C-8-UNIT -5 4TH SEMESTER

Pesticide degradation

Pesticide degradation is the process by which a pesticide is transformed into a benign substance that is environmentally compatible with the site to which it was applied. Globally, an estimated 1 to 2.5 million tons of active pesticide ingredients are used each year, mainly in agriculture. Forty percent are herbicides, followed by insecticides and fungicides. Since their initial development in the 1940s, multiple chemical pesticides with different uses and modes of action have been employed. Pesticides are applied over large areas in agriculture and urban settings. Pesticide use therefore represents an important source of diffuse chemical environmental inputs.

Persistence

In principle, pesticides are registered for use only after they are demonstrated not to persist in the environment considerably beyond their intended period of use. Typically, documented soil half-lives are in the range of days to weeks. However, pesticide residues are found ubiquitously in the environment in ng/liter to low µg/liter concentrations. For instance, surveys of groundwater and not-yet-treated potable water in industrialized countries typically detect 10 to 20 substances in recurrent findings above 0.01 µg/dL (3.6×10^{-12} lb/cu in) the maximum accepted drinking water concentration for pesticides in many countries. About half of the detected substances are no longer in use and another 10 to 20% are stable transformation products.

Pesticide residues have been found in other realms. Transport from groundwater may lead to low-level presence in surface waters. Pesticides have been detected in high-altitude regions, demonstrating sufficient persistence to survive transport across hundreds of kilometers in the atmosphere.

Degradation involves both biotic and abiotic transformation processes. Biotic transformation is mediated by microorganisms, while abiotic transformation involves processes such as chemical and photochemical reactions. The specific degradation processes for a given pesticide are determined by its structure and by the environmental conditions it experiences. Redox gradients in soils, sediments or aquifers often determine which transformations can occur. Similarly, photochemical transformations require sunlight, available only in the topmost meter(s) of lakes or rivers, plant surfaces or submillimeter soil layers. Atmospheric phototransformation is another potential remediating influence.

Information on pesticide degradation is available from required test data. This includes laboratory tests on aqueous hydrolysis, photolysis in water and air, biodegradability in soils and water-sediment systems under aerobic and anaerobic conditions and fate in soil lysimeters. These studies provide little insight into how individual transformation processes contribute to observed degradation in situ. Therefore, they do not offer a rigorous understanding of how specific environmental conditions (e.g., the presence of certain reactants) affect degradation. Such studies further fail to cover unusual environmental conditions such as strongly sulfidic environments such as estuaries or prairie potholes, nor do they reveal transformations at low residual concentrations at which biodegradation may stop. Thus, although molecular structure generally predicts intrinsic reactivity, quantitative predictions are limited.

Biotic transformation

Biodegradation is generally recognized as biggest contributor to degradation. Whereas plants, animals and fungi (Eukaryota) typically transform pesticides for detoxification through metabolism by broad-spectrum enzymes, bacteria (Prokaryota) more commonly metabolize them. This dichotomy is likely due to a wider range of sensitive targets in Eukaryota. For example, organophosphate esters that interfere with nerve signal transmission in insects do not affect microbial processes and offering nourishment for microorganisms whose enzymes can hydrolyze phosphotriesters. Bacteria are more likely to contain such enzymes because of their strong selection for new enzymes and metabolic pathways that supply essential nutrients. In addition, genes move horizontally within microbial populations, spreading newly evolved degradation pathways.

Some transformations, particularly substitutions, can proceed both biotically and abiotically, although enzyme-catalyzed reactions typically reach higher rates. For example, the hydrolytic dechlorination of atrazine to hydroxyatrazine in soil by atrazine-dechlorinating bacterial enzymes reached a second-order rate constant of 105/mole/second, likely dominating in the environment. In other cases, enzymes facilitate reactions with no abiotic counterpart, as with the herbicide glyphosate, which contains a C-P bond that is stable with respect to light, reflux in strong acid or base, and other abiotic conditions. Microbes that cleave the C-P bond are widespread in the environment, and some can metabolize glyphosate. The C-P lyase enzyme system is encoded by a complicated 14-gene operon.

