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Role of Microorganisms for the Sustainable Use of Soil Pollution Abutment in Agriculture Lands

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ABSTRACT

The microorganisms have been introduced to describe the process of using biological agents to remove toxic contamination from agricultural lands. Microorganisms are the most effective management tool to manage the polluted environment and recover contaminated soil. The hazardous wastes generated from the chemical processes/operations are being treated using biological methods by meet the prescribed standard as per the Environmental Protection Act, 1986. The soil pollution treated by the in situ isolated microbes strain, before isolated metagenomic technology into the environment. In spite of the present treatment technology, the organic pollutants are found persisting in the soil-water environment above their acceptable level. Hence, beneficial microorganism is an innovative technology that has the potential to alleviate the toxic contamination.

Introduction

Soil contamination or soil pollution as part of land degradation is caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, polynuclear aromatic hydrocarbons [such as naphthalene and benzo (a) pyrene], solvents, pesticides, lead, and other heavy metals. Contamination is correlated with the degree of industrialization and intensity of chemical usage. The concern over soil contamination stems primarily from health risks, from direct contact with the contaminated soil, vapors from the contaminants, and from secondary contamination of water supplies within and underlying the soil (George *et al.*,2016).

Soil pollution is caused by acid rains and particles loaded with heavy metals, falling at the same time with the acid rains or blown from the sterile stockpiles resulted from floating and smelting processes (Lacatusu *et al.*, 1999). Soil contamination by heavy metals is a significant problem, which leads to changes of soil characteristics and limits productive and environmental functions. Polluted soils are no longer appropriate for agricultural production, because they are unable to produce healthy food. Assessment of soil pollution by heavy metals in Slovakia is determined by limit values of risk elements, which were set by law (Act No. 220/2004).

Agricultural pollution refers to biotic and a-biotic byproducts of farming practices that result in contamination or degradation of the environment and surrounding ecosystems, and/or cause injury to humans and their economic interests. The pollution may come from a variety of sources, ranging from point source pollution (from a single discharge point) to more diffuse, landscape-level causes, also known as non-point source pollution. Management practices play a crucial role in the amount and impact of these pollutants. Management techniques range from animal management and housing to the spread of pesticides and fertilizers in global agricultural practices (Gullan and Cranston, 2010).

Pesticides and herbicides is a substance or mixture of substances used to kill a pest. A pesticide may be a chemical substance, biological agent (such as a virus or bacteria), antimicrobial, disinfectant or device used against any pest. Pests include insects, plant pathogens, weeds, mollusks, birds, mammals, fish, nematodes (roundworms) and microbes that compete with humans for food, destroy property, spread or are a vector for disease or cause a nuisance. Although there are benefits to the use of pesticides, there are also drawbacks, such as potential toxicity to humans and other organisms.

Causes of soil pollution

The European Commission has proposed the following definition of ‘contaminated site’: a site where there is a confirmed presence, caused by human activities, of hazardous substances to such a degree that they pose a significant risk to human health or the environment, taking into account land use (Commission Proposal COM (2006).

Types of contamination

As a starting point for looking at the types of contaminant that could be present in soils and affect human health, it is worthwhile to consider the chemicals that offer the greatest threat to human health first. The grid below gives details on the chemicals of major public health concern identified by the WHO.

Heavy metals

‘Heavy metals’ is a widely-used term for elements with metallic properties - it is not, in fact, a scientifically accurate description, since the definition of ‘heavy’ is not fixed, and some so-called heavy metals, such as arsenic and antimony, are semi-metals or metalloids. Another description often used interchangeably with heavy metals is ‘trace elements’.

These elements occur naturally in rocks and in variable amounts in soils, depending on their location and the rocks that have broken down to make the soil’s components. The group ‘heavy metals ‘for the purpose of discussing health risks or impacts generally includes:

Arsenic (As)

Lead (Pb)

Cadmium (Cd)

Chromium (Cr)
(Although only the form Cr (VI) is toxic)

Copper (Cu)

Mercury (Hg)

Nickel (Ni)

Zinc (Zn)

Asbestos

Asbestos contamination in the soil is of concern in a number of locations, because it can be released to the air by the wind or by human disturbance. Asbestos has long-term health consequences if it is inhaled, with increased mortality from lung cancer and mesothelioma the most extreme outcomes.

Dioxins and dioxin-like chemicals

Dioxins are a group of chemically-related compounds that are persistent organic pollutants (POPs). Highly toxic, dioxins accumulate up the food chain, with the highest levels found in animals at the top of the food chain (an effect known as 'biomagnifications').

