suspended particles.

Water makes up 60 to 70 percent (on average) of the weight of living organisms. It fills cells, thereby giving form and support to many tissues. Water is the medium in which all if life’s chemical reactions occur, and it is an active participant in many of these reactions. Water is a solvent that dissolves the nutrients that cells need for life, as well as the wastes that cells produce. Thus, water is essential in delivering materials to and from cells. Water dissolves salts and other compounds, producing solutions that conduct electricity. These solutions, called electrolytes, also provide the energy that drives photosynthesis.

Clean drinking water and basic sanitation are necessary to prevent communicable diseases and to healthy life. For many of the world’s poorest people, one of the greatest environmental threats to health remains the continued use of polluted water. In 2002 the United Nations estimated that at least 1.1 billion people lacked access to safe drinking water and 2.4 billion didn’t have adequate sanitation. These deficiencies result n hundreds of millions of cases of water-related illness and more than 5 million deaths every year. As populations grow, more people move into cities, and agriculture and industry compete for increasingly scarce water supplies, water shortages are expected to become even worse. By 2025, two-thirds of the world’s people will be living in water-stressed countries-defined by the United Nations as consumption of more than percent of renewable freshwater resources. One of the highest priorities announced at the UN World Summit in Johannesburg in 2002, is to reduce by one-half the proportion of people without reliable access to clean water and improved sanitation.

Some 45 countries, most of them in Africa or the Middle East, cannot meet the minimum essential water needs of all their citizens. In some countries, the problem is access to clean water. In Mali, for example, 88 percent of the population lacks clean water; in Ethiopia, it is 94 percent. Rural people often have less access to clean water than do city dwellers. Causes of after shortages include natural deficits, over consumption by agriculture or industry, and inadequate funds for purifying and delivering good water.

More than two-thirds of the world’s households have to fetch water from outside the home. This is heavy work, done mainly by women and children, and sometimes taking two hours a day. Improved public systems bring many benefits to the poor families.

Availability does not always mean affordability. A typical poor family in Lima, Peru, for instance, uses one-sixth as much water as a middle-class American family but pays three times as much for it. If they followed government recommendation to boil all water to prevent cholera, up to one-third of the poor family’s income could be used just in acquiring and purifying water.

Investments in rural development have brought significant improvements over the past decade. Since 1990, nearly 800 million people-about 13 percent of the world’s population-have gained access to clean water. The percentage of rural families with safe drinking water has risen from less than 10 percent to nearly 75 percent.

**Bioremediation**

Environmental biotechnology is not a new field; composting and wastewater treatments are familiar example of old environmental biotechnologies. Bioremediation is a biotechnical process, which abates or cleans up environmental contamination. In bioremediation term ‘bio’ means living organism and ‘remediate’ means solve the problems. It is a type of waste managenment technique which involves the use of organism to remove or utilize the pollutants from a polluted area.

Due to increased worldwide human population, there is increased demand for food energy and other daily life requirements. The Industrial revolution responds to these needs, which has resulted in the production of various organic and inorganic chemicals in large quantities. These processes are directly or indirectly lead to environmental pollution in various way. Many different technologies are used to reduce pollution, among which is bioremediation technology in which by biological agents are used to neutralize harmful chemicals or less toxicity pollutant.

Recently it was felt that bioremediation is a solution for emerging hazardous contaminant problems that involved number of microbes including algae, fungi, both aerobic & anaerobic bacteria.In this process pollutants are transformed by living organisms through reaction take place as a part of their metabolic processes (Kensa *et al*., 2011). In this process sometimes, naturally occurring bacteria and fungi are used to degrade or detoxify substances which are hazardous to human health and or the environment. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated sites.

**Applications of Bioremediation**

1. It is simple and less labor-intensive method.
2. It is natural process, takes a little time when microbes degrade contaminant by increasing in number, but when contaminant degrade the population of microbes also decreases.
3. Eco-friendly and sustainable.
4. Bioremediation is useful for the complete destruction of wide variety of contaminants by transforming hazardous to harmless products.
5. Instead of transforming contaminants from one environmental medium to another like land to water or air, destruction of pollutants is possible.
6. Bioremediation can be carried out on site, so no need to transport of waste off site; it can avoid threats to human health and environment during transportation.
7. Bioremediation is less expensive than other technologies that are used for clean-up of hazardous waste.
8. Bioremediation esthetic values by protecting environment from industries.
9. Contaminants are destroyed, not simply transferred to different environmental media.
10. Relative ease of implementation.
11. Non-intrusive, potentially allowing for continued site use.