Biodegradation transformation intermediates may accumulate when the enzymes that produce the intermediate operate more slowly than those that consume it. In atrazine metabolism, for example, a substantial steady-state level of hydroxyatrazine accumulates from such a process. In other situations (e.g., in agricultural wastewater treatment), microorganisms mostly grow on other, more readily assimilable carbon substrates, whereas pesticides present at trace concentrations are transformed through fortuitous metabolism, producing potentially recalcitrant intermediates.

Pesticides persist over decades in groundwater, although bacteria are in principle abundant and potentially able to degrade them for unknown reasons. This may be related to the observation that microbial degradation appears to stall at low pesticide concentrations in low-nutrient environments such as groundwater. As yet, very little is known about pesticide biodegradation under such conditions. Methods have been lacking to follow biodegradation in groundwater over the relevant long time scales and to isolate relevant degraders from such environments.

Abiotic Transformation

In surface waters, phototransformation can substantially contribute to degradation. In “direct” phototransformation, photons are absorbed by the contaminant, while in “indirect” phototransformation, reactive species are formed through photon absorption by other substances. Pesticide electronic absorption spectra typically show little overlap with sunlight, such that only a few (e.g., trifluralin) are affected by direct phototransformation.[3] Various photochemically active light absorbers are present in surface waters, enhancing indirect phototransformation. The most prominent is dissolved organic matter (DOM), which is the precursor of excited triplet states, molecular oxygen, superoxide radical anions, and other radicals. Nitrate and nitrite ions produce hydroxyl radicals under irradiation. Indirect phototransformation is thus the result of parallel reactions with all available reactive species. The transformation rate depends on the concentrations of all relevant reactive species, together with their corresponding second-order rate constants for a given pesticide. These constants are known for hydroxyl radical and molecular oxygen. In the absence of such rate constants, quantitative structure–activity relationships(QSARs) may allow their estimation for a specific pesticide from its chemical structure.

The relevance of "dark" (aphotic) abiotic transformations varies by pesticide. The presence of functional groups supports textbook predictions for some compounds. For example, aqueous abiotic hydrolysis degrades organophosphates, carboxylic acid esters, carbamates, carbonates, some halides (methyl bromide, propargyl) and many more. Other pesticides are less amenable. Conditions such as high pH or low-redox environments combined with in situ catalyst formation including (poly)sulfides, surface-bound Fe(II) or MnO_2 Microorganisms often mediate the latter, blurring the boundary between abiotic and biotic transformations. Chemical reactions may also prevail in compartments such as groundwater or lake hypolimnions, which have hydraulic retention times on the order of years and where biomass densities are lower due to almost complete absence of assimilable organic carbon.

Organic pollutants:

Hydrocarbon contamination is of great worry because of their widespread effect on all forms of life. Pollution caused by increasing the use of crude oil is ordinary because of its extensive application and its related transport and dumping problems. Crude oil contains a complex mixture of aliphatic, aromatic, and heterocyclic compounds. Soil naturally consists of heavy metals, and due to human action like refining of oil and use of pesticides, their concentration in soil is rising. Several areas have such high heavy metal and metalloid concentration that surrounding natural ecosystem has been badly affected. The reason is that heavy metals and metalloids limit microbe’s activity rendering it unsuitable for hydrocarbon degradation, thus reducing its effectiveness. Environmental remediation is thus extremely necessary and involves with the elimination of pollutants from soil, air, and water. In the last several decades, different methods have been employed and applied for the cleanup of our environment which includes mechanical, chemical, and biochemical remediation methods. The hydrocarbon pollution consists of many aspects like oil spills, fossil fuels, organic pollutants like aromatics, etc. that are discussed below.

Contamination of hydrocarbon occurs due to toxic organic substances, petroleum, and pesticides which is a serious concern for the environment. Contamination caused by petroleum hydrocarbon is a matter of worry because these are harmful for various life forms. Crude oil contamination is common due to its extensive use and its related dumping process and accidental spills. Complex mixture of a large range of high and low molecular weight hydrocarbons makes up the petroleum. The complex mixture of petroleum consists of saturated and branched alkanes, alkenes, and homo- and heterocyclic naphthenes; aromatics consisting of heteroatoms such as heavy metal complexes and N, S, and O; hydrocarbon consisting of different functional groups such as ethers, carboxylic acids, etc.; and large aromatic molecules such as asphaltenes, resins, and naptheno-aromatics.

