

Microbial Assisted Bioremediation of Polluted Water

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Abstract

Bioremediation is a process to remove or detoxify contaminant present in the environment by certain biomolecules or biomass to bind and concentrate selected ions or other molecules. Water pollution is an issue of great concern worldwide, and it can be broadly divided into three main categories, that is, contamination by organic compounds, inorganic compounds (e.g., heavy metals), and microorganisms. A wide range of microorganisms, including bacteria, fungi, yeasts, and algae, can act as biologically active methylators, which are able to at least modify toxic species. Microorganisms cannot destroy metals, they can alter their chemical properties via a surprising array of mechanisms. Different factors affect bioremediation include environmental factor biological factor, availability of nutrients, temperature, pH, and toxic compounds. Among organic pollutants, hydrocarbons may enter in water either directly by spills or effluents or indirectly from atmosphere. These metals are extremely sensitive at low concentrations and can be stored in food webs, posing a serious public health risk. Several microorganisms (natural/exotic/ engineered) having specific metabolic capability and various enzyme production ability which fall under six main divisions include Oxidoreductases, Transferases, Hydrolases, Lyases, Isomerases and Ligases (synthetases) are used during bioremediation process. The heavy metals associated with environmental contamination, for instance, lead (Pb), cadmium (Cd), and chromium (Cr), which are potentially hazardous to ecosystems. The types of microorganisms that are used in bioremediation processes due to their natural capacity to biosorb toxic heavy metal ions.

Keywords: Bioremediation, Biological Organisms, Environmental Pollution, Metals, Microorganisms, polluted water.

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INTRODUCTION

Environmental contamination by heavy metals from anthropogenic and industrial activities has caused considerable irreparable damage to aquatic ecosystems. Sources include the mining and smelting of ores, effluent from storage batteries and automobile exhaust, and the manufacturing and inadequate use of fertilizers, pesticides, and many others. The metals and metalloids that contaminate waters and are most commonly found in the environment include lead, chromium, mercury, uranium, selenium, zinc, arsenic, cadmium, silver, gold, and nickel. Several different physicochemical and biological processes are commonly employed to remove heavy metals from industrial wastewaters before their discharge into the environment [1].

Conventional physicochemical methods such as electrochemical treatment, ion exchange,

precipitation, osmosis, evaporation, and sorption are not cost-effective, and some of them are not environmentally friendly [2, 3]. The bioremediation strategy is based on the high metal binding capacity of biological agents, which can remove heavy metals from contaminated sites with high efficiency. In this regard, microorganisms can be considered as a biological tool for metal removal because they can be used to concentrate, remove, and recover heavy metals from contaminated aquatic environments [4]. Bioremediation have using microorganisms for the uptake of heavy metals in polluted waters, as an alternative strategy to conventional treatments [5-7]. The term “heavy metal” generally refers to metallic elements with an atomic weight higher than that of Fe (55.8 g mol⁻¹) or density greater than 5.0 g cm⁻³, and these metals are naturally present in the environment [7]. Heavy metal is of economic significance in industrial use and currently becomes a significant environmental problem throughout the whole world [8].

Microorganisms use chemical contaminants as an energy source through their metabolic processes throughout the microbiological process [9]. Microorganisms, in particular, have the ability to degrade, detoxify, and even accumulate harmful organic as well as inorganic compounds. There are different sources of heavy metals in the environment, such as natural, agricultural, industrial solid waste, inland effluent, atmospheric sources, and more sources [10]. On the bioremediation process using various microorganisms, including Algae, bacteria, fungi, and the mechanisms of action, for the potential use of genetic engineering techniques to develop prominent recombinant novel microorganism variants that are more efficient and improvements in the operation conditions of bioremediation technologies [11].

