Advanced Pollution Control Remediation Techniques for Industries

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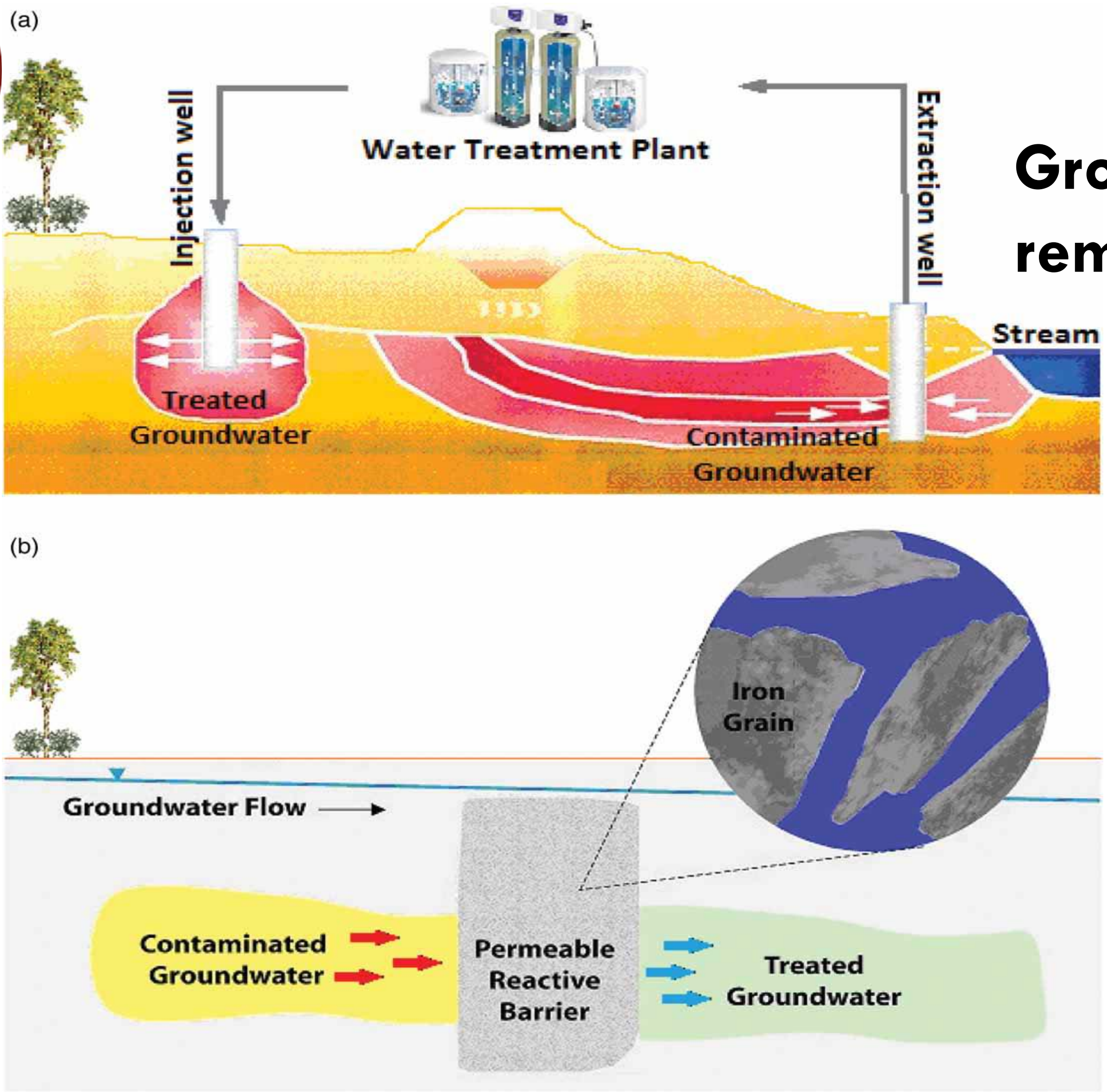
Remediation of contaminants

Remediation is the process to remove, minimize or neutralize the contaminants that can damage human health or ecosystems.

