ENVIRONMENTAL STUDIES & LIFE SCIENCES

Dr. Sasmita Sabat
Department of Biotechnology
PES University, Bangalore - 560085

ENVIRONMENTAL STUDIES & LIFE SCIENCES

Bio-sustainability

- Bio-sustainability
  - Bioremediation
    - Types/ Techniques
  - Phytoremediation
    - Mechanisms

Dr. Sasmita Sabat
Department of Biotechnology

Bio-sustainability - Bioremediation

Introduction

Bioremediation is a process where biological organisms are used to remove or neutralize an environmental pollutant by metabolic process.

The “biological” organisms include microscopic organisms, such as fungi, algae and bacteria, and the “remediation”- treating the situation.

The use of either naturally occurring or deliberately introduced microorganisms to consume and break down environmental pollutants, in order to clean a polluted site.

Employs the microorganisms, to degrade the pollutants and convert them into less toxic or non-toxic form.

Bio-sustainability - Bioremediation

Definition

The suitable organisms can be bacteria, fungi, or plants, which have the physiological abilities to degrade, detoxify, or render the contaminants harmless.

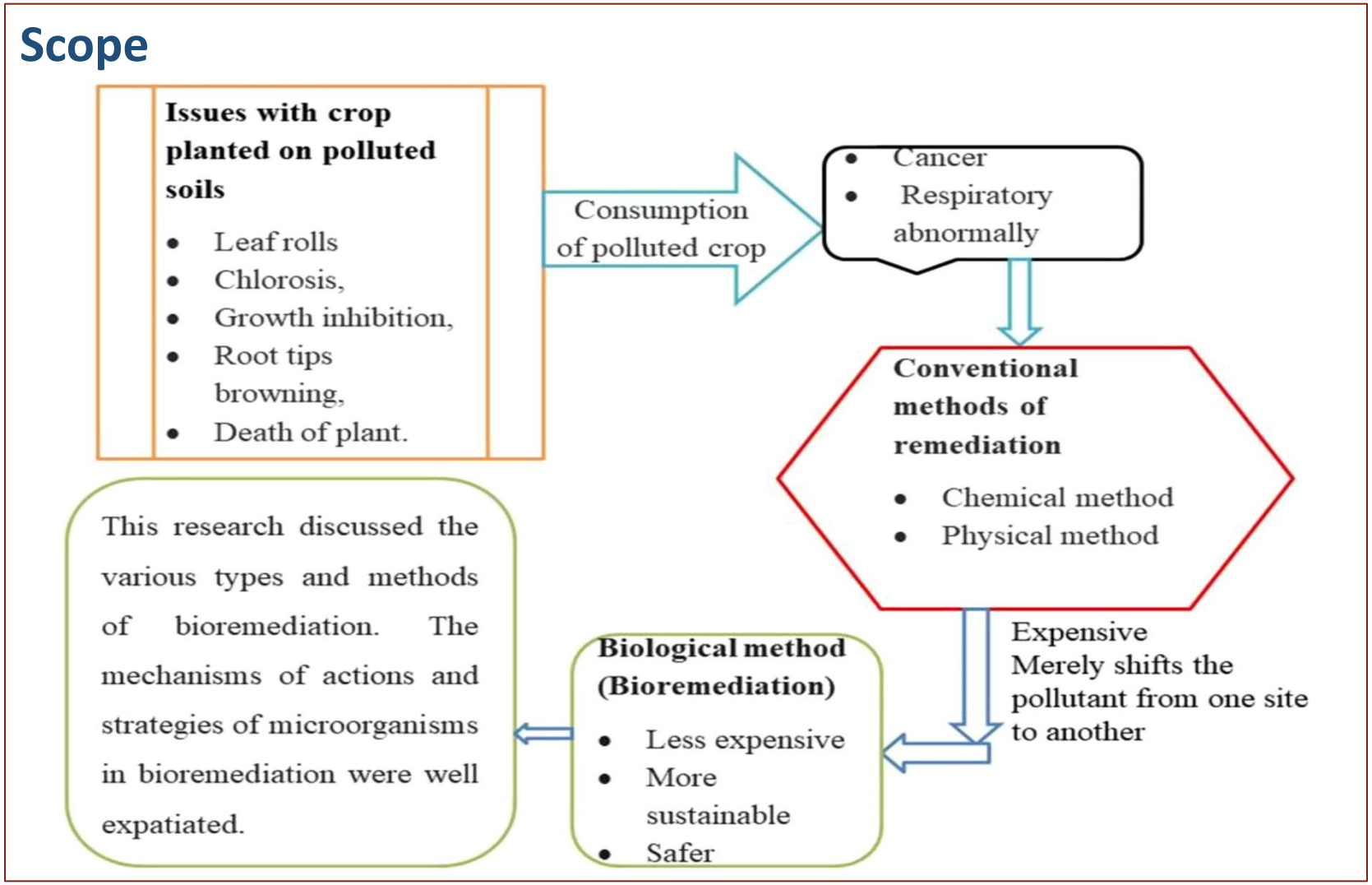
"Bioremediation is a waste management technique that includes the use of living organisms to eradicate or neutralize pollutants from a contaminated site."

"Bioremediation is a 'treatment techniques' that uses naturally occurring organisms to break down harmful materials into less toxic or non-toxic materials."

A mechanism of bioremediation is to reduce, detoxify, degrade, mineralize or transform more toxic pollutants to a less toxic.