Heavy metals are present in crude oil, and its heavy metal content is associated with porphyrins which is the pyrrolic structure. Lube oil waxes, light oil, asphaltenes, naphtha, diesel, kerosene, etc. are the several fractions in which the petroleum is refined. Light ends is the term that is used for the light fractions which are distilled at atmospheric pressure, and heavy ends is used for heavy fractions such as asphaltenes and lube oil. Due to different hydrocarbon compositions of light and heavy ends of petroleum, light ends consists of a lower percentage of aromatic compounds and lower molecular weight saturated and unsaturated hydrocarbons, while heavier ends consists of higher molecular weight saturated and unsaturated hydrocarbons, aromatic compounds with high molecular weight, and organometallic compounds. This part is relatively affluent in metals and nitrogen, sulfur, and oxygen-containing compounds .

Concentration of heavy metal is rising in the soil as a consequence of human action. There is a large impact of higher heavy metal and metalloid concentration in some areas.

2. Hydrocarbon pollution

This is caused mainly by accidents on oil platforms and ships used for hydrocarbon transportation but also by discharging water into the sea which is used to wash tanks of tanker vessels. Crude oil and petroleum products form a waterproof film on water that prevents the oxygen exchange between environment and water causing damages to plants, animals, and human beings. Nowadays during transport overseas, “double-hulled” tankers are used to avoid leaks in case of accidents. Best international practices are adopted with regard to oil platforms to face or eventually adequately deal with any type of inconvenience.

3. Organic pollutants

With the onset of industrialization, the use and buildup of organic compounds have increased. Major sources which are responsible for organic contaminants are anthropogenic activities including the use of fuels, solvents, and pesticides. Various organic compounds are harmful and are related to health concerns globally.

Diverse sources are responsible for the generation of hydrocarbons in sediments which are categorized below:

- Anthropogenic sources
- Petroleum inputs
- Partial burning of fuels
- Fires of forest and grass
- Biosynthesis of hydrocarbons by marine or terrestrial organisms
- Diffusing from the petroleum source rocks, reservoirs, or mantle

Organic pollutant is responsible for environmental and health-related problems; hence bioremediation provides an efficient explanation to this problem.

Sources and effects of hydrocarbon-contaminated wastewater effluents:

Numerous sources such as pesticides, petroleum, or different harmful organic substances which are discharged into the water streams as effluents are responsible for the hydrocarbon pollution into the wastewater. Water contaminated with hydrocarbons is known to be carcinogenic, neurotoxin, and mutagenic to flora and fauna. Contaminated lands, oil spillage, pesticides, automobile oils, and urban stormwater discharges are the major causes for the hydrocarbon contamination.

Oil spill is one of the major sources of hydrocarbon contamination. Oil spills caused mainly by accidents on oil platforms and ships are needed for transportation of hydrocarbon but also by disposal of water into the sea which is used to wash tanks of tanker vessels. Underground oil storage tanks and leaking pipelines are also responsible for oil spilling in water.

Increase use of vehicles and automobiles leads to increase in utilization of automobile oil, which is the major cause of hydrocarbon contamination in water. This type of contamination occurs when oil from the car drops onto the ground and leaks; it could be washed into water streams by runoffs.

Pesticides are another source of hydrocarbon contamination in water. Pesticides include herbicides, fungicides, and insecticides. Only small amount of pesticide is able to achieve the target, while the major proportion stays in the soil, and it can be washed away by the rain in the water stream. Herbicides, out of all the pesticides, are most hazardous because it is directly applied on the soil in order to kill the weed and can be washed away during rainfall into the water streams.

Another source of hydrocarbon contamination in water is the land where some type of industrial action is being carried out. These lands contaminated by hydrocarbons or toxic organic compounds are washed due to rainfall into the water steams, thus causing pollution.

One of the main sources of hydrocarbon pollution is the discharge of urban stormwater. In urban communities, car parks and roads are frequently polluted by gasoline and oil from the vehicles, and during rainfall, these pollutants are washed into water streams and hence can contaminate them.