The microbes are biochemically discovered and their potential to resist heavy metals such as zinc and copper will be determined [12]. A Bioremediation technique, with the ultimate goal being to effectively restore polluted environments in an eco-friendly approach at very low cost is available [13]. The process of pollutant removal depends primarily on the nature of the pollutant, which may include agrochemicals, chlorinated compounds, dyes, greenhouse gases, heavy metals, hydrocarbon, nuclear waste, plastics, and sewage. Apparently, taking into consideration the site of application, bioremediation techniques can be categorized as ex-situ or in-situ. Pollutant nature, depth and degree of pollution, type of environment, location, cost, and environmental policies are selected of the selection criteria that are considered when choosing any bioremediation technique [14]. Heavy metals can play a role as micronutrients, such as Cu, Fe, Mn, Mo, Zn, and Ni, but they can also be toxic to humans, e.g., Hg, Pb, Cd, Cu, Ni, and Co [15]. Heavy metals are notable contaminants because they are toxic, nonbiodegradable in the environment, and easily accumulated in living organisms [16]. The contamination of waters with heavy metals occurs through natural and anthropogenic activities, mainly related to industrialization.

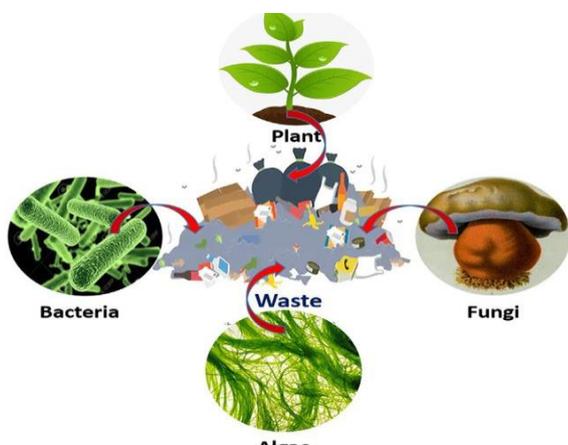


Figure 1: Types of microorganisms used in bioremediation processes [16]

Principal of Bioremediation

Bioremediation is defined as the process whereby organic wastes are biologically degraded under controlled conditions to an innocuous state, or to levels below concentration limits established by regulatory authorities [17]. The aim of bioremediation is encouraging them to work by supplying optimum levels of nutrients and other chemicals essential for their metabolism in order to degrade/ detoxify substances which is hazardous to environment and living things. Bioremediation relies on stimulating the growth of certain microbes that use contaminants like oil, solvents, and pesticides as a source of food and energy.

These microbes consume the contaminants, converting them into small amounts of water and harmless gases like carbon dioxide. All metabolic reactions are mediated by enzymes [18]. These belong to the groups of oxidoreductases, hydrolases, lyases, transferases, isomerases and ligases. Many enzymes have a remarkably wide degradation capacity due to their nonspecific and specific substrate affinity. Bioremediation is occurred naturally and encouraged within addition of living things and fertilizers. Bioremediation technology is principally based on biodegradation. It refer to complete removal of organic toxic pollutants in to harmless or naturally occurring compounds like carbon dioxide, water, inorganic compounds which are safe for human, animal, plant and aquatic life [19].

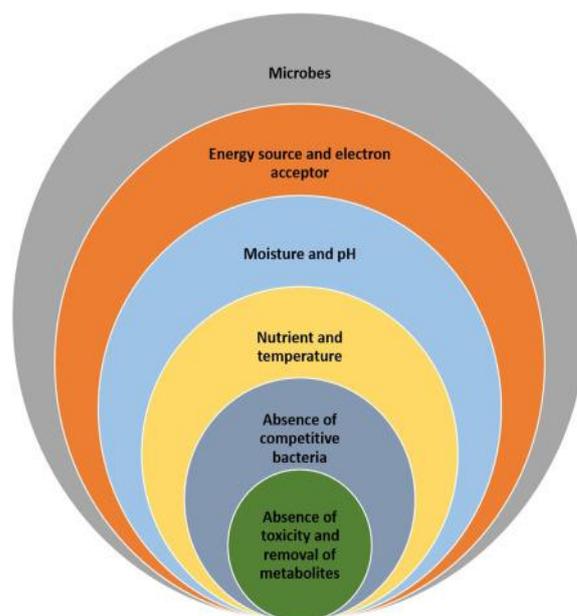


Figure 2: Principals of Bioremediation [19]

Mechanism of Bioremediation

Bioremediation is a biological treatment system to destroy, or reduce the concentration of hazardous waste from a contaminated site.