Bio-sustainability - Bioremediation

Scope



Source: https://www.frontiersin.org/files/Articles/937186/fsoil-02-937186-HTML/image_m/fsoil-02-937186-g003.jpg

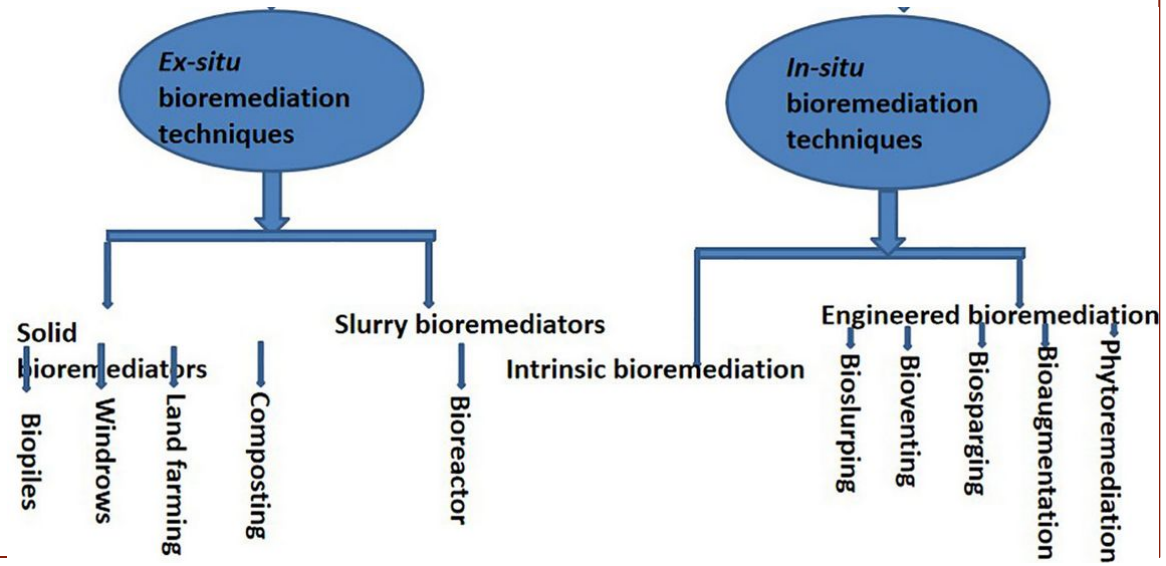
PES UNIVERSITY

Bio-sustainability - Bioremediation

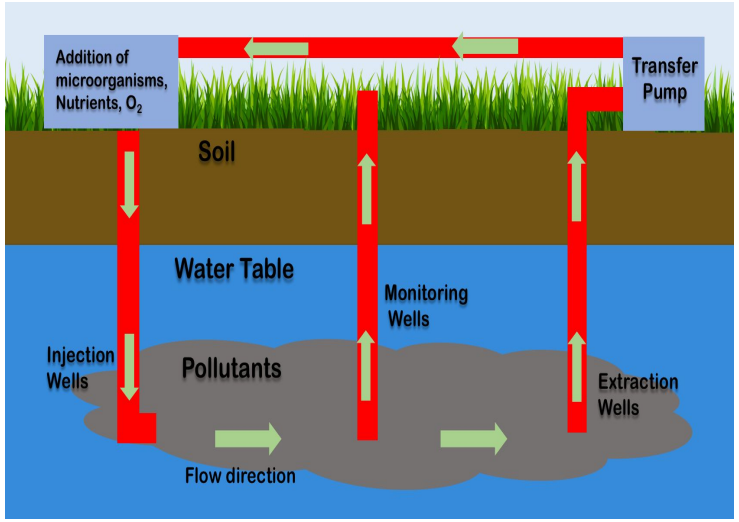
Types / Techniques

Bioremediation technologies can be classified into two general categories: ***ex situ*** and ***in situ***.

The ***ex situ*** techniques require the physical removal of the contaminated material and its transportation to another area for further treatment by bioreactors, land farming, or composting, where as ***in situ*** technologies involve treatment of contaminated material in place.