Groundwater remediation



Yunus , et al.,(2012) Environmental Technology Reviews, 1:1, 136-148

Types of remediation

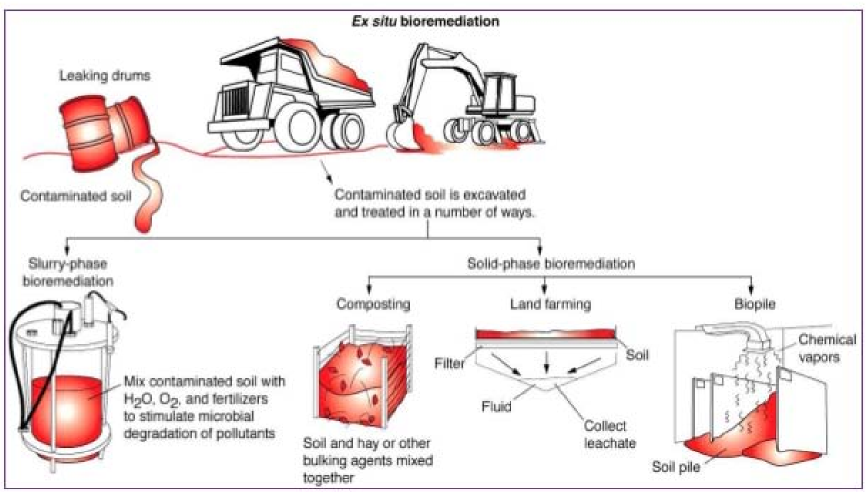
- **Physical**
  - **air striping, filtering of water, etc.**
- **Chemical**
  - **include addition of chemicals that facilitate physical or biological treatments, or oxidize contaminants, etc.**
- **Biological**
  - **utilizes complex biochemical pathways of various organisms to degrade or detoxify contaminants**

Environmental remediation

The two main types of remediation are *ex-situ* and *in-situ*.

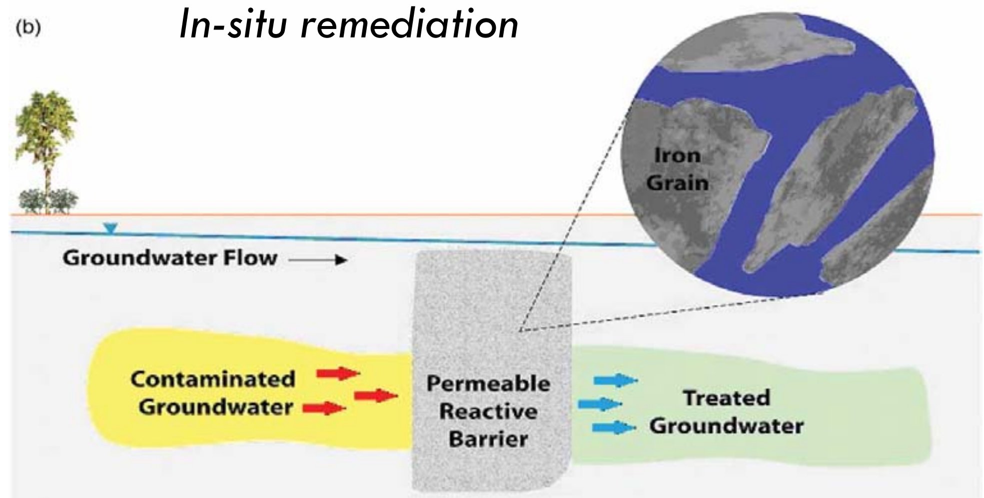
- *Ex-situ* involves physically extracting media from a contaminated site and moving it to another location for treatment whereas
- *In-situ* remediation involves treating contaminants on-site.

Ex-situ remediation



(Source: http://ndpublisher.in/ndpjournal.php?j=IJAEB)

In-situ remediation



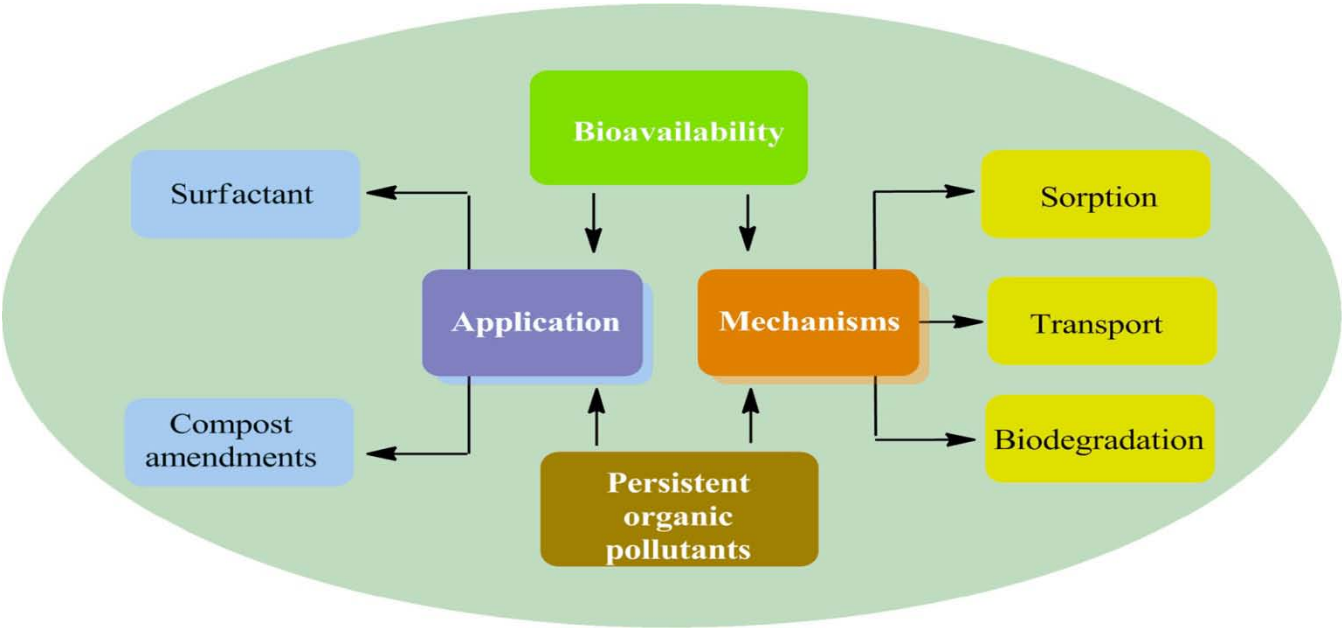
Factors Affecting Potentially Applicable Remedial Technologies