**Bioremediation Types**

**Microbial bioremediation**

Use of bacteria and fungi microorganism for remove toxic pollutant. Microbes can grow at below zero temperature presence of hazardous compound. The factors are mainly microbial population for degrading the pollutants, the accessibility of contaminants to the microbial population and environment factors like type, of soils, pH, temperature, oxygen and nutrients( Sharma, 2020).

**Phytoremediation**

In this process, the use of green plants and the associated microorganism for remove toxic environmental contamination to harmless. Phytoremediation based on several process that is Phytodegradation, phytovolatilization, Phytoaccumulation and Phytoextraction. The cost of phytoremediation is lower than other traditional processes and useful to increase soil health, yield and plant Phytochemicals (Singh *et al.,* 2017).

**Mycoremediation**

In term of Mycoremediation, the process of degrading toxic materials the environment using fungi. Enzymes of fungi are non-specific and are able to breakdown many kinds of substance. The most developed branch of mycoremediaton is ‘White rot fungi’ (Tomer et al., 2021).

**Bio- Stimulation**

Bio-stimulation is an ability to deliver the stimulus to the environment. Bio-stimulation is one of most mature method of bio-remediation of hydrocarbons recently advanced in geophysics, stable isotope analyses and molecular microbiology. The injection of specific nutrients at the site (Soil/ Ground water) to stimulate the activity of indigenous microorganisms include naturally existing bacteria and fungus community, by supplying firstly fertilizers, growth supplements and trace minerals, secondly providing other environmental factors like PH, Temperature and Oxygen to seed up their metabolism rate. In that presence of small amount of pollutant also act as stimulants by turning on for bioremediation enzymes. Nutrients and Oxygen helps most of time to continue these paths by helping to indigenous microorganisms (Kensa *et al.,* 2011).

**Bioatteuation**

In bioattenuation, the pollutants are transformed to less harmful form. These transformation processes are largely due to biodegradation by microorganism and some extent process by the reaction with naturally occurring chemicals and sorption on the geologic media. Natural attenuation process is contaminated specific accepted as method for treating fuel compound, not for many other classes.

Many polluted sites may not require an aggressive approach to remediation. Bioattenuation is efficient and cost effective (Maitra, 2018).

Bioattenuation depends on natural process of degradation. This is method of monitoring the natural progress of degradation to ensure that contaminant concentration decreases with time at relevant sampling points (Sharma *et al*., 2020).

**Biopile**

This is ex-situ technique is progressively measured because of its cost effectiveness feature allows operative biodegradation conditions include PH, Nutrients, Temperature and Aeration are effectively controlled.

Biopile also known as bio-cells, bio-heaps, bio-compound and compost piles are used to reduce concentrations of petroleum pollutants in excavated soils during the time of biodegradation. This technique comprises aeration, irrigation, nutrients, leachate collection and treatment bed systems. The biopile use to treat volatile low molecular weight pollutants can also be used effectively.

Biopile systems connected to additional field ex-situ bioremediation techniques, such as land farming, bioventing, biosparging, robust engineering, maintenance and operation cost, lack of power supply at remote sites, which facilitated constant air circulation in contaminated piled soil through air pump.

Extreme heat of air can lead to soil drying undertaking bioremediation, which inhibit microbial activities and which stimulation volatilization than biodegradation.

The microbial activity is enhanced through microbial respiration then result in degradation of adsorbed petroleum pollutant became high (Sharma *et al*., 2020).

**Bioventing**

Bioventing technique involve controlled stimulation of airflow by delivering oxygen to unsaturated zone in order to increase activities of indigenous microbes for bioremediation, amendments are made by adding nutrients and moisture to increase bioremediation, that achieve microbial transformation of pollutants to harmless state.

Effective bioremediation of petroleum contaminated soil using bioventing. Bioventing can significantly reduce the concentration of a range of hydrocarbons and other organic contaminants in unsaturated soils. Bioventing remediation systems should be designed and minimize the volatilization of constituents. It reduces cost of remediation by reducing need off-gas treatment (LEE *et al*., 1993).