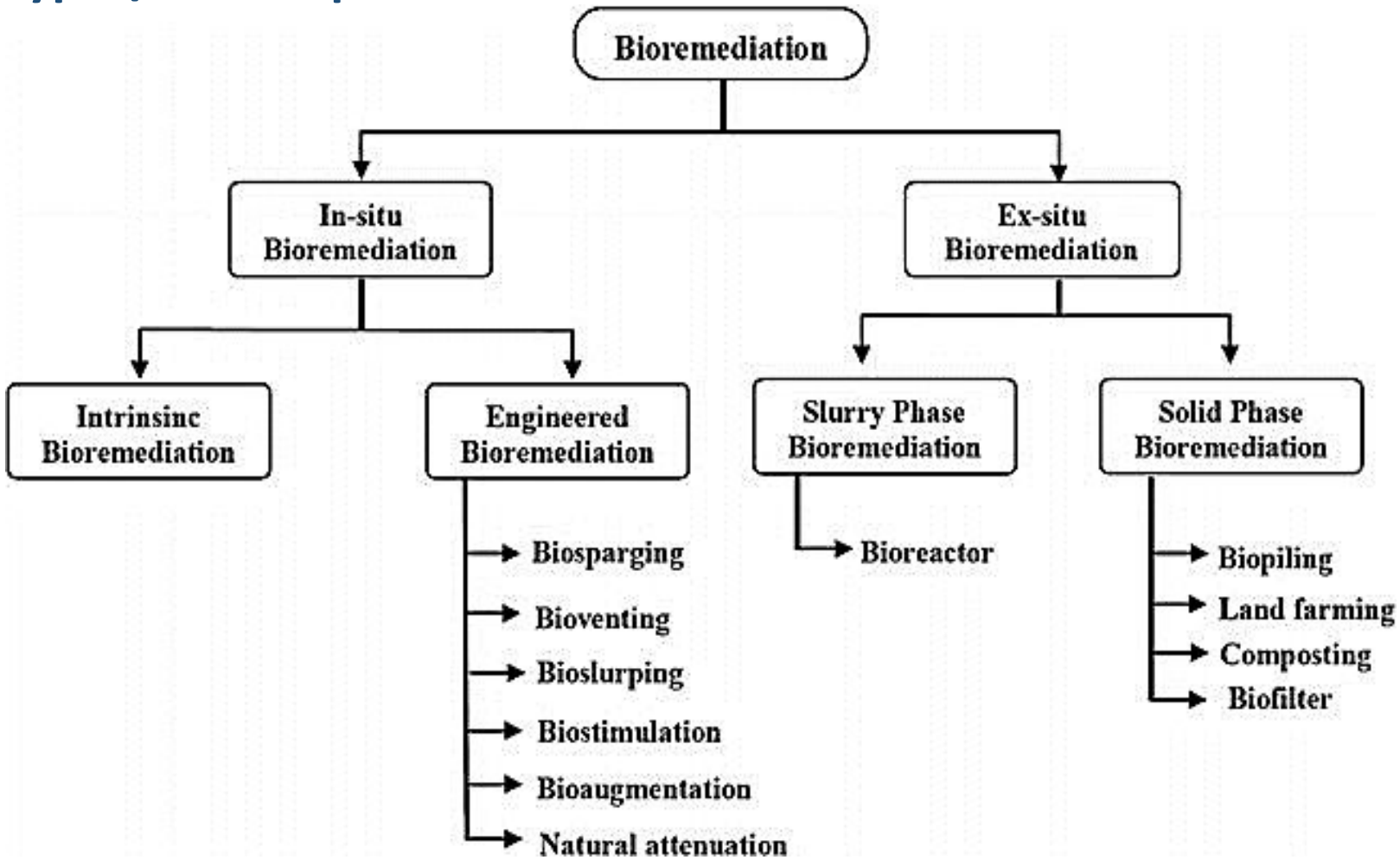


Source: Bioremediation techniques as affected by limiting factors in soil environment By Elizebath *et. al.*



Bio-sustainability - Bioremediation

Types/ Techniques



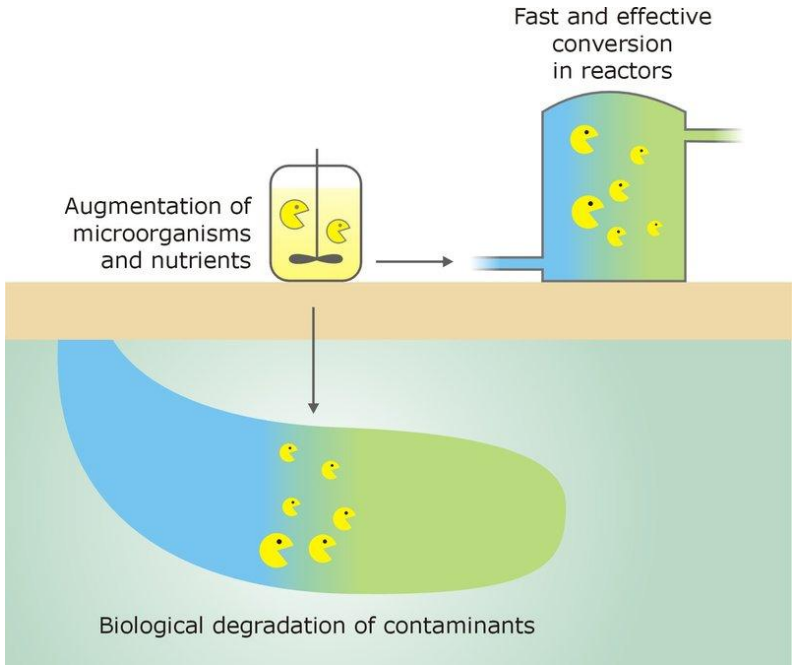
Source: Bioremediation Techniques for Polluted Environment: Concept, Advantages, Limitations, and Prospects | IntechOpen

ENVIRONMENTAL STUDIES & LIFE SCIENCES

Bio-sustainability - Bioremediation

Bioremediation Techniques

Bioaugmentation	**Addition of bacterial cultures to a contaminated medium; frequently used in bioreactors and ex situ systems**
Biostimulation	Stimulation of indigenous microbial populations in soils or groundwater by adding nutrients to the existing bacteria; which can be performed either in situ or ex situ
Bioreactors	Biodegradation in a container or reactor; may be used to treat several liquid wastes or slurries but relatively high capital and operational cost