Site characteristics	which may limit or promote the use of certain remedial technologies
Waste characteristics	quantity/concentration, chemical composition, acute toxicity, persistence, biodegradability, radioactivity, ignitability, reactivity/corrosivity, infectiousness, solubility, volatility, density, partition coeffi cient, compatibility with chemicals, and treatability
Technology limitations	including level of technology development, performance record, inherent construction, operation, and maintenance problems

Pure-compound recovery:

- Organic contaminants like oil and gasoline are less soluble in water and can often be pumped off the surface of aquifers.
- The specific gravity of the compound may require pumping from the bottom of a confined aquifer (if > 1.0).
- Sometimes, the product recovered is still usable for its original function.

Bioremediation techniques

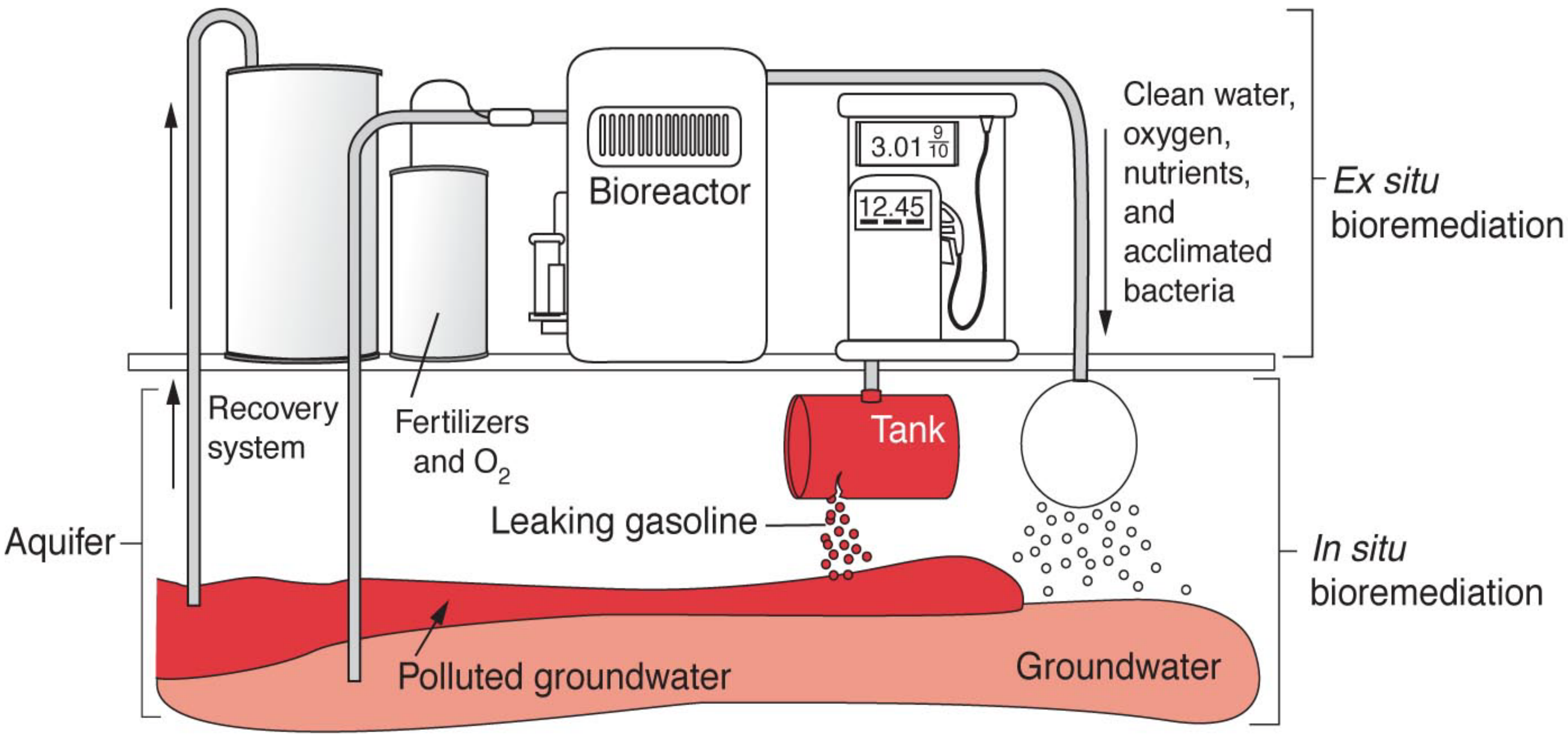


Bioremediation is the use of living organisms like bacteria, plants, animals, or fungi to speed up the remediation process.