Wastewater contaminated by hydrocarbons has an adverse effect in nature, animals, human beings, and plants. Lack of oxygen, decrease in crop yield, and effects on aquatic plants are various effects of hydrocarbon contamination in nature. There would be decrease in the crop yield and available food for household due to inappropriate crop's growth when the farmland is irrigated by water contaminated with hydrocarbon. Soil fertility can be decreased to an extent due to the presence of oil in water due to the reason that most of the vital nutrients are no longer accessible for crop consumption which results in the decrease of the crop yield.

Polycyclic hydrocarbons are toxic and found to have serious effects on human beings. The immune system, liver, respiratory system, reproductive system, circulatory system, kidney, etc. are the organs which are affected due to the hydrocarbon ingestion. individual's susceptibility and level of exposure are the factors on which the degree of damage depends. Cancer risk and hormonal problems that can disturb developmental and reproductive processes are the other effects of effluents polluted by hydrocarbons on human beings.

Remediation techniques for hydrocarbons:

Contamination due to petroleum is widespread in the environment and contaminates surface and groundwater. Several operations in petroleum exploration, leaking of underground storage tanks, and its production and transportation are responsible for affecting the environment. Contamination causes threat to human health and safety and can affect nature by contaminating surface and groundwater.

There are three methods involved in the remediation of sites contaminated due to hydrocarbon:

- Phytoremediation
- Bioremediation
- Chemical remediation

Bioremediation
Bioremediation is a cost-efficient method used for the treatment of soil polluted with oil and wastes of petroleum consisting of biodegradable hydrocarbons and indigenous microbes.

The management of suitable levels of nutrient fertilizer addition, moisture control to optimize soil degradation by microorganisms, aeration and mixing, and pH amendment are required for the process of land treatment.
Enzymes attack on some inorganic compounds and on most of the organic compounds through the activities of living organisms. Bioremediation is the technique which involves the productive use of the biodegradative process for the elimination or detoxification of pollutants from the environment.

Oil spill causes contamination of soil which is considered as the chief worldwide concern. Pollution of soil due to petroleum causes a serious effect to human being, affects the groundwater, decreases the agricultural production of the soil, and causes economic loss and ecological problems. Plants, animals, microorganisms, and humans are affected by the toxicity of the petroleum hydrocarbons. Oil spill and accidents occur due to the transportation of crude oil which is generally through tankers on water or through land pipeline. Problems of the oil contamination occur mostly due to the reason that the main oil-producing countries are not the chief oil clients; hence petroleum is transported to the consumption area. Certain microorganisms are accountable for the petroleum hydrocarbon degradation and are used as the resource of carbon and energy for growth and maintenance. Soil contamination can be remediated by many ways including both physicochemical and biological techniques.

Biological techniques are more economical and proficient than physicochemical techniques. The degradation rate of petroleum products is increased by developing several remediation methods. Bioremediation through microorganism is considered to be the most effective method in comparison to other biological methods, but the high molecular weight hydrocarbons with low adsorption and solubility limit their accessibility to microorganisms.
Principle of bioremediation
Composite mixture of diverse chemical substances makes up the crude oil. Oil and its component are recognized by microbes using bioemulsifiers and biosurfactants, and then they join themselves; hydrocarbon is used as the resource of carbon and energy. High molecular weight hydrocarbons due to their low adsorption and solubility limit their accessibility to microorganisms. Oil biodegradation rates are improved by the biosurfactant's addition which increases the elimination and solubility of these pollutants.

The oil constituents vary particularly in susceptibility, volatility, and volubility to biodegradation. A number of substances are easily degraded, some are non-biodegradable, and some oppose degradation. Diverse species of microbes preferentially attack diverse compounds due to this biodegradation of petroleum that occurs at different rates but concurrently. Enzymes produced by microorganisms in the presence of sources of carbon are accountable for attacking the hydrocarbon molecules. Hydrocarbon present in the petroleum is degraded by different enzymes and metabolic pathways. Hydrocarbon degradation is prevented by the lack of suitable enzyme.