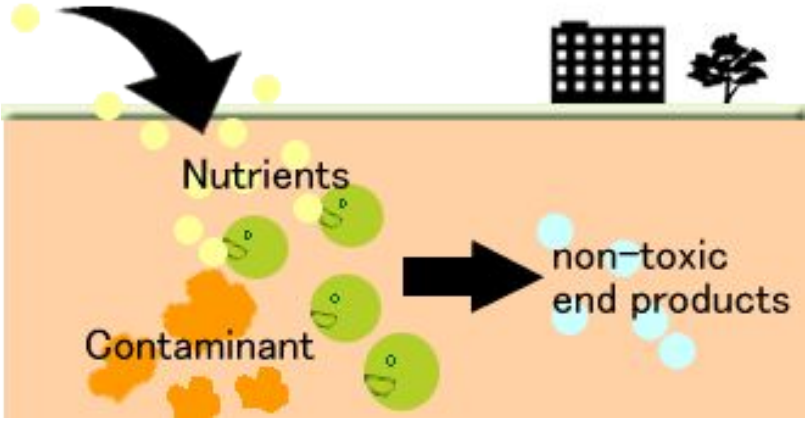


ENVIRONMENTAL STUDIES & LIFE SCIENCES

Bio-sustainability - Bioremediation

Bioremediation Techniques

Bioaugmentation	Addition of bacterial cultures to a contaminated medium; frequently used in bioreactors and ex situ systems
Biostimulation	**Stimulation of indigenous microbial populations in soils or groundwater by adding nutrients to the existing bacteria; which can be performed either in situ or ex situ**
Bioreactors	Biodegradation in a container or reactor; may be used to treat several liquid wastes or slurries but relatively high capital and operational cost

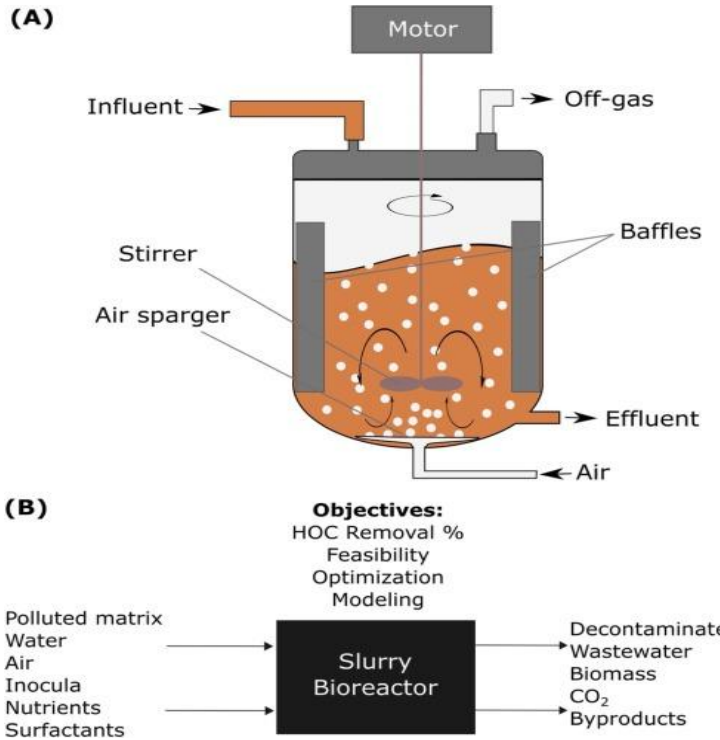


PES UNIVERSITY

Bio-sustainability - Bioremediation

Bioremediation Techniques

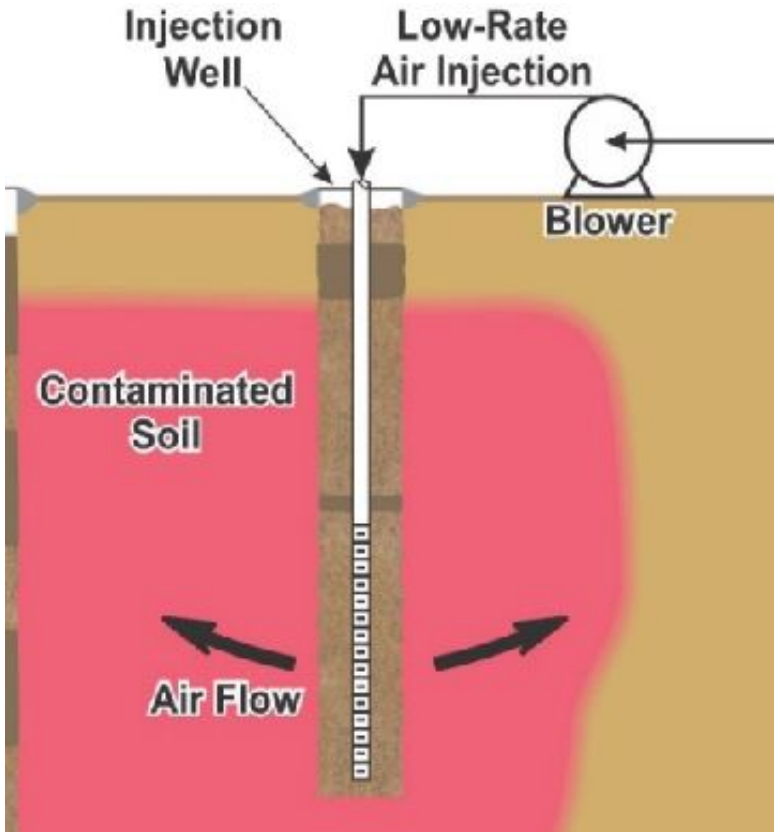
Bioaugmentation	Addition of bacterial cultures to a contaminated medium; frequently used in bioreactors and ex situ systems
Biostimulation	Stimulation of indigenous microbial populations in soils or groundwater by adding nutrients to the existing bacteria; which can be performed either in situ or ex situ
Bioreactors	**Biodegradation in a container or reactor; may be used to treat several liquid wastes or slurries but relatively high capital and operational cost**