Bioremediation techniques

- A tremendous variety of microbes have been used for remediation of contaminants.
- In-situ bioremediation introduces microbes directly into the water which then degrade contaminants through biochemical processes.
- **Due to nature and/or type of pollutant, there is no single bioremediation technique that serves as a 'silver bullet' to restore polluted environments.**

Bioremediation techniques



Bioremediation Strategies

- **In situ bioremediation**
  - *Bioventing*
  - *Biosparging.*
  - *Bioaugmentation.*
- **Ex situ bioremediation**
  - *Land farming*
  - *Composting*
  - *Biopiles*
  - *Bioreactors.*

Table 4 Summary of bioremediation strategies.

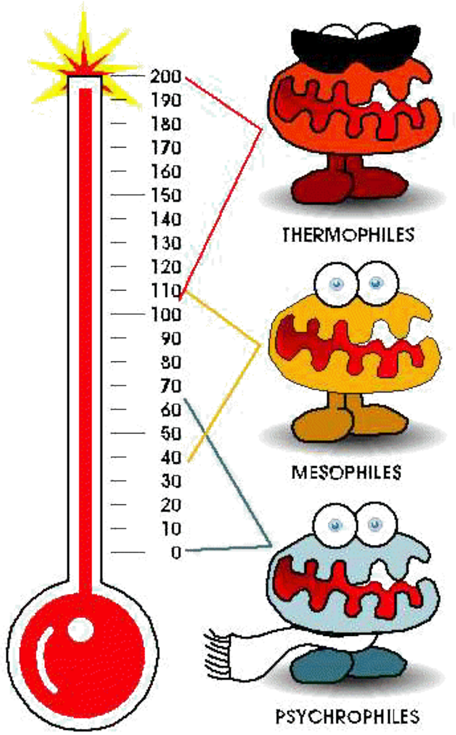
Technology	Examples	Benefits	Limitations	Factors to consider
In situ	*In situ* bioremediation Biosparging Bioventing Bioaugmentation	Most cost efficient Noninvasive Relatively passive Natural attenuation processes Treats soil and water	Environmental constraints Extended treatment time Monitoring difficulties	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

Bioaccumulation

- Some pollutants can be taken up by living organisms and become concentrated in their tissues over time.
- This tendency of some chemicals to be taken up and then concentrated by living organisms is a major consideration, since even relatively low background levels of contamination may accumulate up the food chain.
- The amount of a pollutant available for exposure depends on its persistence and the potential for its bioaccumulation

Why use Bioremediation?

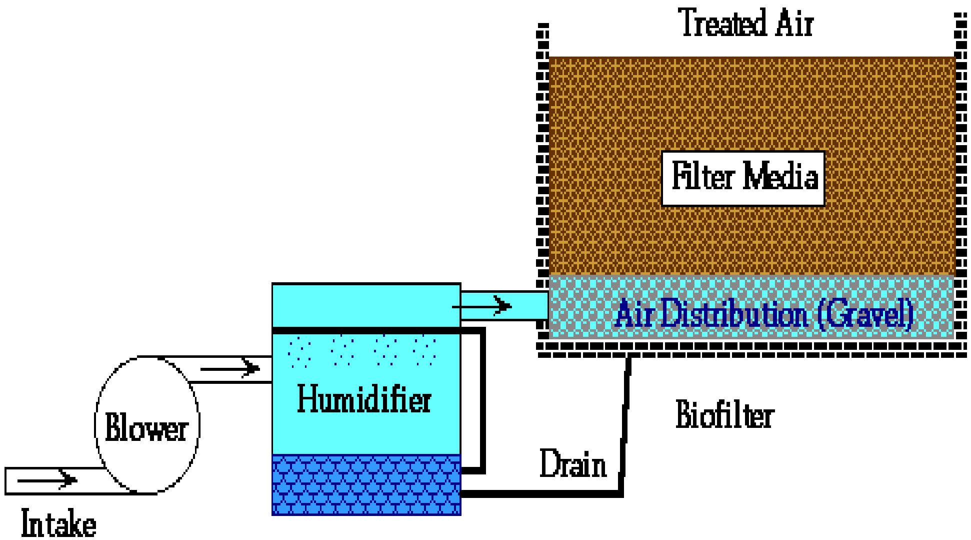
- No additional disposal costs
- Low maintenance
- Does not create an eyesore
- Capable of impacting source zones and thus, decreasing site clean-up time



Genetically-engineered microbes

- Attempts have been made to genetically engineer microbes so that they degrade contaminants more efficiently and quickly.
- Microbes have been patented for this purpose ("superbug" to degrade oil spills).
- There is concern that these "unnatural" microbes may become pests in the environment.