More than 90% of human exposure to dioxins is through food, mainly meat and dairy products, fish and shellfish.

Organic pollutants, including hazardous pesticides

Organic (carbon-based) pollutants include pesticides. Those that were once released into air or water will end up in soils, with the exception of those that are deposited at the bottom of oceans. Among organic pollutants some are referred to as 'POPs,' or persistent organic pollutants, which do not break down quickly in the environment.

Types of organic pollutants found in soil include

Polychlorinated biphenyls (PCBs)

Polybrominated biphenyls

Polychlorinated dibenzofurans (PCDFs)

Polycyclic aromatic hydrocarbons (PAHs)

Organophosphorus and carbamate insecticides (pesticides)

Herbicides

Organic fuels (gasoline, diesel)

Pharmaceuticals and their metabolites

The effects of the soil and organisms within it upon organic pollutants are unknown. The data that do exist tend to be on short-term, high level exposure of these chemicals, which is less relevant to the potential low-level, long term health impacts from living near to contaminated soil (Burgess, 2013).

Sources of heavy metals in contaminated soils

Direct sources

The prime direct source of xenobiotics is wastewater and solid residual releases from the industries like chemical and pharma, plastics, paper and pulp mills, textile mills, agricultural (enhancement products like pesticides, herbicides etc.). Some of the common residual compounds in the wastewater and other effluents are Phenol, hydrocarbons, different dyes, paint effluents, Pesticides and Insecticides etc.

Indirect sources

Indirect sources of xenobiotics include NSAIDs, pharmaceutical compounds, pesticide residues etc. Pharmaceutically active compounds, being an indirect source of xenobiotics are discharged directly by manufacturers of the pharmaceuticals or effluents from hospitals which have performed their biologically intended effect and are passed onto the environment in either their complete or a fragmented state. These mainly include hormones, anesthetics and antibiotics which bioaccumulation in an organism and passed on the other through the common food chain.

Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace (<1000 mg kg−1) and rarely toxic (Kabata-Pendias and Pendias, 2001, Pierzynski, *et al.*, 2000]. Due to the disturbance and acceleration of nature's slowly occurring geochemical cycle of metals by man, most soils of rural and urban environments may accumulate one or more of the heavy metals above defined background values high enough to cause risks to human health, plants, animals, ecosystems, or other media (D'Amore, *et al.*, 2005).

Fertilizers

Agriculture was the first major human influence on the soil (Scragg, 2006). To grow and complete the lifecycle, plants must acquire not only macronutrients (N, P, K, S, Ca, and Mg), but also essential micronutrients. Some soils are deficient in the heavy metals (such as Co, Cu, Fe, Mn, Mo, Ni, and Zn) that are essential for healthy plant growth (Lasat, 2000).

Fertilizer industry is considered to be source of natural radionuclide's and heavy metals as a potential source. It contains a large majority of the heavy metals like Hg, Cd, As, Pb, Cu, Ni, and Cu; natural radionuclide like 238U, 232Th, and 210Po (FAO, March, 2009). However, in recent years, fertilizer consumption increased exponentially throughout the world, causes serious environmental problems. Fertilization may affect the accumulation of heavy metals in soil and plant system. Plants absorb the fertilizers through the soil; they can enter the food chain. Thus, fertilization leads to water, soil and air pollution.

Pesticides

Although some persistent organ chlorine pesticides have been banned from agricultural and public health use during the past few decades, high concentrations of DDT and its metabolites have been found in soil, water, and sediment samples (Shen *et al.,* 2005; Miersma *et al.,* 2003; Yan˜ ez *et al.,* 2002; Bould, 1994). Furthermore, other insecticides, such as endosulfan and lindane, are currently in use throughout the world (EPA, 2002) and their presence in air, water, and soil is a problem of great concern. Reducing their levels in the environment has therefore become an important goal.

Several common pesticides used fairly extensively in agriculture and horticulture in the past contained substantial concentrations of metals. For instance in the recent past, about 10% of the chemicals have approved for use as insecticides and fungicides in UK were based on compounds which contain Cu, Hg, Mn, Pb, or Zn. Examples of such pesticides are copper-containing fungicidal sprays such as Bordeaux mixture (copper sulphate) and copper oxychloride (Jones and Jarvis, 1981).