**Bioremediation of water waste of textile and dye industry**

**Textile dye**

Commercial synthetic dyes find their application in various industry such as textiles, leather, paper printing, paint, food, cosmetic, pigments, plastic and pharmaceutical industries with an annual consumption of >7X105metric tons.

The textile industry plays a significant role in the economic development of any country, with China being the largest exporter of textile products, followed by the European Union, India, The USA and, the Turkey (Sudarshan *et al*. 2023)

**Textile Waste Toxicity**

Medical conditions such as Nausea, Hemorrhage, Skin and Mucous membrane ulceration, Dermatitis, Perforation of the nasal septum, and Numerous respiratory tract irritations may result from the usage of textile dyes.

Also causes Breathing problems and possibly causing nausea, vomiting, diarrhea, gastritis, and mental disorientation when inhaled.

Improperly disposed textile dye effluent into water bodies results in intense coloration of the water, which reduces light penetration can also affecting photosynthetic activity, so it increases heterotrophic activity, it leads to completely lowers dissolved oxygen levels which affects aquatic life (Sudarshan *et al.*2023*)*

**Types**

1. **Bioremediation of textile water waste by Bacteria**

Bacteria and cyanobacteria are the most effective degraders of synthetic dyes due to their short life cycles low secondary waste generation and adaptability to a variety of substrates and these cyanobacteria do not need organic carbon as a source of energy, since they are photosynthetic bacteria.

Microorganism acclimatize themselves to the hazardous chemical environment and dye-resistant strains develop by naturally, which transform toxic chemicals into less or non-harmful forms.

Some bacterial strains, such as *Bacillus cereus*, *Pseudomonas patida* and *Pseudomonasfluorescence, 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% decolorization within 72hrs. | Unnikrishnan *et al*., (2018) |
| 5. | Reactive Yellow 145 | *Pseudomonas aeruginosa & Thiosphaera pantothropha ATCC 35512* | Each culture has 50% decolorization within 96 hrs. | Garg*et al*., (2020) |
| 6. | Disperse Blue 284 | *Klebsiella pneumoniae GM-04* | 95% decolorization within 24 hrs. | Mustafa*et al*., (2021) |
| 7. | Reactive Red HE8B | *Pseudomonas aeruginosa* | 86% decolorization within 48 hrs. | Patel*et al*., (2016) |
| 8. | Reactive Black 5 | *Aeromonas hydrophila* | 76% decolorization within 24 hrs. | El Bouraie*et al*., (2016) |
| 9. | Reactive Red 120 | *Shewanella haliotis* | 99% decolorization in 2.5 hrs. | Birmole*et al.,* (2019) |
| 10. | Congo Red, Reactive Black 5 | *Enterococcus faecalis R1107* | 65.57% & 72.64 % decolorization Resp. within 48 hrs. | Wang*et al.,* (2022) |
| 11. | Malachite Green | *Pandoraea pulmonicola* | 85.2% decolorization | Chen*et al*., (2009) |
| 12. | Reactive Blue 59 | *Bacillus odyssey SUK3, Morganella morganii SUK5 & Proteus sp. SUK7* | 100% decolorization within 60h, 30h. & 24h resp. | Patil*et al*., (2008) |
| 13. | Reactive Orange 16 | *Pseudomonas sp.* | 100% decolorization within 48 hrs. | Jadhav*et al.,* (2010) |
| 14. | Reactive Green 19A | *Micrococcus glutamicus NCIM-2168* | 100% decolorization within 42hrs. | Saratale *et al*., (2009) |
| 15. | Direct Black 22 | *Bacterial consortium* | 100% decolorization within 12 hrs. | Mohana *et al.,* (2008) |
| 16. | Metanil Yellow | *Bacillus sp. AK1 & Lysinibacillus sp. AK2* | 100% decolorization within 27 hrs.& 12 hrs. Resp. | Anjaneya *et al*., (2011) |
| 17. | 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. | Prabhakare*t al*., (2022) |
| 18. | Acid Black, Congo red, Acid red 27, Reactive black, Methylene Blue | *Bacillus licheniformis* | 51.2%, 1.9%, 32.05%, 36.2% decolorization resp. | Kesebiret e*t al.,* (2021) |
| 19. | Congo red, brilliant blue,& Bromophenol blue, Crystal violet | *Staphylococcus haemolyticus* | 80% and 40% decolorization resp. within 3 hrs. | Li e*t al*., (2020) |
| 20. | Malachite Green | *Dietzia sp.* | 72.05% decolorization | Bera*et al*., (2016) |
| 21. | Amido Black 10B | *Chroococcus minutus* | 55% decolorization | Parikh *et al.,* (2005) |
| 22. | Reactive Dark blue | *Exiguobacterium sp.* | 97% decolorization within 24 hrs. | Qu *et al*., (2010) |