Biofilter

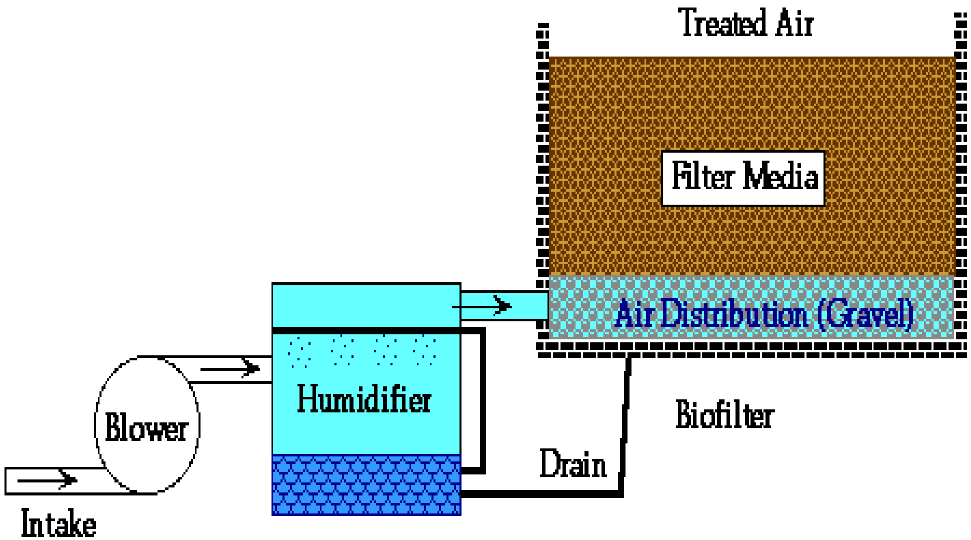


- This method involves passing polluted air over a replaceable culture medium containing micro-organisms that degrade contaminates into products such as carbon dioxide, water or salts.

- A biofilter uses moist organic materials to adsorb and then biologically degrade odorous compounds.

http://compost.css.cornell.edu/odors/odortreat.html

Biofilter



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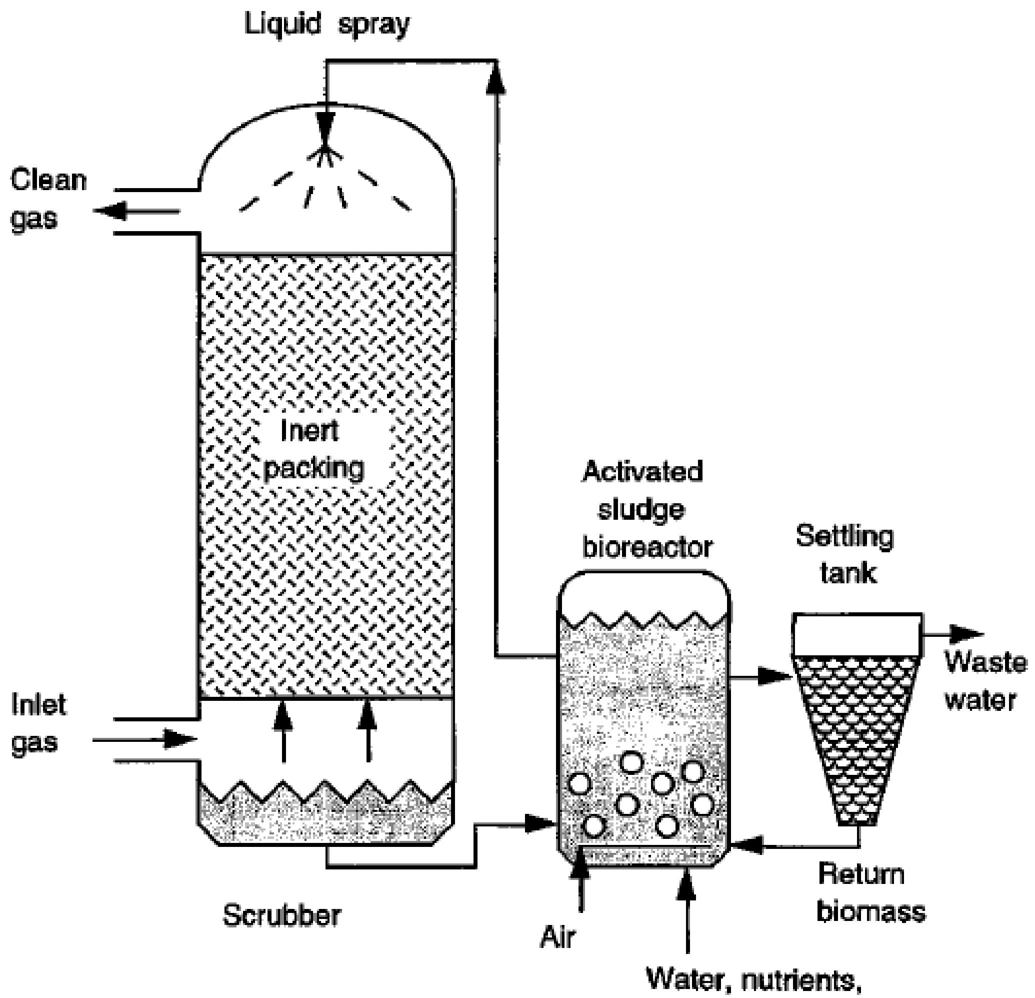
- The materials that have been used for biofilter construction include compost, soil, peat, chipped brush and bark, sometimes blended with a biologically inert material such as gravel to maintain adequate porosity.
- Biofilters have been shown to be effective at treating essentially all of the odors associated with composting, including ammonia and a wide range of volatile organic compounds