Herbicide

Three different herbicides were considered in our research: terbuthylazine, simazine and linuron. They were selected because they are common soil and groundwater contaminants (Di Corcia *et al.*, 1999; Barra Caracciolo *et al.,* 2005b and 2005d, Guzzella *et al.,* 2006a and 2006b). The phenylurea herbicides, such as linuron, are an important group of pesticides used predominantly in either pre- or post-emergence treatment of cotton, fruit, cereal or other agricultural crops. The degradation data reported are quite variable; with DT50values in the range of 38–135 days in laboratory studies and 13–82 days in field ones (Caux *et al.,* 1998; Rodríguez-Cruz *et al.,* 2001; Rasmussen *et al.,* 2005).

Bioslids and manures

The application of numerous biosolids (e.g., livestock manures, composts, and municipal sewage sludge) to land inadvertently leads to the accumulation of heavy metals such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Tl, Sb, and so forth, in the soil.

Heavy metals most commonly found in biosolids are Pb, Ni, Cd, Cr, Cu, and Zn, and the metal concentrations are governed by the nature and the intensity of the industrial activity, as well as the type of process employed during the biosolids treatment (Basta, 2005).

Under certain conditions, metals added to soils in applications of biosolids can be leached downwards through the soil profile and can have the potential to contaminate groundwater (Mattigod and Page, 1983). Recent studies on some New Zealand soils treated with biosolids have shown increased concentrations of Cd, Ni, and Zn in drainage leachates (McLaren *et al.,* 2005; Keller *et al.,* 2002).

Wastewater

The application of municipal and industrial wastewater and related effluents to land dates back 400 years and now is a common practice in many parts of the world [Reed, *et al.,* 1995]. Worldwide, it is estimated that 20 million hectares of arable land are irrigated with waste water.

In several Asian and African cities, studies suggest that agriculture based on wastewater irrigation accounts for 50 percent of the vegetable supply to urban areas (Bjuhr, 2007).

Metal mining and milling processes and industrial wastes

Mining and milling of metal ores coupled with industries have bequeathed many countries, the legacy of wide distribution of metal contaminants in soil.

During mining, tailings (heavier and larger particles settled at the bottom of the flotation cell during mining) are directly discharged into natural depressions, including onsite wetlands resulting in elevated concentrations (DeVolder, *et al.,* 2003).

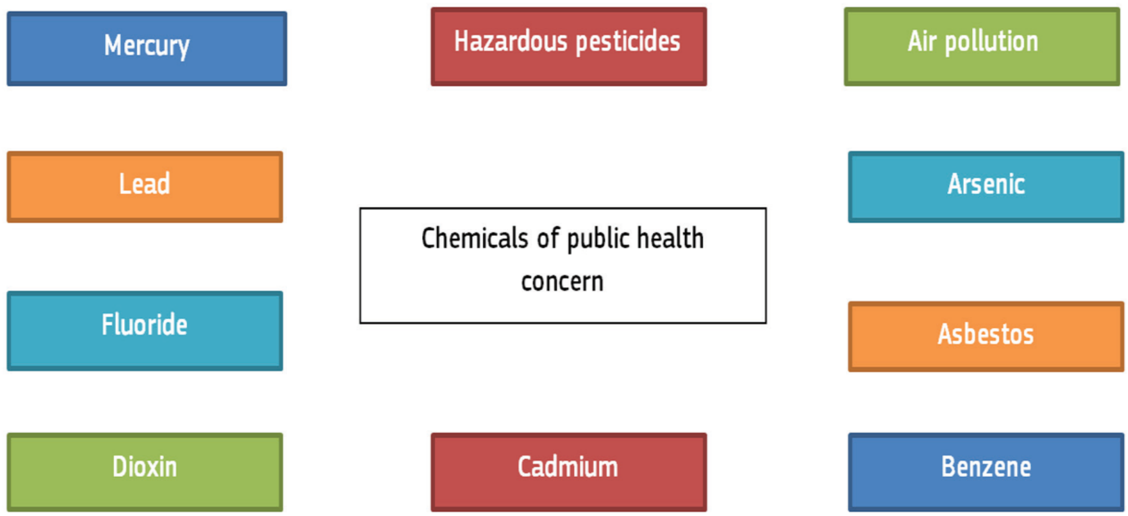
Other materials are generated by a variety of industries such as textile, tanning, petrochemicals from accidental oil spills or utilization of petroleum-based products, pesticides, and pharmaceutical facilities and are highly variable in composition. Although some are disposed of on land, few have benefits to agriculture or forestry.

In addition, many are potentially hazardous because of their contents of heavy metals (Cr, Pb, and Zn) or toxic organic compounds and are seldom, if ever, applied to land. Others are very low in plant nutrients or have no soil conditioning properties (Sumner, 2000).