Bio-sustainability - Bioremediation

Bioremediation Techniques

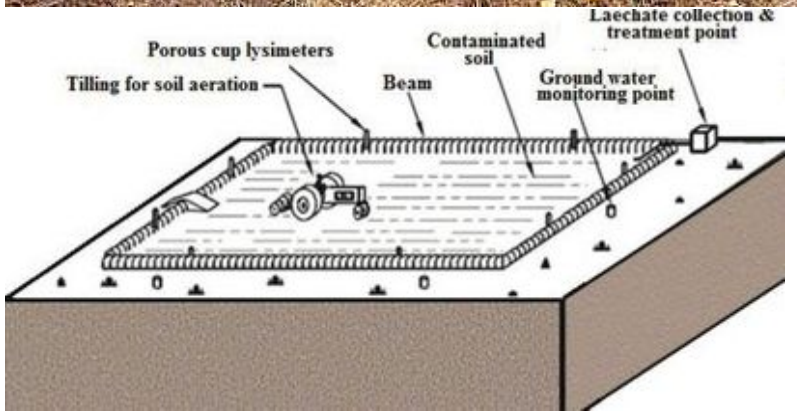
Bioventing	**Method of treating contaminated soils by drawing oxygen through the soil to stimulate microbial growth and activity**
Composting	Aerobic, thermophilic treatment process; can be performed by using static piles, aerated piles, or continuously fed reactors; extended treatment time
Land farming	Solid-phase treatment system for contaminated soils; may be performed in situ or in a constructed soil treatment cell; cost-efficient



Bio-sustainability - Bioremediation

Bioremediation Techniques

Bioventing	Method of treating contaminated soils by drawing oxygen through the soil to stimulate microbial growth and activity
Composting	**Aerobic, thermophilic treatment process; can be performed by using static piles, aerated piles, or continuously fed reactors; extended treatment time**
Land farming	**Solid-phase treatment system for contaminated soils; may be performed in situ or in a constructed soil treatment cell; cost-efficient**



Bio-sustainability - Bioremediation

Bioremediation Process

- Most bioremediation systems operate under aerobic conditions; however, anaerobic conditions are also applicable, thus enabling the degradation of recalcitrant molecules by using specific microorganisms.

- Mainly microorganisms, microbial or plants or its enzymes are used to detoxify contaminants in the soil and other environments.

- Bioremediation, as a technique, can offer several advantages over other more conventional treatment methods.

Bio-sustainability - Bioremediation

Advantages

- Bioremediation is an eco-friendly cleaning process that treats environmental pollutants like pesticides, oils, solvents, and petroleum products. It helps in the removal of Contaminated groundwater, Clean up oil spills, Pollutants, Toxins from soil, Toxins from water and Other environmental contaminants.
- The residue of the bioremediation process, such as water, carbon dioxide, and cell biomass, is harmless to the environment.
- This is a natural process of cleaning nature by eliminating the pollutants and problems related to the processing and storage of pollutants.
- Suitable microbial populations can degrade a wide range of contaminants, rendering a hazardous compound to a harmless one.
- The potential threats to human health and to the environment are minimal . It can be used for crime scene clean-up.

Bio-sustainability - Bioremediation

Disadvantages

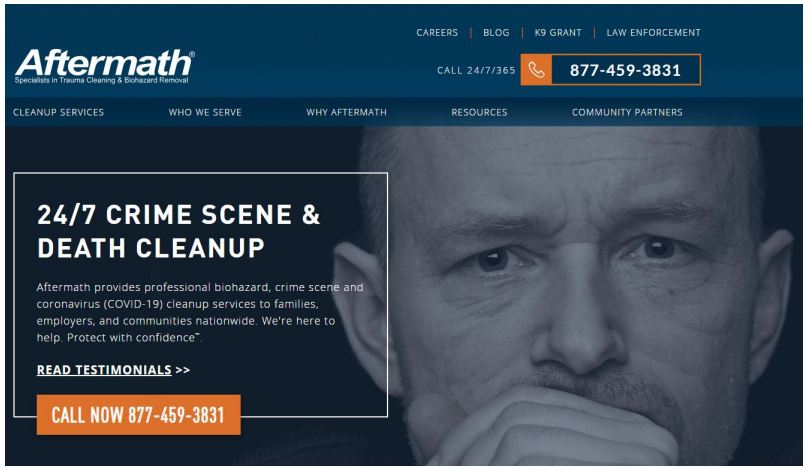
- The bioremediation process operates under specific conditions that may or may not be present in the field where pollutants exist.
- It is not mandatory that microorganism-treated toxins can be entirely turned into harmless compounds.
- Not suitable for all pollutant and applicable only for biodegradable substances
- The effectiveness of bioremediation is highly susceptible to the microbial growth and other environmental parameters of the site.
- Bioremediation often requires more time than other treatment options.

ENVIRONMENTAL STUDIES & LIFE SCIENCES

Bio-sustainability - Bioremediation

Bioremediation examples

- **Crime scene cleanup:** Bioremediation in this sense involves the cleanup of blood and bodily fluids that can pose health risks such as hepatitis, HIV, and MRSA. Rather than using standard cleaning agents like bleach or ammonia, crime scene cleaners use enzyme cleaners to rid the scene of harmful substances. Aftermath is a company that specializes in this area of bioremediation. Aftermath does not remediate environmental pollutants.
- **The cleanup of contaminated soil**: Human activity has introduced many toxic substances into the environment's soil and groundwater. Microbes utilize chemical contaminants in the soil as an energy source and, through oxidation-reduction reactions, metabolize the target contaminant into useable energy for microbes.