1. **Bioremediation of Textilewaste water by using Microalgae**

Waste water generated from the textile industry contains numerous pollutants, most of dyes, causes adverse effects, including negative impact on aesthetics, eutrophication, decrease of photosynthetic activity and bioaccumulation of toxins in aquatic ecosystem, if discharged without adequate treatment.

The cultivation of microalgae in the textile dye effluent has identifies as a promising alternative conventional method of waste water treatment.

The treatment using microalgae reduces color and nutrient load of textile effluent, which reduce numerous negative environmental impacts causes by its discharge into natural environment, as well as conventional treatment process by using of microalgae for bioremediation of textile effluents provided valuable biomass that can be processed into bioproducts, biofuels and bioenergy (Premarathe *et al*., 2021).

(80% of the dye in 20 days)

**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 vulgaris | 98% Decolorization | Mahalakshmi *et al*., (2015) |
| 3. | Direct Red 5B | Comamonas sp. UVS | 100% decolorization | Jadhav *et al*., (2008) |
| 4. | Congo Red | Haematococcus 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 | Chlamydomona reinhardtii | 72.97% Decolorization | San *et al.,* (2015) |
| 12. | Remazol Black B | Phormidium animale | 99.96 % decolorization | Bayazit *et al.,* (2020) |

1. **Bioremediation of textile waste water by using Fungi-**

Biological method by using different microorganism and fungi consider as most effective and less energy intensive to removing the bulk of the pollutants from water.

Fungi removal of industrial dye by using adsorption process but in some fungi like White Rot Fungi both adsorption and degradation can occur simultaneously.

The decolorization of textile dyes by using pellets of the white rot fungus *Funalia trogii.*

The decolorization activity was significantly affected by dye concentration, amount of pellet, temperature and agitation of the media.

The deculturation of dyes by fungi i.e., white rot fungi, can secrete ligninolytic enzymes binds to non-specifically to substrate and thereafter degrade wide variety of recalcitrant compound (i. e., pollutant including dyes) (Jebapriya *et al*., 2013).

**Table 3. Summary of decolorization of various dyes by Fungi**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Species** | **Dye** | **Percentage Removal** | **References** |
| 1. | *Aspergillus versicolor* | 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 W-NN | 33% decolorization | Biyik *et al*., (2012) |
| 13. | *Cyathus bulleri* | Reactive Red 198, Reactive Orange | 80 % decolorization | Chhabra *et al*., (2008) |

**Environmental and human health impacts of some commonly used dyes**

1. Malachite green is used as an antifungal and antiprotozoal agent in aquaculture. It also widely used in the food, textile, leather, paper and paint industries, which affects immune and reproductive system of humans.
2. Commercial Xanthene and Rhodamine B, it is widely used water tracer dye, food colorant and in the textile, paper paint and leather industries, these has genotoxic, carcinogenic and neurotoxic activity in human and animals.

Rhodamine B contaminated drinking water can cause subcutaneous tissue-borne sarcoma.

1. Brilliant green- Used in paper, textile, rubber and plastic industries. It is carcinogenic and mutagenic in both of humans and aquatic life.
2. Azo dyes-used in textile, leather, food, cosmetics, paper printing, paint and pharmaceutical industries, they are mutagenic, carcinogenic, and genotoxic compound.
3. Monoazo dyes(Metanil yellow)-used as colorant in food, beverages, soap, spirit lacquer, shoe polish, wood paints, leather dyeing, ink and for manufacturing of colored paper. It is carcinogenic after gene expression and has been decrease rate of spermatogenesis, oral consumption causes toxic methemoglobinemia and cyanosis in humans.
4. Methyl orange-used in textile industry and in laboratory as a PH indicator. It is reported as a toxic and mutagenic, produce acute and chronic effects on aquatic life (Sudarshan *et al*. 2023).