Bioscrubber filters



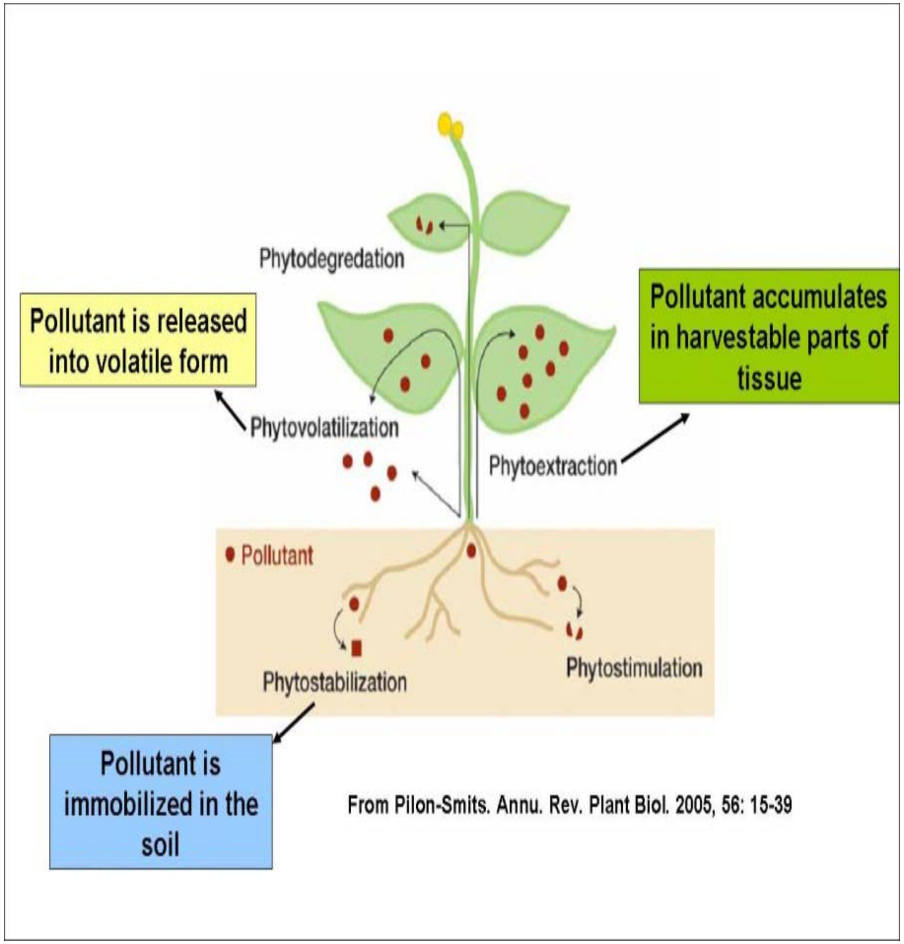
Mudliar et al. (2010) Bioreactors for treatment of VOCs and odours – A review, Journal of Environmental Management 91, 1039–1054

Animal remediation

- Animal remediation is according to the characterization of some lower animals adsorbing heavy metals, degrading, migrating the heavy metals and thus removing and inhibiting their toxicity.

- Reported studies show that
  - the treatment of the earthworm-straw mulching combinations enhanced plant Cu concentration
  - the earthworm could accumulate Pd effectively from contaminated soil