Bioremediation process involves the utilization of natural microorganisms for the decontamination of atmosphere. This process converts pollutants into useful or nontoxic substances by using bacteria, fungi, and yeast which are the naturally occurring microorganisms. This is also a process in which microorganisms restore the quality of the environment by degrading and metabolizing the chemical substances.Table represents the main microorganisms which are included in the remediation of hydrocarbons.

Bacteria	**Yeast and fungi**
Achromobacter	*Aspergillus*
Acinetobacter	*Candida*
Alcaligenes	*Cladosporium*
Arthrobacter	*Penicillium*
Bacillus	*Rhodotorula*
Brevibacterium	*Sporobolomyces*
Corynebacterium	*Trichoderma*
Flavobacterium	*Fusarium*
Nocardia	
Pseudomonas	*Trichoderma*
Vibrio	

Bacteria

Microbial species has efficient hydrocarbon degradation capability in natural environments. Various microbial species have been isolated from heavily polluted coastal areas, variety of oil spill, or soil contaminated by petroleum. These are isolated on the basis of their capability to metabolize different sources of carbon such as aliphatic and aromatic compounds and their chlorinated derivate. Enrichment culture procedures were used for obtaining the microorganisms, and for the selection criterion, maximum final cell concentration or maximum specific growth rate was used. Various microorganisms such as fungi, microalgae, bacteria, and yeast are used for degrading the petroleum hydrocarbons. Out of these microorganisms, bacteria play a significant role for hydrocarbon degradation. Rapid degradation of low molecular weight alkanes is reported by various studies. The capability of microorganisms to use hydrocarbons to assure the growth of cell and energy requirements by degrading hydrocarbon is the driving force for the petroleum biodegradation. Biodegradation of petroleum is carried out more extensively by mixed cultures in comparison to pure culture. Adequate indigenous microbial community in many ecosystems is capable of biodegradation of oil, but for oil degradation metabolic activity, environmental conditions should be favorable. Indigenous microorganisms have several advantages than adding microorganisms for hydrocarbon degradation.

Fungi
For the biodegradation of hydrocarbons in soils, fungi play a more vital role than bacteria. Filamentous fungi which are found in aquatic structures are mostly related with surface films and sediments. The enzymatic processes used by mammalian organizations are also used by fungi in polycyclic aromatic hydrocarbons (PAHs). Two major types of cytochrome P450 monooxygenases have been well characterized in yeasts and filamentous fungi. Several fungi have the ability to oxidize polycyclic aromatic hydrocarbons to phenols, dihydrodiols, and other metabolites and conjugates, but only some fungi such as *Phanerochaete chrysosporium* have the capability to catabolize them totally to CO2.

Example:

Mitosporic Ascomycota

DothiorellaAureobasidium

Saccharomycetales candida

Yeast
The biodegradability of various yeasts decreases from n-alkanes > branched alkanes > low molecular weight aromatic hydrocarbons > cycloalkanes > high molecular weight aromatic and polar compounds.

Bioremediation process involves the detoxification of pollutants due to the various metabolic capabilities of microorganisms which is the developing method for elimination of contaminants from nature together with the yields of the petroleum industry. Bioremediation technique is considered to be cost-effective and noninvasive. Petroleum and other hydrocarbon contaminants can be eliminated from the atmosphere by using microorganisms which is considered as primary mechanism, and it is the cheaper method in comparison to other remediation technologies. Microorganisms having suitable metabolic capabilities are the essential requirement.

Alkylaromatic degradation is carried out by various microorganisms such as Arthrobacter, Mycobacterium, Sphingomonas, Burkholderia, Rhodococcus, and Pseudomonas.

Fungi, bacteria, and yeast are accountable for the biodegradation of hydrocarbons in the environment. Six percent to 82% is the reported efficiency of biodegradation for soil fungi, 0.003–100% for marine bacteria, and 0.13% to 50% for soil bacteria. Complex mixtures of hydrocarbons such as crude oil in freshwater, aquatic environments, and soil are degraded by mixed populations with overall wide enzymatic capacities.