WHAT WE DO

If you're faced with cleaning up a death, crime scene, biohazard, or coronavirus (COVID-19) we are here to help. Aftermath Services is the nation's premier crime scene cleanup and biohazard remediation company with over 100 regional offices and mobile units located across the country.

WHO WE HELP

We provide professional and compassionate bio scene cleanup services nationwide to families, employers, and communities after traumatic events such as homicides, suicides, unattended deaths, infectious disease outbreaks (COVID-19), accidents, and other biohazard situations. We care about making your home or business safe and livable again, which is why we provide rapid emergency response 24/7/365. No matter when you need us, we'll be there to help.

Bio-sustainability - Bioremediation

Bioremediation examples

- **Oil spill clean-up**: The Deepwater Horizon oil spill that happened in 2010, where 3.19 million barrels of oil spilled off the Gulf of Mexico.
- Due to the effectiveness and lower cost of bioremediation, two methods were used to clean-up after the Deepwater Horizon oil spill.

Bio-augmentation: The injection of a small amount of oil-degrading microbes into an affected area.

Bio-stimulation: The addition of nutrients to stimulate the growth of innate oil-degrading microbes to increase the rate of remediation.

E.g.: Exxon Valdez spill, Prince William Sound, Alaska, 1989

Exxon Valdez Oil spill

Image source: RGB Ventures

Bio-sustainability - Bioremediation

Bioremediation examples

- There are species of marine bacteria in several families, including *Marinobacter, Oceanospiralles, Pseudomonas*, and *Alkanivorax,* that can eat compounds from petroleum as part of their diet.

- In fact, there are at least seven species of bacteria that can survive solely on oil.

- These bacteria are nature's way of removing oil that ends up in the ocean, whether the oil is there because of oil spills or natural oil seeps.

Bio-sustainability - Bioremediation

Bioremediation examples

First Patent on a Genetically Modified Microrganisms

First patent to Ananda Mohan Chakrabarty for a genetically modified Pseudomonas bacterium that would eat up oil spills.

US Patent No. 4259444

United States Patent [19] [11] 4,259,444

Chakrabarty [45] Mar. 31, 1981

[54] MICROORGANISMS HAVING MULTIPLE COMPATIBLE DEGRADATIVE ENERGY-GENERATING PLASMIDS AND PREPARATION THEREOF

[75] Inventor: Ananda M. Chakrabarty, Lathan, N.Y.

[73] Assignee: General Electric Company, Schenectady, N.Y.

[21] Appl. No.: 240,343

[22] Filed: Jan. 7, 1972

[51] Int. Cl.² C12N 15/00

[52] U.S. Cl. 435/172; 435/253; 435/264; 435/281; 435/820; 435/875; 435/877

[58] Field of Search ..... 195/28 R, 1, 3 H, 3 R, 195/96, 78, 79, 112; 435/172, 253, 264, 820, 281, 875, 877

[56] References Cited

PUBLICATIONS

Annual Review of Microbiology vol. 26 Annual Review Inc. 1972 pp. 362-368.

Journal of Bacteriology vol. 106 pp. 468-478 (1971).

Bacteriological Reviews vol. 33 pp. 210-263 (1969).

Primary Examiner—R. B. Penland

Attorney, Agent, or Firm—Leo I. MaLossi; James C. Davis, Jr.

[57] ABSTRACT

Unique microorganisms have been developed by the application of genetic engineering techniques. These microorganisms contain at least two stable (compatible) energy-generating plasmids, these plasmids specifying separate degradative pathways. The techniques for preparing such multi-plasmid strains from bacteria of the genus Pseudomonas are described. Living cultures of two strains of Pseudomonas (*P. aeruginosa* [NRRL B-5472] and *P. putida* [NRRL B-5473]) have been deposited with the United States Department of Agriculture, Agricultural Research Service, Northern Marketing and Nutrient Research Division, Peoria, Ill. The *P. aeruginosa* NRRL B-5472 was derived from *Pseudomonas aeruginosa* strain 1c by the genetic transfer therein, and containment therein, of camphor, octane, salicylate and naphthalene degradative pathways in the form of plasmids. The *P. putida* NRRL B-5473 was derived from *Pseudomonas putida* strain PpG1 by genetic transfer therein, and containment therein, of camphor, salicylate and naphthalene degradative pathways and drug resistance factor RP-1, all in the form of plasmids.