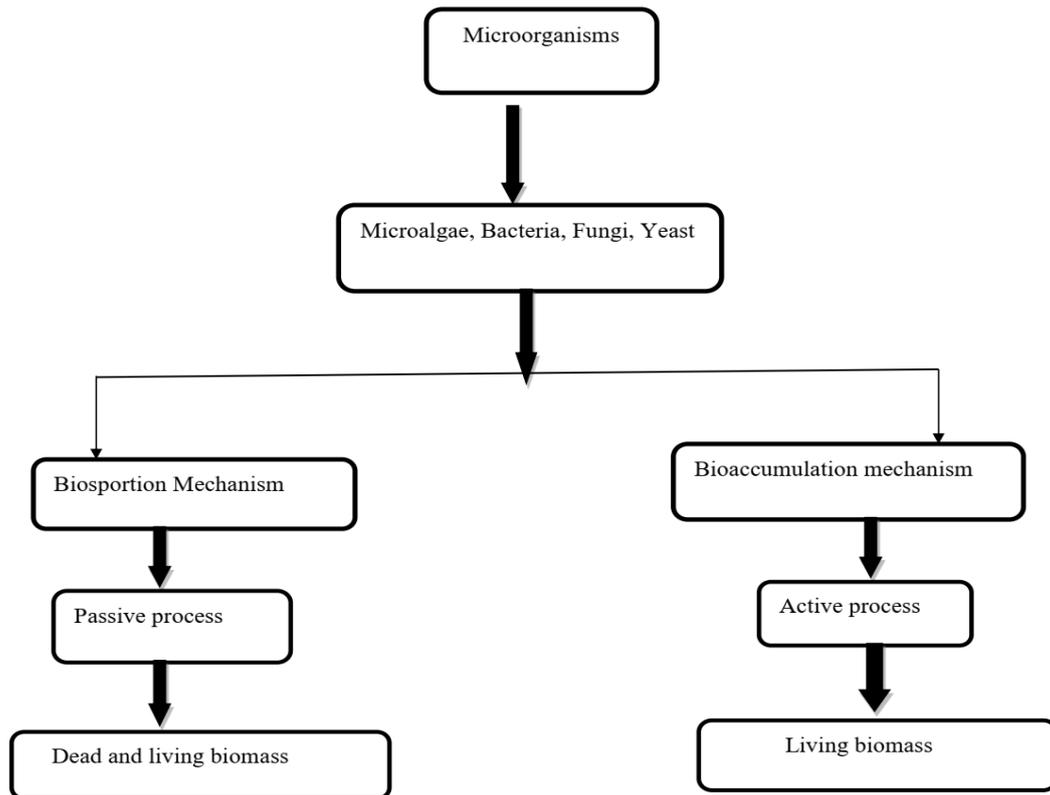


Figure 2: Microorganisms employed in the bioremediation and processes/mechanisms Involved in the case of dead and living biomass [20, 21]

Mechanisms of microbial metal resistance includes precipitation in stable states such as phosphates, sulfates etc, metal volatilization by addition of methyl group, intracellular accumulation due to presence of specific proteins named as cysteine –rich proteins [22, 23]. Bioremediation can be separated into two categories, biosorption and bioaccumulation. Biosorption is a passive adsorption mechanism that is fast and reversible [24, 25].