**Bioremediation of pesticides**

The use of pesticides in agriculture increases crop productivity and reduces the loss of crops. Pesticides releases agricultural discharge into water increase the pesticides toxicity of water and disturbs the aquatic life (Singhal *et al.,* 2021).

Total amount of global usage of pesticide are, 52.8% is used Asia, 30.0% is used by USA, 13.7%is used by Europe ,2.2% is used by Africa and 1.3% used by Oceania (FAO, 2018).

The removal of pesticide depends on two aspects: first is related to the optimal conditions of the biome and its survival and activity and second one is related to the chemical structure of the pesticide, factors related to organism (microalgae), including the number of appropriate organisms, biological and substrate, available water, oxygen tension and redox potential, surface bonding, the presence of alternative carbon substrates, and other electron acceptors. (Nie,2019)

Pesticides has massively contributed to the agricultural in controlling pests worldwide, therefor increasing the crop yield from agricultural, but large amount of applying pesticidal chemical effect in the agricultural land and adverse effect on natural ecosystem as well as human health. This reason the discovery of rapid pesticides detoxification technique is more important.

Bioremediation play a great role in detoxifying residual pesticides in the environment. Various microorganism has capability of to degrade or detoxify pesticides such as Algae, Bacteria, and fungi.

Pesticides treatment method majorly depends on the composition of pesticides in contaminant of pesticides in contaminant wastewater, treatment cost and simplicity of operation therefore, a Comprehensive analysis of influent characteristics and the coupling of the most suitable treatment technology are required for the design of treatment facilities targeted for removal of emerging pollutant such as pesticides in wastewater. Physical, chemical, and biological methods have been widely used for removal of degradation of pesticides in aqueous medium (Nie*et al.,* 2020).

**Harmful effect of pesticides and heavy metals on human health**

Most toxic pesticides are Organophorus (op), Carbamate (CB) and OC pesticides, these pesticides are powerful chemicals that act as by disrupting nervous system function (Riodolfi*et al.,*2014).

**Table 4. Harmful effect of pesticides on human health**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sr no.** | **Pesticides** | **Health effects** | Green *et al*., 2004) |
| 1. | Aldrin | Nervous system effects. Probable carcinogen. |
| 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. |

**Microalgae based sustainable bioremediation of contaminated by pesticides**

Algae are important component of soil microflora, probably accounting for up to 27% of the total microbial biomass in the soil. It also involved in maintaining soil fertility and oxygen production and important for the nitrogen economy of soils. Algae fix carbon Dioxide(Co2) and release oxygen (O2)by photosynthesis and increase BOD. Algae is utilized as soil conditioners, or biofertilizer. Play an important role in controlling and biomonitoring of organic pollutant in aquatic ecosystem(Nie *et al* 2019).

In bioremediation present different mechanism for removal of pesticide by microalgae including bio adsorption, bioaccumulation, and biodegradation. (Nie *et al* 2019).

Bio adsorption is passive process (Ardal *et al.,*2014). Recentstudy (Mishaqa*et al*., 2017) reported by 87-96% of various pesticides (atrazine, simazine, molinate, isoproturn, carbofuran, propanil, dimethoate, metolachlor, pendimethalin, and pyriproxin) in aqueous phase removed by bio adsorption by cultivated algae.

Bioaccumulation is active process (Ardal*et al*., 2014) can be expressed by bio-concentration factor (BCF)values are mostly affected by differences in the bioconcentration mechanism, bioavailability of chemicals, physicals barrier, methods of BCF determination, dissolved organic matter, metabolism, ionization of ionizable compounds and environmental conditions (Wang *et al.,*2014) In other information, BCF values differ at different concentration. And BCF values found of prometryne at concentrations of 2.5(or 5.0) g/L were higher than those at concentration of 10.0 (or12.5) g/L IN green algae (Jin*et al.,*2012).