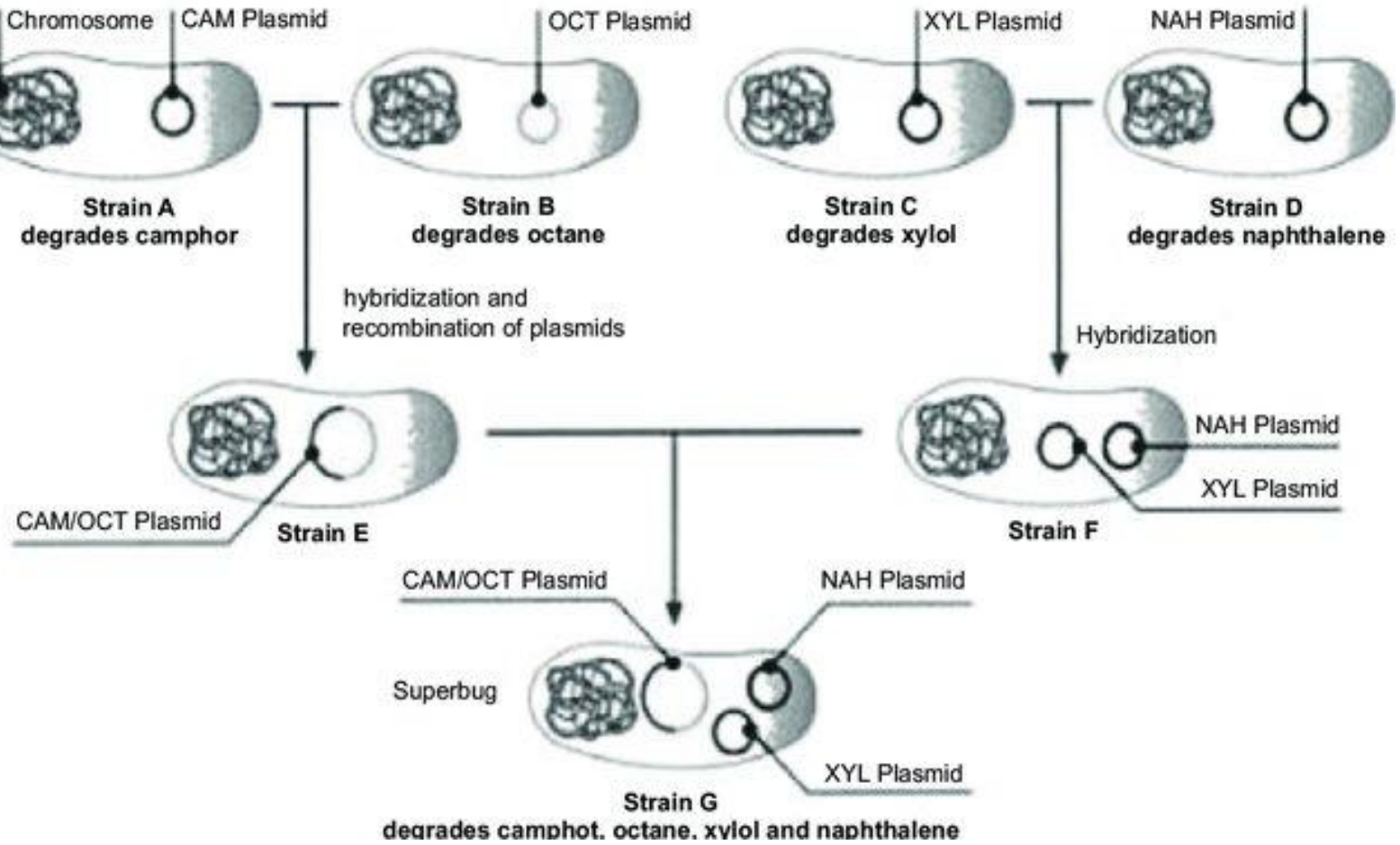
18 Claims, 2 Drawing Figures

8 December 2015

Ananda Mohan Chakrabarty genetically engineered a new species of Pseudomonas bacteria ("The ***Oil-eating bacteria***") in **1971** while working for the R&D Centre at General Electric Company in Schenectady, New York.

Bio-sustainability - Bioremediation

GE approach to improve bacterial oil degradation



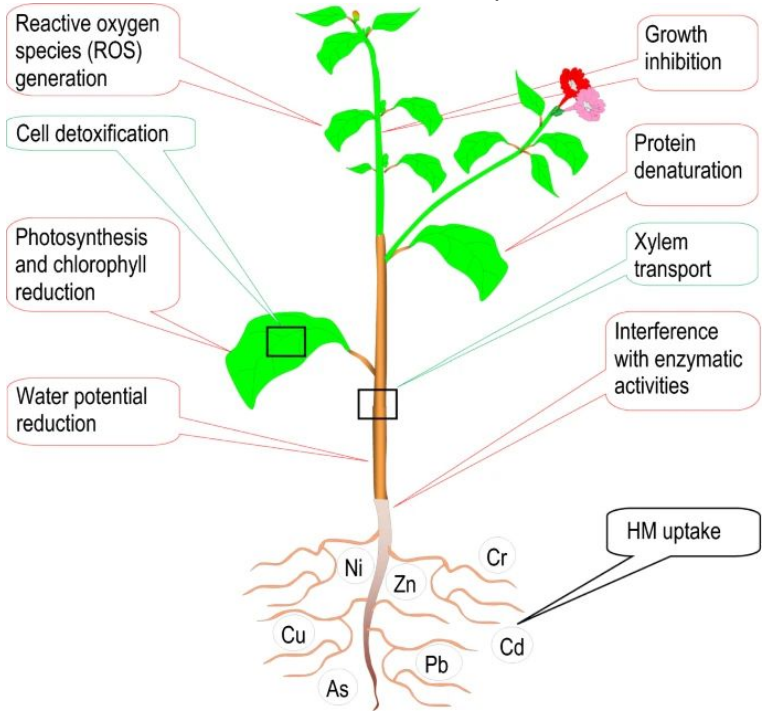
ENVIRONMENTAL STUDIES & LIFE SCIENCES

Bio-sustainability - Bioremediation

Phytoremediation

- Toxic metal contamination of soil is a major environmental hazard.
- Chemical methods for heavy metal's (HMs) decontamination such as heat treatment, electroremediation, soil replacement, precipitation and chemical leaching are generally very costly and not be applicable to agricultural lands.
- The phytoremediation is a promising method based on the use of hyper-accumulator plant species that can tolerate high amounts of toxic HMs present in the environment/soil.
- Such a strategy uses green plants to remove, degrade, or detoxify toxic metals.
- ***Five types of phytoremediation technologies*** have often been employed for soil decontamination: phytostabilization, phytodegradation, rhizofiltration, phytoextraction and phytovolatilization.