Factors affecting microbial bioremediation

Bioremediation is involved in degrading, removing, altering, immobilizing, or detoxifying various chemicals and physical wastes from the environment through the action of bacteria, fungi and plants. Microorganisms are involved through their enzymatic pathways act as biocatalysts and facilitate the progress of biochemical reactions that degrade the desired pollutant [26]. The efficiency of bioremediation depends on many factors; including, the chemical nature and concentration of pollutants, the physicochemical characteristics of the environment, and their availability to microorganisms [27]. The availability of contaminants to the microbial population and environment factors (type of soil, temperature, and pH, the presence of oxygen or other electron acceptors, and nutrients).

Biological factors

A biotic factors are affect the degradation of organic compounds through competition between

microorganisms for limited carbon sources, antagonistic interactions between microorganisms or the predation of microorganisms by protozoa and bacteriophages [28]. The expression of specific enzymes by the cells can increase or decrease the rate of contaminant degradation. The major biological factors are included here: mutation, horizontal gene transfer, enzyme activity, interaction (competition, succession, and predation), its own growth until critical biomass is reached, population size and composition [29].

Environmental Factors

The metabolic characteristics of the microorganisms and physicochemical properties of the targeted contaminants determine possible interaction during the process. The actual successful interaction between the two; however, depends on the environmental conditions of the site of the interaction [30]. Microorganism growth and activity are affected by pH, temperature, moisture, soil structure, solubility in water, nutrients, site characteristics, redox potential and oxygen content, lack of trained human resources in this field and Physico-chemical bioavailability of pollutants (contaminant concentration, type, solubility, chemical structure and toxicity). This above listed factors are determine kinetics of degradation [31] Biodegradation can occur under a wide range of pH; however, a pH of 6.5 to 8.5 is generally optimal for biodegradation in most aquatic and terrestrial systems.

Temperature

Among the physical factors temperature is the most important one to determining the survival of microorganisms and composition of the hydrocarbons [32]. In cold environments such as the Arctic, oil degradation via natural processes is very slow and puts the microbes under more pressure to clean up the spilled petroleum. The sub-zero temperature of water in this region causes the transport channels within the microbial cells to shut down or may even freeze the entire cytoplasm, thus, rendering most oleophilic microbes metabolically inactive [33]. Biological enzymes are participated in the degradation pathway have an optimum temperature and will not have the same metabolic turnover for every temperature. Moreover, the degradation process for specific compound needs specific temperature. Temperature also speed up or slow down bioremediation process because highly influence microbial physiological properties. The rate of microbial activities increases with temperature, and reaches to its maximum level at an optimum temperature [34].

PH

PH of compound which is acidity, basicity and alkalinity nature of compound, it has its own impact on microbial metabolic activity and also increase and decrease removal process. The measurement of pH in soil could indicate the potential for microbial growth [35]. Higher or lower pH values showed inferior results; metabolic processes are highly susceptible to even slight changes in pH [36]

Moisture content

Microorganisms require adequate water to accomplish their growth. The soil moisture content has adverse effect in biodegradation agents [37].

Concentration of oxygen

Different organisms require oxygen others also do not require oxygen based on their requirement facilitate the biodegradation rate in a better way. Biological degradation is carried out in aerobic and anaerobic condition, because oxygen is a gaseous requirement for most living organisms. The presence of oxygen in most cases can enhance hydrocarbon metabolism [32].

Availability of nutrients

The addition of nutrients adjusts the essential nutrient balance for microbial growth and reproduction as well as having impact on the biodegradation rate and effectiveness. Nutrient balancing especially the supply

of essential nutrients such as N and P can improve the biodegradation efficiency by optimizing the bacterial C: N: P ratio [38]. To survive and continue their microbial activities microorganisms need a number of nutrients such as carbon, nitrogen, and phosphorous. The addition of an appropriate quantity of nutrients is a favorable strategy for increasing the metabolic activity of microorganisms and thus the biodegradation rate in cold environments [39]. Biodegradation in aquatic environment is limited by the availability of nutrients [40]. Similar to the nutritional needs of other organisms, oil-eating microbes also require nutrients for optimal growth and development. These nutrients are available in the natural environment but occur in low quantities [41]

Toxic compounds

When in high concentrations of toxic nature of some contaminants can create toxic effects to microorganisms and slow down decontamination. The degree and mechanisms of toxicity vary with specific toxicants, their concentration, and the exposed microorganisms. Some organic and inorganic compounds are toxic to targeted life forms [27].