Air-borne sources

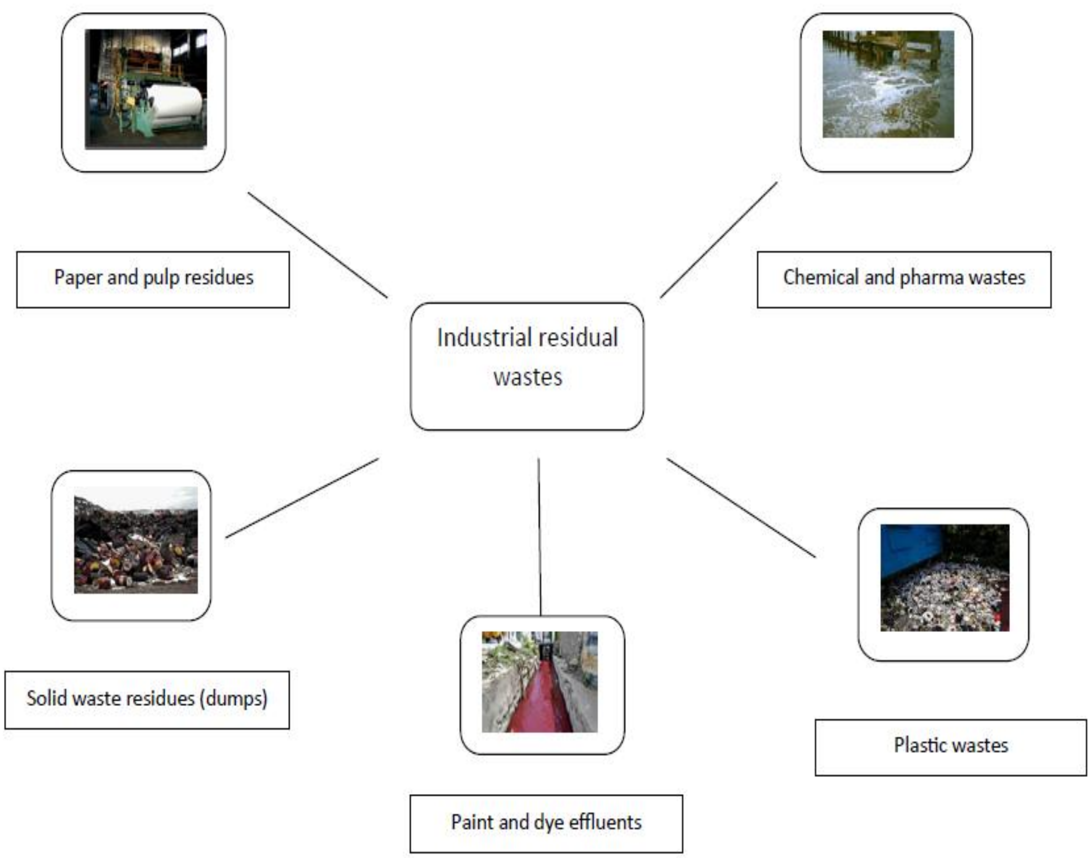
Airborne sources of metals include stack or duct emissions of air, gas, or vapor streams, and fugitive emissions such as dust from storage areas or waste piles. Metals from airborne sources are generally released as particulates contained in the gas stream. Some metals such as As, Cd, and Pb can also volatilize during high-temperature processing. These metals will convert to oxides and condense as fine particulates unless a reducing atmosphere is maintained (Smith *et al.,* 1995).