Heavy metal toxicity in plants and their tolerance strategies (uptake/translocation and detoxification)

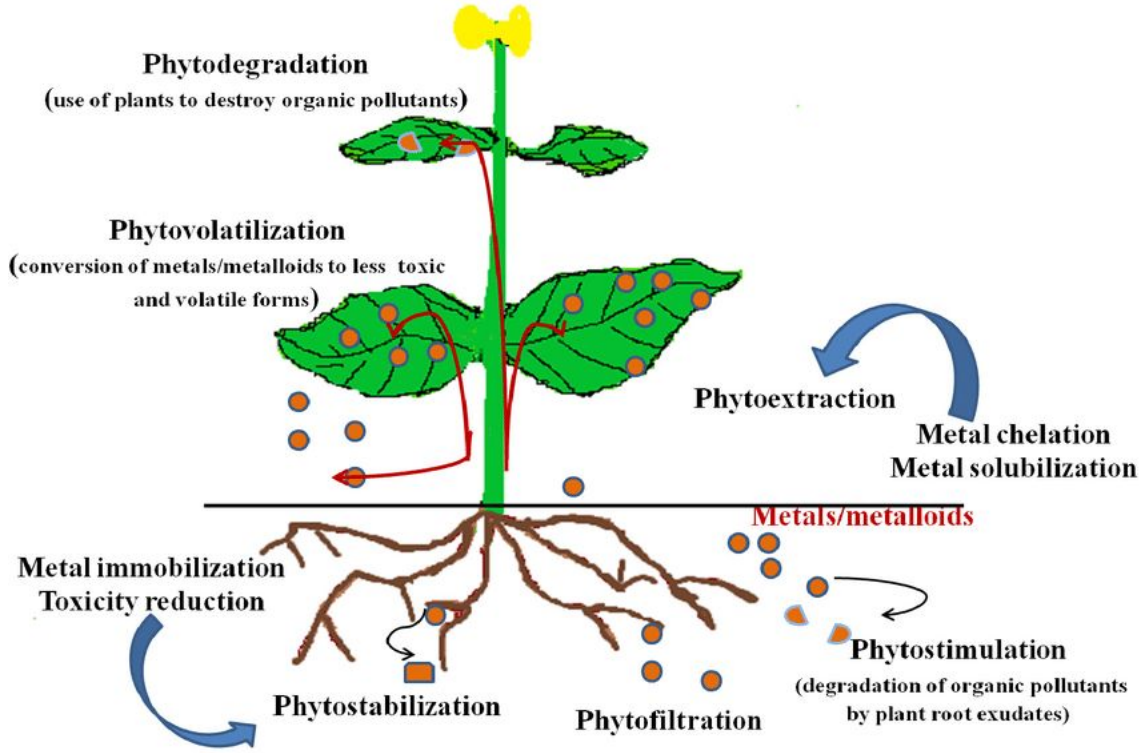


Source: https://link.springer.com/article/10.1007/s42452-021-04301-4

Bio-sustainability - Bioremediation

Phytoremediation - Mechanisms

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. There are several different types of phytoremediation mechanisms.



Bio-sustainability - Bioremediation

Phytoremediation - Mechanisms

Phytotechnology	Mechanism	Pollutants	Plants
Phytoextraction	Hyperaccumulation in harvestable parts of plants	Inorganic: Co, Cr, Ni, Pb, Zn, Au, Hg, Mo, Ag, Cd Radionuclides: Sr, Cs, Pb, U	*Brassica juncea, Thalspi caerulescens, Helianthus annus*
Rhizofilteration	Rhizosphere accumulation though sorption, concentration and precipitation	Organics/Inorganics: Metals like Cd, Cu, Ni, Zn,Cr Radionuclides	*Brassica juncea, Helianthus annus,* Tobacco, Rye, Spinach and Corn
Phytovolatilization	Volatilization by leaves through transpiration	Organics/Inorganics: Chlorinated solvents, inorganics (Se, Hg, As)	*Arabidopsis thaliana*, Poplars, Alfalfa, *Brassica juncea*
Phytodegradation	Pollutant eradication	Organic compounds, Chlorinated solvents, Phenols, Herbicides, Munitions	Hybrid poplars, Stonewort, Black willow, Algae
Phytostabilization	Complexation, sorption and precipitation	Inorganics: As, Cd, Cu, Cr, Pb, Zn, Hs	*Brassica juncea*, Hybrid poplars, Grasses

Bio-sustainability - Bioremediation

Phytoremediation

- Bioremediation helps clean up polluted environments, including soils, groundwater, and marine environments. Such systems can include bacteria, fungi, algae, and plant species.

- They are capable of metabolizing, immobilizing, or absorbing toxic compounds from their environment.

- The a major **advantage** of these systems is that they are less harmful to the environment with minimum or no by-products.

THANK YOU

Dr. Sasmita Sabat

Department of Biotechnology

sasmitasabat@pes.edu

+91 80 26721983 Extn 347