Water Pollution, contamination and diseases caused by heavy metals

Water pollution is the contamination of water bodies like lakes, rivers, oceans, aquifers and groundwater. Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Different concentrations of heavy metal elements commonly occur in all ecosystems. Several compounds have diverse properties, such as Zn, Cu, Ni, Fe, and Mn, are essential trace elements [42]. Heavy metals can cause severe toxic effects to expose plants, animals, and humans when exposed to excessive concentrations [43]. When the concentration of heavy metals enters the human body through absorption, these metal ions can bind various biomolecules, such as proteins, nucleic acids, and interfere with their functions [228] Globally, open water and aquatic ecosystems are contaminated with several heavy metals through various human activities that indirectly or directly lead to these pollution [44]. The most serious water pollution has occurred with some waterbodies, such as rivers, lakes, oceans, and groundwater. In addition, a high amount of materials can change the water properties and pollute the water, thus resulting in an unfit for intended uses. Water pollution can be classified into two distinct types that are point sources and nonpoint sources [45].

Table 1: Contamination sources, uses, and adverse health effects of some heavy metals [46-49]

Element	Contamination sources		Uses	Adverse health effects
	Natural	Anthropogenic		
Cd	Zn and Pb Minerals, phosphate rocks	Mining waste, electroplating, Battery plants	Automobile exhaust	Respiratory, cardiovascular, Renal effects
Cr	Chromites mineral	Electroplating, metal alloys, industrial sewage, Anticorrosive products	Pesticides, detergents	mental disturbance, cancer, ulcer, hypokerotos
Cu	Sulfides carbonates,	Electroplating, metal alloys, domestic and industrial waste, mining waste, Pesticides	Most uses are based on electrical conductor properties	Anemia and other toxicity effects induced indirectly through interaction with Other nutrients
Pb	Galena mineral	Battery plants, pipelines, Coal, gasoline, pigments	Batteries, alloys	Neurotoxic
Ni	Soils	Metal alloys, battery plants Industrial waste, production catalysts of vegetable oils	Batteries, electronics,	Skin allergies, lung fibrosis Diseases of the cardiovascular system
Zn	Minerals oxides, silicates)	sulfides, Metal alloys, pigments, Electroplating, industrial waste, pipelines	Fertilizers, plastics Pigments	Abdominal pain, nausea Vomiting and diarrhea gastric irritation, headache, irritability, lethargy, anemia

Table 2: Comparison of biosorption and bioaccumulation processes [50]

Characteristics	Biosorption	Bioaccumulation
Cost	Usually low. Biomass can be obtained from industrial waste. Cost associated mostly with transportation and production of biosorbent	Usually high. The process occurs in the presence of living cells that have to be Supported.
capacity of heavy metals	The solution pH strongly affects the sorption pH However, the process can occur within a wide pH range	Significant changes in PH can strongly affective living cells.
Selectivity	However, this can be increased by Modification/biomass transformation.	Better than increase in the case of biosorption.
Rate of removal	Most mechanisms occur at a fast rate	Slow rate than in the case of biosorption because intercellular accumulation long time.
Regeneration and reuse	Biosorbents can be regenerated and reused in many cycles.	Reuse is limited due to intercellular Accumulation.
Recovery of metals	With an adequate eluent the recovery of heavy metals is possible.	Even if possible, biomass cannot be used for other purposes

Bioremediation Methods / techniques

Bioremediation technology includes phytoremediation (plants) and rhizoremediation (plant and microbe interaction). At present, the process is used to check contamination in soil, groundwater and surface water. The system does not require construction or any major modification of drains or diversion of flow. It takes place in open drains without displacement of sewage. The process also does not require any additional land or power, making it a simple and easy system.