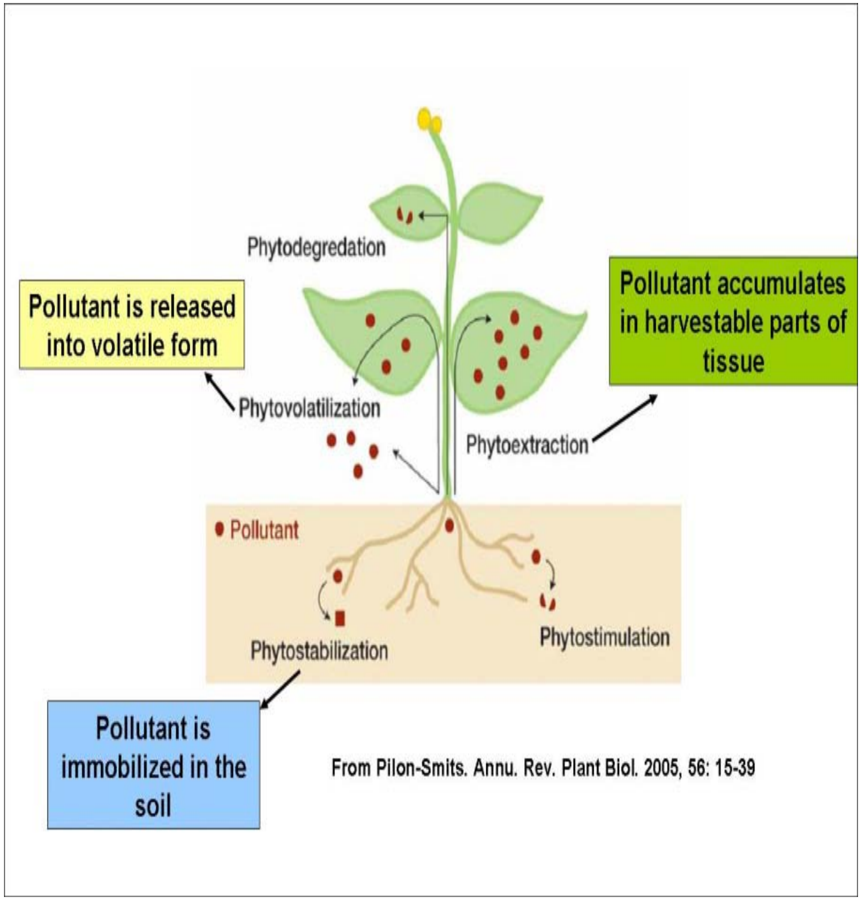
Phytoremediation



https://blogs.umass.edu/natsci397a-eross/phytoremediation-the-future-of-environmental-remediation/

- Using plants in remediation (i.e., phytoremediation) is a relatively new concept and the technology.
- Phytoremediation is proved to be helpful to reduce pollutants in soil, water and air; it is energy-economizing and cost-effective compared with those physical or chemical methods since it is solar-energy driven cleanup technology
- Applications of phytoremediation include Landfill caps, buffer zones for agricultural runoff and even drinking water and industrial wastewater treatment

Phytoremediation



Plants facilitate remediation via several mechanisms:

1. Direct uptake, and incorporation of contaminants into plant biomass
2. Immobilization, or Phytostabilization of contaminants in the subsurface
3. Release plant enzymes into the rhizosphere that act directly on the contaminants
4. Stimulation of microbial mediated degradation in the rhizosphere

https://blogs.umass.edu/natsci397a-eross/phytoremediation-the-future-of-environmental-remediation/

Phytoremediation

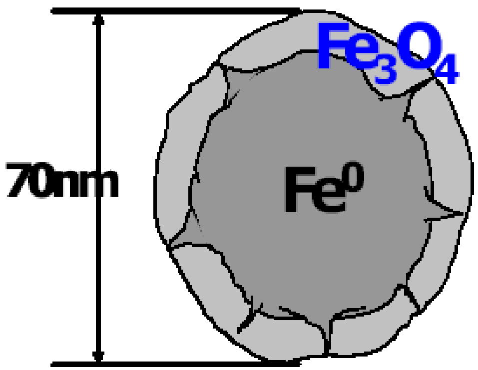
- Phytoremediation may be used for contaminants like
- toxic heavy metals,
- radio nuclides,
- organic contaminants such as chlorinated solvents,
- BTEX compounds,
- non-aromatic petroleum hydrocarbons,
- nitro toluene and other ammunition wastes,
- excess nutrients

Approximately 400 plant species have been classified as hyperaccumulators of heavy metals, such as grasses, sunflower, corn, hemp, flax, alfalfa, tobacco, willow, Indian mustard, poplar, water hyacinth, etc.