The biodegradation of pesticides in environment depends on the metabolism of various enzymes. Considered predominant enzymes in the process of pesticides detoxification are Esterase, transferase, and cytochrome P450 (Devonshire and field,1991). Degradation of pesticides is multi-step process involving enzyme metabolism as (i) activation of pesticides in the absence of functional groups by cytochrome P450 *via* oxidation, reduction, and hydroxylation reactions to obtain more hydrophilic ,soluble, degradable less toxic compounds; (ii) transfer of enzymes in the cytosol to pesticides that are activated functional groups forming conjugation with glutathione, glucose, and malonate; and (iii) transportation of such conjugates into vacuoles by glutathione transporters (Ghasemi *et al*.,2011; Kumar and Singh, 2017; Laura *et al*., 2013; Mau *et al*., 2017).

The co-culture of microalgae with bacteria helpful for removal of contaminants has been studied. Key to their coexistence is microalgae can produce oxygen for photosynthesis to promote bacteria growth, while the carbon dioxide produced by bacterial metabolism is used by microalgae for photosynthesis.

**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. | *Monoraphidiumbraunii* | Bisphenol | 48% | Gattulla*et al.,* (2012) |
| 3. | *Scenedemusaquadricauda* | Dimethomorph pyrimethanil  Isoproturon | 24%  10%  58% | Olette*et al.,* (2010) |
| 4. | *Selenastrumcapricornutum*  *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% | Wanetal*et al.,*(2020) |
| 7. | *Chalamydomonasreinhardtii* | Fluroxypyr | 57% | Zhang *et al.,* (2011) |
| 8. | *Chlamydomonas reinharditi* | Trichlorforn | 51.3% | Wanetal 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. | *Serratialiquefaciens*  *Serratia marcescens*  *Pseudomonas sp.* | Diazin | 80%-92% | Cycon*et al.,*(2009) |

**Microbial degradation of different pesticides in liquid and soil medium**

Bacterial bioremediation potentials are benefical for environment and economical stand.

Complete biodegradation of pesticide involves the oxidation of the parent compound resulting in to carbon dioxide and water, this provides energy to microbes. *Bacterium raoultella* sp.is found to degrade pesticides (uqab *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 Microorganisms**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **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*7 | | Diazinon | 63% | | | Aly *et al.,*(2017) |
| 5. | *Phanerochaetevelutina* | | Polyaromatic  Hydrocarbons  PHAs | 96% | | | Winquist *et al.,* (2014) |
| 6. | *Pleurotusostreatus* | | Polychlorinatrd biphenyls (PCBs) | 50.5% | | | Stella *et al.,* (2017) |
| 7. | *Rhizopus sp.*  *Pencillium funiculosm*  *Aspergillus sydowi* | | Petroleum hydrocarbon  (TPH)  Aliphatic hydrocarbons(AH)  Polycyclic aromatic hydrocarbon(PAH) | 36%  30%  17% | | | Lopez *et al.,*(2008) |
| 8. | *T.versicolor (*R26 and R101)  *P.ostreatus* | | Dieldrin  Trifluralin  Simazine | 80% | | | Fragoeiro*et al.,*(2005) |
| 9. | *Pleurotus.Cystidious*  *Pleurotussajor-caju*  *Trametessocotrana*  *Polystictussanguimeaus*  *Trametesveriscolar*  *t.versicolar*  *phanerochaetechrysosporium* | | Simazine  Trifluranin  Dieldrin | 50% | | | Magalet*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. | *Sphingomonastrueperi CW3* | Allethrin | | | 93% | Bhatt *et al.,*(2020) | |
| 16. | *Brucella spp.* | Dimethoate | | | 83% | Ahmad *et al.,*(2022) | |

Fungi are more relevant of pollutants as compare to other microbes, they canquicklycolonize because their hyphae canpenetrate into soil to reach faster to words soil contaminates than other microorganism (Readdy and Mathew 2002; Harms *et al*., 2011).

Fungi are eukaryotic organism, and diversify all over the world in any environmental condition, having high bioremediation potential to degrade pesticide residue with their enzymatic activity such fungal enzymes like, lignin, degrading enzymes, laccase, oxidoreductases and peroxidases have the prominent capacity to remove the pesticides and insecticides residue from contaminated soil. Degradation of pesticide depends upon contaminated concentration types of microorganism, physical and chemical properties of soil (Khatoon *et al.,*2021)

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