1. Phytoextraction

Metals are extracted from soil by pollution accumulating plants then metals concentrate in the plant's harvestable parts [51]. Phytoextraction depends

on employment of plants which can accumulate pollutants such plants remove organics and metals from soil, by accumulating them in plant harvestable parts [52, 53]. Phytoextraction is based on the employment of pollutant-accumulating plants to remove metals and organics from soil by concentrating them in harvestable sections [54].

2. Phytostabilization

Precipitation, Sorption, metals valence reduction and complexation, can all help in phytostabilization [55]. Those which prevention of pollutants and the migration in the environment by plant exudates, resulting in a decrease in the contaminants' bioavailability and the mobility [56]. It is remediation technology that use plants to stabilises wastes and

prevents exposure paths through water erosion and wind; offers hydraulic control, which stops pollutants from migrating vertically into groundwater; chemically and physically immobilises toxins by root sorption and chemical fixation with different soil amendments [57, 58, 59]

3. Rhizofiltration

The absorption of pollutants from aqueous streams by plant roots [60]. Water hyacinth, duckweed and pennywort are among aquatic plants that may remove metals from water. Because of their slow growing and short roots, these plants are inefficient at removing metals and have limited rhizofiltration capacity [61]. Plants employed in rhizofiltration have the potential to extract toxic metal 60% more than their dry weight. Plants are grown hydroponically and then transplanted into water that's metal polluted, where they concentrate and absorb metals from soil in their shoots and roots [62].

4. Phytovolatilization

The process of contaminants being released into atmosphere by plants [63] Plants generally diffuse out water in form of vapour, however they may also transpire volatile chemicals. It happens when water diffuses from xylem of leaves or bark. Although phytovolatilization has mostly been used in groundwater, it may also be used in sediments, sludge and soil. Plants have the potential to act as efficient pump and serve as effective treatment system for mobile pollutants [64].

5. Phytomining

Plants' ability to remove huge amounts of metals from soils, which may be used to recover high-value metals from soils and ore deposits [65].

Phytomining is the process of producing a metal crop by cultivating large number of plants which can gather high concentration of metals. Metal hyperaccumulation occurs naturally in various plants, but it can also be generated in others [66]. The capacity of plants to extract enormous amounts of metals from soil can be used to recover economically valuable metals from soil and ore deposits. Studies have revealed that metals extraction from soil using specific plants is commercially viable [66].

Microbial bioremediation of polluted water

Natural organisms, either indigenous or extraneous, are the important agents used for bioremediation [67]. The organisms vary, depending on the chemical properties of the polluting substances, and are to be chosen cautiously as they only sustain within a stipulated limit of chemical contaminants [68, 69]. Bioremediation can take place naturally or through intervention processes. Bioremediation is based on the co-metabolism action of one organism or a consortium of microorganisms [70]. In this process, the transformation of contaminants presents a little efficiency or no benefit to the cell, and therefore this process is described as non-beneficial biotransformation [71, 72].

Bioremediation by Bacteria

The microbes have often been reported for the degradation of pesticides and hydrocarbons. A large number of bacteria utilize the contaminant as the sole carbon and energy sources. Metals play important role in the life processes of microbes. Some metals such as chromium (Cr), calcium (Ca), magnesium (Mg), manganese (Mn), copper (Cu), sodium (Na), nickel (Ni) and zinc (Zn) are essential as micronutrients for various metabolic functions and for redox functions.