Bioremediation involves two processes as follows:

Bioaugmentation

Biostimulation

Bioaugmentation

Bioaugmentation process involves the degradation of the harmful hydrocarbons by the addition of microorganisms in order to achieve the pollutant reduction. It is also the injection of polluted water with microorganisms capable of hydrocarbon degradation. This process sometimes involves biodegradation of the hydrocarbon pollutants by adding the genetically engineered microorganisms into the polluted water. Bioaugmentation process is not often used for the hydrocarbon degradation because microorganisms responsible for hydrocarbon degradation naturally exist in the environment. Bioaugmentation process is not so much effective to be used in oil spill remediation sites, and nonindigenous microorganisms used in this process can cause competition with the microbes already present in the environment.

Biostimulation

Biostimulation is the process which involves degradation of the harmful compounds by adding the nutrients required by indigenous hydrocarbon-degrading microbes. The growth of microorganisms responsible for the degradation of oil during oil spillage is activated by the increase in carbon. The tendency of the microorganisms to degrade the hydrocarbons is enhanced by addition of suitable concentration of supplemental nutrients. Due to this reason, microorganisms are competent of achieving their utmost rate of growth and consequently the utmost rate of contaminant uptake. The maximum biostimulation is achieved by obtaining the ideal nutrient concentration which is required for the utmost growth of the microorganisms and maintaining concentration as long as possible for microorganisms.

Inorganic pollutants:

Human sources are mainly responsible for the heavy metal contamination, but contamination due to natural and biological processes are also common which includes:

Mineral weathering over time.

Erosion and volcanic actions.

Forest fires and biogenic resource.

Vegetation causes release of particles.

Cellular binding sites of microbes are responsible for the absorption of heavy metals. By various mechanisms, heavy metals can be complexed with extracellular polymers of microbes. Organic contaminants can be mineralized by these microorganisms and convert into metabolic intermediates which can be utilized as primary substrates for growth of the cell. Heavy metals can be eliminated from the metal-polluted soil by microbes which can change the heavy metal oxidation state by immobilizing them. Research on bioremediation of heavy metals by microbes has not been carried out extensively due to metal adsorption and incomplete knowledge of the genetics of the microbes.

Phytoremediation

Phytoremediation is the process which involves the use of plants for the degradation, extraction, and elimination of the contaminants from the air, water, and soil. It includes various mechanisms which can lead to degradation of contaminants, dissipation, immobilization, and accumulation.

Various phytoremediation applications with examples are systematically given in table.

Application	Media	Contaminants	Typical plants
Phytotransformation	Soil, groundwater, landfill leachate, land application of wastewater	Herbicides, aromatics, chlorinated aliphatics, nutrients, ammunition waste	Phreatophyte trees (popular, willow, cottonwood, aspen) Grasses (rye, Bermuda, sorghum, fescue) Legumes (clover, alfalfa, cowpeas)
Rhizosphere bioremediation	Soil, sediments, land application of wastewater	Organic contaminants (pesticides, aromatics, and polynuclear aromatic hydrocarbons)	Phenolic releasers (mulberry, apple, Osage orange) Grasses with fibrous roots (rye, fescue, Bermuda) for contaminants 0.3 ft deep Phreatophyte trees for 0.10 ft Aquatic plants for sediments
Phytostabilization	Soil, sediments	Metals (Pb, Cd, Zn, As, Cu, Cr, Se, U), hydrophobic organics (PAHs, PCNBs, dioxins, furans, pentachlorophenol, DDT, dieldrin)	Phreatophyte trees to transpire large amounts of water for hydraulic control Grasses with fibrous roots to stabilize soil erosion Dense root systems are needed to sorb/bind contaminants
Phytoextraction	Soil, brown fields, sediments	Metals (Pb, Cd, Zn, Ni, Cu) with EDTA addition for Pb selenium (volatilization)	Sunflowers Indian mustard Rape seed plants Barley Hops Crucifers Serpentine plants Nettles Dandelions
Rhizofiltration	Groundwater, water and wastewater in lagoons or created wetlands	Metals (Pb, Cd, Zn, Ni, Cu), radionuclides (137Cs, 90 Sr, U), hydrophobic organics	Aquatic plants: emergents (bulrush, cattail, coontail, pondweed, arrowroot, duckweed); submergents (algae, stonewort, parrot's feather, Eurasian watermilfoil, hydrilla)