Ten chemicals of major public health concern

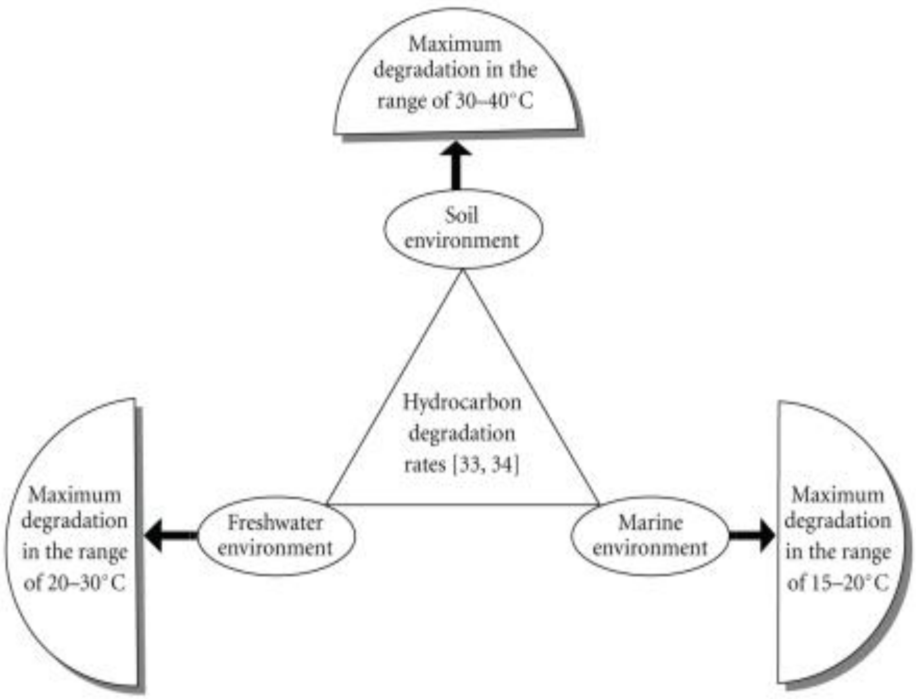


Source: adapted from WHO

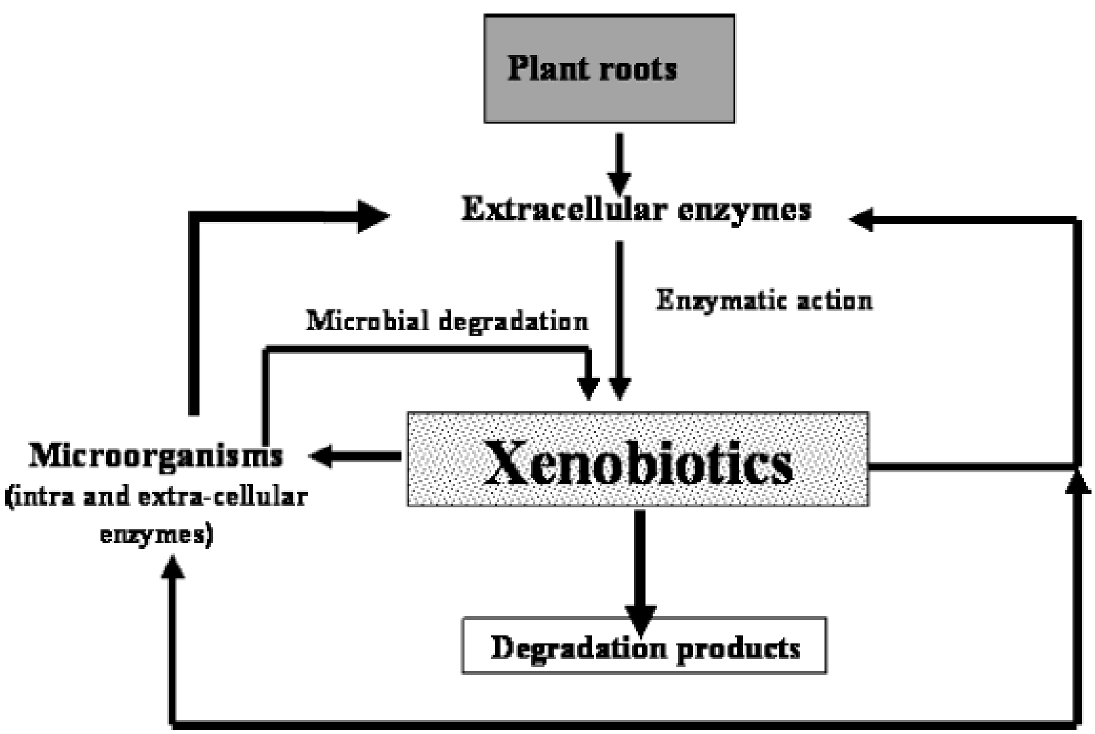
Sources of heavy metals in contaminated soils



Biodegradation



Anaerobic biodegradation



Bioremediation

Technology	Examples	Benefits	Limitations	Factors to consider
In situ	*In situ* bioremediation Biosparging Bioventing Bioaugmentation	Most cost efficient Noninvasive Relatively passive Natural attenuation processes Treats soil and water	Environmental constraints Extended treatment time Monitoring difficulties	Biodegradative abilities of indigenous microorganisms Presence of metals and other inorganics Environmental parameters Biodegradability of pollutants Chemical solubility Geological factors Distribution of pollutants
Ex situ	Landfarming Composting Biopiles	Cost efficient Low cost Can be done on site	Space requirements Extended treatment time Need to control abiotic loss Mass transfer problem Bioavailability limitation	See above
Bioreactors	Slurry reactors Aqueous reactors	Rapid degradation kinetic Optimized environmental parameters Enhances mass transfer Effective use of inoculants and surfactants	Soil requires excavation Relatively high cost capital Relatively high operating cost	See above Bioaugmentation Toxicity of amendments Toxic concentrations of contaminants