Table 2: Bioaccumulation and biotransformation of organic molecules by bacteria

Bacteria	Toxic chemicals	References
<i>Bacillus sp</i>	Cresol, phenols, aromatics, long chain alkanes, phenol,	[72]
<i>Pseudomonas sp</i>	Benzene, anthracene, hydrocarbons, PCBs	[73, 74]
<i>Flavobacterium sp</i>	Aromatics	[75]
<i>Azotobacter sp</i>	Aromatics	[75]
<i>Xanthomonas sp</i>	Hydrocarbons, polycyclic hydrocarbons	[76]
<i>Nocardia sp</i>	Hydrocarbons	[77]
<i>Streptomyces sp</i>	Phenoxyacetate, halogenated hydrocarbon, diazinon	[78]
<i>Mycobacterium sp</i>	Aromatics, branched hydrocarbons benzene, cycloparaffins	[79]

Table 3: Heavy metals utilizing bacteria

Bacteria	Heavy metals	References
<i>Bacillus sp</i>	Cu, Zn	[80]
<i>Pseudomonas aeruginosa</i>	U, Cu, Ni, Cr	[81, 82]
<i>Aerococcus sp</i>	Pb, Cr, Cd	[83]
<i>Aeromonas sp</i>	Cr	[84]
<i>Rhodopseudomonas palustris</i>	Pb	[85]
<i>Citrobacter sp</i>	Cd, U, Pb	[86, 87]

Bioremediation by Fungus

Fungi represent the promising group of microbes for biodegradation. The ability of fungi, both

yeasts and moulds, to convert a broad variety of hazardous chemical substances has developed interest to use them in bioremediation [9].

Table 4: Bioaccumulation and biotransformation of organic molecules by fungi

Fungi	Toxic chemicals	References
<i>Coprinellus radians</i>	PAHs, methylnaphthalenes, and dibenzofurans	[88]
<i>Marasmiellus troyanus</i>	Benzo [a] pirene	[89]
<i>Gloeophyllum trabeum</i>	1, 1, 1-trichloro-2, 2-bis (4-chlorophenyl) ethane (DDT)	[90]
<i>Pleurotus ostreatus</i>	Bisphenol A	[91]
<i>Fomitopsis pinicola</i>	1, 1, 1-trichloro-2, 2-bis (4-chlorophenyl) ethane (DDT)	[92]
<i>Penicillium simplicissimum</i>	Polyethelene	[93, 94]
<i>Phanerochaete chrysosporium</i>	Polyvinylamine sulfonate anthrapyridone	[95, 96]

Bioremediation by Algae

Biodegradation of pesticides is determined by two groups of factors, the first relates to microbial consortium and the optimum condition for their survival and activity while the second relates to the chemical structure of the pesticides. Factors related to microorganisms including the presence and number of

appropriate microorganisms, the contact between microorganisms and the substrate (pesticide), pH, temperature, salinity, nutrients, light quality and intensity, available water, oxygen tension and redox potential, surface binding, presence of alternative carbon substrates and alternative electron acceptors [97, 98].

Table 5: Bioaccumulation and biotransformation of organic molecules by algae

Algae	Elements	References
<i>Chlamydomonas sp</i>	Naphthalene	[97]
<i>Dunaliella sp</i>	Naphthalene, DDT	[97]
<i>Euglena gracilis</i>	DDT, Phenol	[98]
<i>Selenastrum capricornutum</i>	Benzene, toluene, chlorobenzene, 1, 2- dichlorobenzene, nitrobenzene naphthalene, 2, 6-dinitrotoluene, phenanthrene, di-n-butylphthalate, pyrene	[97]
<i>Chlorella sp</i>	Toxaphene	[97]
<i>Cylindrotheca sp</i>	DDT	[97]

The capability of algae to absorb hazardous metals has been known for many years. Algae have the ability to remove toxic heavy metals from the

environment, which results in higher concentrations than those of the surrounding water [99].