Mechanisms of phytoremediation

Contaminated land and water are remediated more feasibly by using plants involving a variety of pollutant attenuation mechanisms than physical and chemical remediation techniques. Plants due to their sedentary nature had developed various abilities for dealing with hazardous compounds. Plants serve as solar-driven pumping and filtering systems as they take up pollutants from the soil through the roots which is transported to various parts of the plant by the help of plant tissues where they can be volatilized, metabolized, or sequestered. Different types of mechanisms are used by the plant for removing the pollutants from the soil. They consist of biophysical and biochemical processes such as adsorption, translocation, and transport, as well as mineralization and transformation by plant enzymes are the mechanisms of phytoremediation Halogenated substances like TCE are degraded by plants using oxidative degradation pathways, and it includes plant-specific dehalogenases. After the death of the plant, the dehalogenase activity is still maintained. Laccases, P450 monooxygenases, nitroreductases, dioxygenases, phosphatases, peroxidases, dehalogenases, and nitrilases are various contaminant-degrading enzymes which are present in plants. The basic physiological mechanisms involved in phytoremediation in higher plants and related microorganisms, such as mineral nutrition, photosynthesis, transpiration, and metabolism. The root of the plant is responsible for the uptake of the organic and inorganic compounds from the soil, and it can bind and stabilize substance on its external surfaces on interaction with microorganism in the rhizosphere. Uptake or release of molecules occurs through exchanging gases from the aerial plant's parts with the atmosphere.
For addressing different contaminants in different substrates, six phytotechnologies have been recognized by Interstate Technology and Regulatory Cooperation:

For organic contaminants, phytotransformation is ideal in all substrates.

Rhizosphere bioremediation is used in soil containing organic contaminants.

Phytostabilization is used in soil for organic and inorganic pollutants.

Phytoextraction is useful in substrates containing inorganic pollutants.

Phytovolatilization is used for volatile substances.

Hydraulic flow can be controlled in the contaminated environment by using evapotranspiration.

Biosurfactant
Biosurfactant usually refers to surfactants of microbial origin. Most of the bio-surfactants produced by microbes are synthesized extracellularly and many microbes are known to produce bio-surfactants in large relative quantities.Some are of commercial interest.
Examples

Common biosurfactants include:

Bile salts are mixtures of micelle-forming compounds that encapsulate food, enabling absorption through the small intestine.
Lecithin, which can be obtained either from soybean or from egg yolk, is a common food ingredient.

rhamnolipids, which can be produced by some species of *Pseudomonas*, e.g., *Pseudomonas aeruginosa*.
Sophorolipids are produced by various nonpathogenic yeasts.
Emulsan produced by *Acinetobacter calcoaceticus*.

Microbial biosurfactants are obtain by including immiscible liquids in the growth medium.

Applications
Potential applications include herbicides and pesticides formulations, detergents, healthcare and cosmetics, pulp and paper, coal, textiles, ceramic processing and food industries, uranium ore-processing, and mechanical dewatering of peat.

Oil spill remediation
Biosurfactants enhance the emulsification of hydrocarbons, thus they have the potential to solubilise hydrocarbon contaminants and increase their availability for microbial degradation. These compounds can also be used in enhanced oil recovery and may be considered for other potential applications in environmental protection.

Major types of Biosurfactants:

Biosurfactant class		**Microorganism**	**Application**
Glycolipids	Rhamnolipids	*P. aeruginosa and P. putida*	Bioremediation
		P. chlororaphis	Biocontrol agent
		Bacillus subtilis	Antifungal agent
		Renibacterium salmoninarum	Bioremediation
	Sophorolipids	*Candida bombicola and C. apicola*	Emulsifier, MEOR, alkane dissimilation
	Trehalose lipids	*Rhodococcus spp.*	Bioremediation
		Tsukamurella sp. and Arthrobacter sp.	Antimicrobial agent
	Mannosylerythritol lipids	*Candida antartica*	Neuroreceptor antagonist, antimicrobial agent
		Kurtzmanomyces sp	Biomedical application
Lipopeptides	Surfactin	*Bacillus subtilis*	Antimicrobial agent, biomedical application
	Lichenysin	*B. licheniformis*	Hemolytic and chelating agent