Degradable Organic Hazardous Wastes and the Associated Microorganisms

Hazardous Organic Compounds	Microorganisms Involved in Degradation
Phenylmercuric acetate	*Pseudomonas, Arthrobacter, Citrobacter, Vibrio*
Raw rubber, hevea latex	*Actinomycetes*
Detergents	*Nocardia, Pseudomonas*
PCBs	Not identified
Malathion	*Trichoderma, Pseudomonas*
Endrin	*Arthrobacter, Bacillus*
Lindane	*Closteridium*
DDT	*Escherichia, Hydrogenomonas, Saccharomyces*
Dieldrin	*Mucor*

Sources: Various Publications of UNEP, WWF and WHO (1992-2002)

Table.1 Microorganisms having biodegradation potential for xenobiotics

Microorganisms	Toxic Chemicals	Reference
Pseudomonas spp.	Benzene, anthracene, hydrocarbons, PCBs	Cybulski*et al,* 2003
Alcaligenes spp.	Halogenated hydrocarbons, linear alkylbenzene sulfonates, polycyclic aromatics, PCBs	Kapley*et al.,* 1999
Arthrobacter spp.	Benzene,hydrocarbons,pentachlorop henol, phenoxyacetate, polycyclic aromatic, Aromatics, long chain alkanes, phenol, Cresol	Jogdand, 1995
Bacillus spp.	Halogenated hydrocarbons, phenoxyacetates	Cybulski*et al.,*2003
Corynebacterium spp.	Aromatics	Jogdand, 1995
Flavobacterium spp.	Aromatics Naphthalene, biphenyl	Jogdand, 1995
Azotobacter spp.	Aromatics, branched hydrocarbons benzene,cycloparaffins	Jogdand, 1995 DeanRoss*et al.,*2002
Rhodococcus spp.	Hydrocarbons Aromatics	DeanRoss*et al.,*2002
Mycobacterium spp.	Aromatics Hydrocarbons, polycyclic hydrocarbons	Park *et al.,* 1998
Nocardia spp.	Phenoxyacetate, halogenated hydrocarbon diazinon	Jogdand, 1995
Methosinus sp.	PCBs, formaldehyde	Ijah, 1998
Methanogens	PCBs, polycyclic aromatics, biphenyl	Jogdand, 1995

Source, Vidali 2001

Genetic engineering for biodegradation of contaminants

Microorganisms	Modification	Contaminants	Reference
Pseudomonas. putida	pathway	4-ethylbenzoate	Ramos *et al.,*
P. putida KT2442	pathway	toluene/benzoate	Panke and Sanchezromero
Pseudomonas sp.FRI	pathway	chloro-, methylbenzoates	Rojo *et al.,*
Comamonas. testosteroni VP44	substrate specificity	o-, p-monochlorobiphenyls	Hrywna *et al.,*
Pseudomonas sp. LB400	substrate specificity	PCB	Erickson and Mondello
P. pseudoalcaligenes KF707-D2	substrate specificity	TCE, toluene, benzene	Suyama *et al.,*

Indigenous microorganisms in remediation of contaminated soils

Degradation of organic compound by indigenous microbes without any artificial enhancement is termed as an "intrinsic bioremediation" and this is one of the best remedial actions for soil contamination. Generally, biodegradation means mineralization of organic constituents to the soluble inorganic compounds or to transform organic constituents to other soluble organic compounds. In the process of biodegradation of an organic compound, a wide variety of microbial enzymes are involved in transforming both artificial and natural hydrocarbons into intermediate compounds which may be less or equally hazardous than the parental compounds (Baduru Lakshman Kumar and Sai Gopal, 2015).

Remediation of environment niches such as soil, sediments and water amended with heavy metals can be achieved through biologically encoded changes in the oxidation state. Bioremediation is the microbe-mediated process for clearance or immobilization of the contaminants, including all possible toxins like hydrocarbons, agrochemicals and other organic toxicants. But for inorganic toxic compounds such as heavy metals, microbes are unable to simplify them into harmless compounds, and they should be used according to their specialization for the type of contaminants. Thus the bioremediation strategy for heavy metals depends on the active metabolizing capabilities of microorganisms (Ahemad, 2014) (Table 1).