Table 6: Heavy metals utilizing algae

Algae	Heavy metals	References
<i>Zooglea sp</i>	Co, Ni, Cd	[100]
<i>Phormidium valderium</i>	Cd, Co, Cu, Ni	[101, 102]
<i>Chlorella vulgaris</i>	Au, Cu, Ni, U, Pb, Hg, Zn	[102, 103]
<i>Volvariella volvacea</i>	Cu, Hg, Pb	[104]
<i>Oscillatoria sp</i>	Ni, Cu, Co, Pb, Zn	[105, 106]
<i>Tetraselmis chuii</i>	Cu	[107]
<i>Spirogyra hyalina</i>	Cd, Hg, Pb, As	[103]
<i>Chlorella pyrenoidosa</i>	Zn, Cu, As, Pb, Cd, Cr, Ni, Hg	[107]
<i>Lyngbya spiralis</i>	Cd, Pb, Hg	[104]

Advantages

1. Bioremediation is a Natural Process

Bioremediation is a natural process and accepted by the public as a waste treatment process for contaminated material such as soil. Microbes degrade the contaminant, increase in numbers and release harmless products. Bioremediation is an eco-friendly and sustainable approach that can destroy a pollutant or convert harmful contaminants into harmless substances [108].

2. Complete Destruction

Bioremediation is useful for the complete destruction of a wide variety of contaminants. Many hazardous compounds can be transformed into harmless products. Bioremediation can prove less expensive than other technologies that are used for clean-up of hazardous waste [109].

3. Cost-Effective Process

Bioremediation is less expensive compared to other methods that are used for the removal of

hazardous waste. Bioremediation can often be carried out on site, often without causing a major disruption of normal activities [109].

4. Recovery of polluted sites

The major function is speed up the recovery of waste polluted sites, increase substrate degradation, displays a high catalytic or utilization capacity with a small amount of cell mass, create safe and purified environmental conditions by decontamination or neutralizing any harmful substances [110].

Disadvantages

1. Specificity

Biological processes are highly specific. Important site factors required for success include the presence of metabolically capable microbial populations, suitable environmental growth conditions, and appropriate levels of nutrients and contaminants. The main disadvantage of bioremediation technology is that it is restricted to biodegradable compounds [111].

2. Time Taking Process

Bioremediation takes a longer time to compare to other treatment options, such as excavation and removal of contaminants from the site. Finally, introduced foreign modified strain to the system leads to un-reacted and cause un-measurable adverse effect on the natural structural and functional microorganism's community composition and occurrence [111].

3. Regulatory Uncertainty

We are not certain to say that remediation is 100% completed, as there is no accepted definition of clean. Due to this, the performance evaluation of bioremediation is difficult, and there is no acceptable endpoint for bioremediation treatment. The major drawbacks are never carried out in traditional procedure, in some case the death of cells are happened, having challenge associated with their release in the surrounding, in a particular level it showed that delay of growth and substrate degradation, seasonal variation and other a biotic factor fluctuation have direct and indirect impact and relationship on microbial activity [112].

4. Technological Advancement

Bioremediation technologies those are suitable for sites with complex mixtures of contaminants that are not evenly distributed in the environment. Bioremediation often takes longer than other treatment options, such as excavation and removal of soil or incineration [112].

CONCLUSION

Numerous pollutants contaminate water bodies including organic, inorganic pollutants, heavy metals, detergents are most common. These pollutants have deleterious effects on environment and human health. Soil and water are being polluted by various organic

and inorganic pollutants due to rapid industrialization and use of agrochemicals in imbalanced proportions. Different techniques used to control water pollution Phytoextraction, Phytostabilization, Rhizofiltration, Phytovolatilization, and phytomining. Restrictive and clean up measures to avert hazards from contaminated soil belong to the curative soil protection. Bioremediation is a unique and cost-effective technique for cleaning up pollution by intensifying the natural biodegradation processes. So developing an understanding of microbial and plant communities with their response to the natural environment and contaminants, elaborating the knowledge of the genetics of the microorganisms helps to increase capabilities to degrade pollutants and recovery of land and ground water. To that combined use of microorganisms such as bacteria and fungi can make remediation method more effective and rapid that can help in protection of human's as well aquatic system both.

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