Bioremediation

Bioremediation is not only a process of removing the pollutant from the environment but also it an eco-friendly and more effective process (Singh and Tripathi, 2007). The pollutants can be removes or detoxify from the soil and water by the use of microorganism, known as bioremediation (Talley, 2005). The purpose of bioremediation is to make environment free from pollution with help of environmental friendly microbes. Bioremediation broadly can be divided in two category i.e. In-situ bioremediation and ex-situ bioremediation.

Bioremediation is a microorganism mediated transformation or degradation of contaminants into nonhazardous or less-hazardous substances. The employability of various organisms like bacteria, fungi, algae, and plants for efficient bioremediation of pollutants has been reported (Vidali, 2001; Leung, 2004). The involvement of plants in the bioremediation of pollutants is called as phytoremediation. The process of phytoremediation is an emerging green technology that facilitates the removal or degradation of the toxic chemicals in soils, sediments, groundwater, surface water, and air (RTDF). Genetically, engineered plants are also in use. For instance arsenic is phytoremediated by genetically modified plants such as *Arabidopsis thaliana* which expresses two bacterial genes. One of these genes allows the plant to modify arsenate into arsenite and the second one binds the modified arsenite and stores it in the vacuoles (Leung, 2004).

Microbiological cultures, enzyme additives, or nutrient additives that significantly increase the rate of biodegradation to mitigate the effects of the discharge were defied as bioremediation agents by U.S.EPA (Nichols, 2001). Bioremediation agents are classified as bioaugmentation agents and biostimulation agents based on the two main approaches to oil spill bioremediation. Numerous bioremediation products have been proposed and promoted by their vendors, especially during early 1990s, when bioremediation was popularized as "the ultimate solution" to oil spills (Hoff, 1993).

Biodegradation

Biodegradation of petroleum hydrocarbon compounds toluene and o-xylene (BTX) by Pseudomonas putida strain MHF 7109 Pseudomonas putida MHF 7109 has been isolated and identified from cow dung microbial consortium for biodegradation of selected petroleum hydrocarbon compounds – benzene, toluene, and o-xylene (BTX). Each compound was applied separately at concentrations of 50, 100, 250, and 500mgL-1 in minimal salt medium to evaluate degradation activity of the identified microbial strain. The mass spectrometry analysis identified the intermediates as catechol, 2-hydroxymuconic semialdehyde, 3-methylcatechol, cis-2- hydroxypenta-2,4-dienoate, 2-methylbenzyl alcohol, and 1,2-dihydroxy-6- methylcyclohexa- 3,5-dienecarboxylate, for BTX, respectively. P. putida MHF 7109 has been found to have high potential for biodegradation of volatile petroleum hydrocarbons (Singh and Fulekar, 2010).

Microorganisms provide a potential wealth in biodegradation. The ability of these organisms to reduce the concentration of xenobiotics is directly linked to their long-term adaptation to environments where these compounds exist. Moreover, genetic engineering may be used to enhance the performance of such microorganisms that have the preferred properties, essential for biodegradation (Schroll *et al.,* 2004).

The contamination of soils and groundwater with petroleum compounds is among the most prevalent problems in environments worldwide (Alquati, 2005). In situ biodegradation is one of the primary mechanisms by which petroleum and other hydrocarbons are eliminated from the environment. Hydrocarbon-degrading bacteria are widely distributed in marine, freshwater, soil habitats and their use in bioremediation of hydrocarbon-contaminated soils, which exploits their ability to degrade and/or detoxify organic contaminants, has been established as an efficient, economical, versatile and environmentally sound treatment (Margesin and Schinner, 1997).

The five microorganisms used in this study differed in their ability to degrade aromatic hydrocarbons. Some of them, such as *Pseudomonas* strain W, could degrade all investigated hydrocarbon compounds, but the maximum degradation of aromatic hydrocarbons was shown by *Pseudomonas* strain L. Catechol and aniline best supported bacterial growth.

Whyte, *et al.,* (1997) conducted similar experiments, studying biodegradation of naphthalene by bacteria isolated from oil-contaminated soils.

Toledo *et al.*, (2006) studied bacterial strains isolated from waste crude oil and their capacity for growth with naphthalene, phenanthrene, fluoranthene and pyrine as sole carbon sources. Our study differs from these, however, in that we studied growth rate of bacteria only in the presence of aromatic hydrocarbons.

Microbial degradation of xenobiotic compounds

Xenobiotics are organic in nature and many of the xenobiotic compounds released into the environment and accumulate because they are only degraded very slowly and in some cases so slowly as to render them effectively permanent. The degradation of xenobiotic compounds are depends upon microbial activity. Some example includes degradation of parathion.

It should be examine the degradation pathway of xenobiotic compound when single substrate is available there. In absence of oxygen there should be an alternative electron accepter nitrate, sulphate, selenate, carbonate etc. There are no microbes or group of microbes that degrade all compounds. So there should be a group of organism, metabolically versatile that is applicable for the degradation of large no of compound.

Microorganisms play a major role in degradation of xenobiotics. They transform toxic contaminants in to non-hazardous or less hazardous substances. Most of the micro-organisms, particularly bacteria are known for detoxifying abilities. They mineralize, transform or immobilize the pollutants. Examples of aerobic and anaerobic xenobiotics degradative bacteria are *Pseudomonas*, *Gordonia*, *Bacillus*, *Moraxella*, *Micrococcus*, *Escherichia*, *Sphingobium*, *Pandoraea*, *Rhodococcus*, and anaerobic xenobiotics degradative bacteria are *Pelatomaculum*, *Desulphovibrio*, *Methano-spirillum*, *Methanosaeta desulfotomaculum*, *Syntrophobacter*, *Syntrophus*.

Biodegradation pathway of xenobiotics compound

Microorganisms apply two modes of action for degradation of xenobiotics compound: (a) aerobic biodegradation and (b) anaerobic biodegradation.

Aerobic biodegradation pathway

Some of the xenobiotics like petroleum hydrocarbons, chlorinated aliphatics, benzene, toluene, phenol, naphthalene, fluorine, pyrene, chloroanilines, pentachlorophenol and dichlorobenzenes are rapidly and potentially degraded by the aerobic degradation process. Many bacterial consortia capable to grow on these chemicals they are producing enzymes which degrade toxic compounds to non-toxic compounds.

Xenobiotic compound + O2----------------CO2 + H2O + biomass + residue(s) (Shimao, 2001).

The process of conversion of biodegradable materials to gases like carbon dioxide, methane, and nitrogen compounds is called mineralization. Mineralization process is completed, when all the biodegradable biomass is consumed and all the carbon is converted into carbon dioxide (Kyrikou and Briassoulis, 2007).

Anaerobic biodegradation

Some pollutants are not mineralized by an aerobic degradation process; they are polychlorinated biphenyls (PCBs), chlorinated dioxins and some pesticides like DDT. It is necessary to overcome the high persistence of halogenated xenobiotics from the biosphere, for achieving these, reductive attacks by anaerobic bacteria is

Xenobiotic compound----------------------- CO2 + CH4 + H2O + biomass + residue (s) (Jayasekara *et al.*, 2005).

The four processes are briefly discussed next. Particular attention is dedicated to pesticides, which stand out as one of the major developments of the twentieth century. During the last years, however, concern has arisen as to the extent that their presence in the environment poses a threat to wildlife and humankind. Certainly, pesticides have improved longevity and the quality of life, chiefly in the area of public health. The use of pesticides also constitutes an important aspect of modern agriculture, for without chemicals to control various pests like insects, weeds, plant diseases, worms, and rodents, our food supply would decrease and prices would increase.

GMO as a tool of soil pollution reduction

Recombinant DNA techniques have been studied intensively to improve the degradation of hazardous waste under laboratory condition. The genetically engineered microorganisms have higher degradative capacity and have been demonstrated successfully for the degradation of various pollutants under defined conditions. Genetic modification technology has resulted often in a wide variety of current and potential applications for use in the process of bioremediation. Bioremediation explores gene diversity and metabolic versatility of microorganisms (Fulekar, 2009).

The use of genetically modified (GM) bacteria represents a research frontier with broad implications. The potential benefits of using genetically modified bacteria are significant. But the need for GM bacteria may be questionable for many cases, considering that indigenous species often perform adequately but we do not tap the full potential of wild species due to our limited understanding of various phytoremediation mechanisms, including the regulation of enzyme systems that degrade pollutants.

Moreover, the efficiency of microorganisms engineered with organophosphate hydrolyses (the most involved degrading enzyme) encoding gene opd (organophosphate-degrading) genes was tested against a wide range of organophosphorus compounds in liquid cultures and soil systems (Singh and Walker, 2006).

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