Phytoremediation

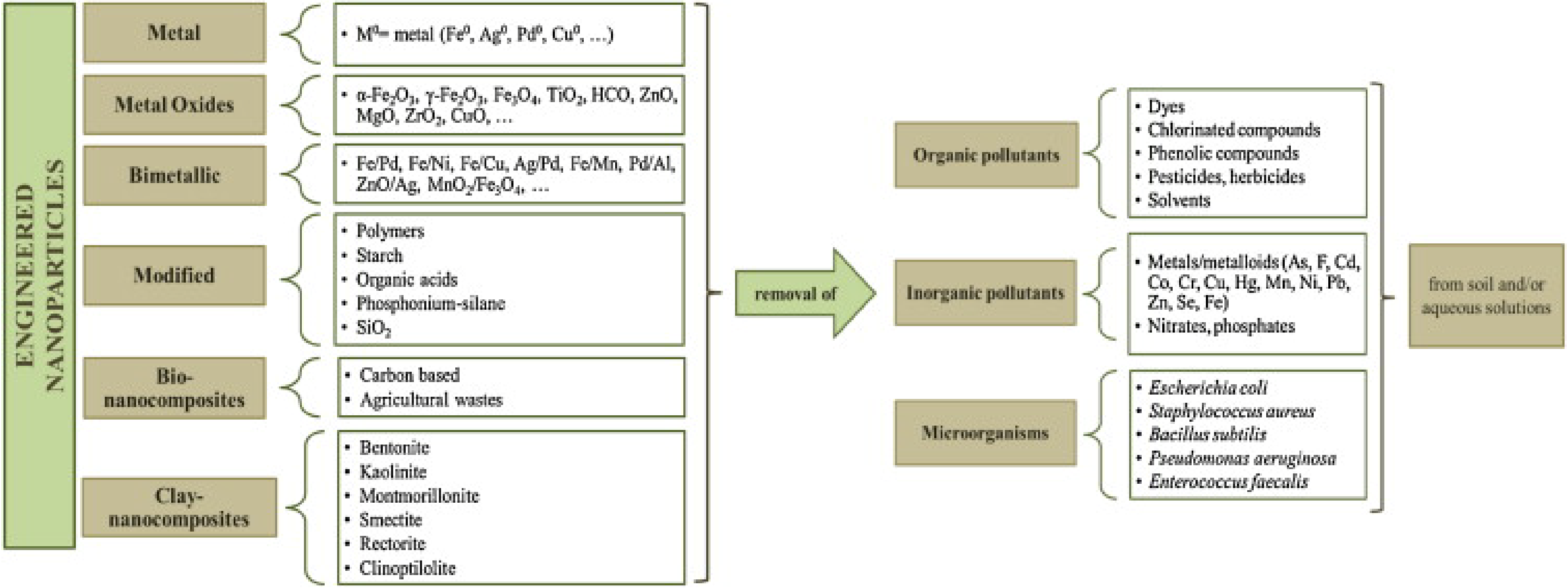
- Vegetation has been used to shield dust in many countries, and the process is called phytofiltration.
- NO_2 enter into the plant and most of them are metabolized to organic compounds, e.g. amino acid, through nitrate assimilation pathway.
- SO_2 enters into plants mainly through stoma, and can be utilized in a reductive sulfur cycle in plants.
- Spider plants (Chlorophytum comosum L.) shoot can metabolize low concentration of formaldehyde (8.5 mg/ m^3) into organic acids, amino acids, free sugars, lipids and cell-wall components.

Nanotechnology



- One of the most popular applications of nanotechnology is the use of nano compounds, devices and tools for air remediation.
- Nanotechnology is being incorporated and improvised in *in-situ* conditions for detecting air contaminants, as well as cleaning, maintaining and enhancing air quality.
- Some materials such as titanium dioxide (TiO_2), zinc oxide (ZnO), iron (III) oxide (Fe_2O_3) and tungsten oxide (WO_3) may serve as photocatalysts.
- Nanometer-sized zeolites (10–100 nm) are being developed to selectively oxidize hydrocarbons, such as toluene to benzaldehyde

Nanotechnology



J. Trujillo-Reyes et al. (2014), Journal of Hazardous Materials 280, 487–503

Nanotechnology for air purification

Nanofilters

- In automobile tailpipes and factory smokestacks to separate out contaminants and prevent them from entering the atmosphere

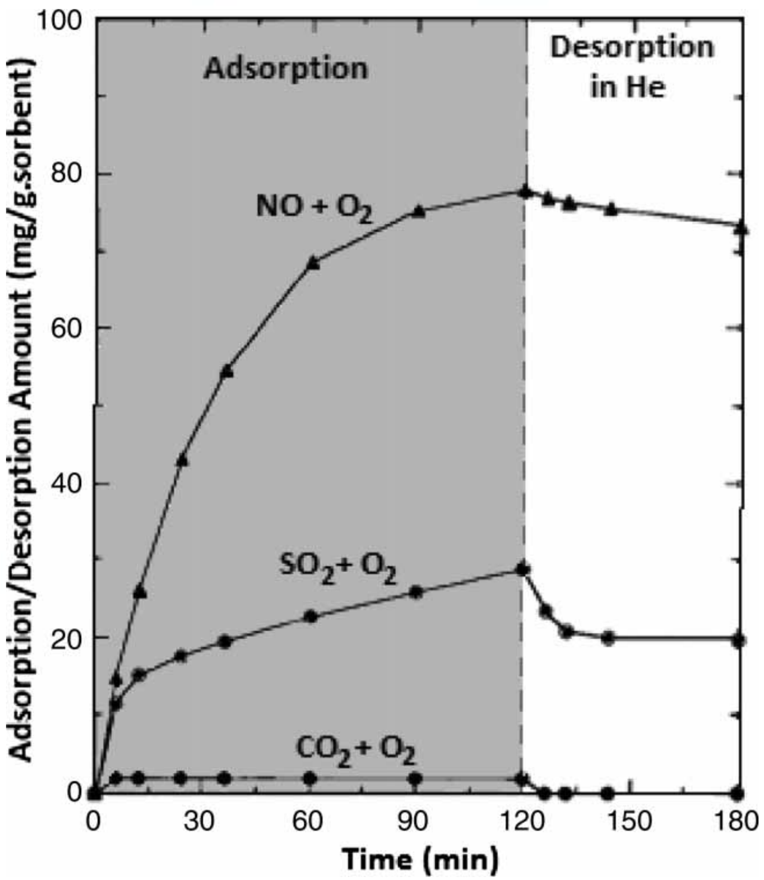
Indoor filters

- to purify indoor air volumes in building

Nanosensor

- to sense toxic gas leaks at extremely low concentrations

Carbon nanotubes (CNTs)

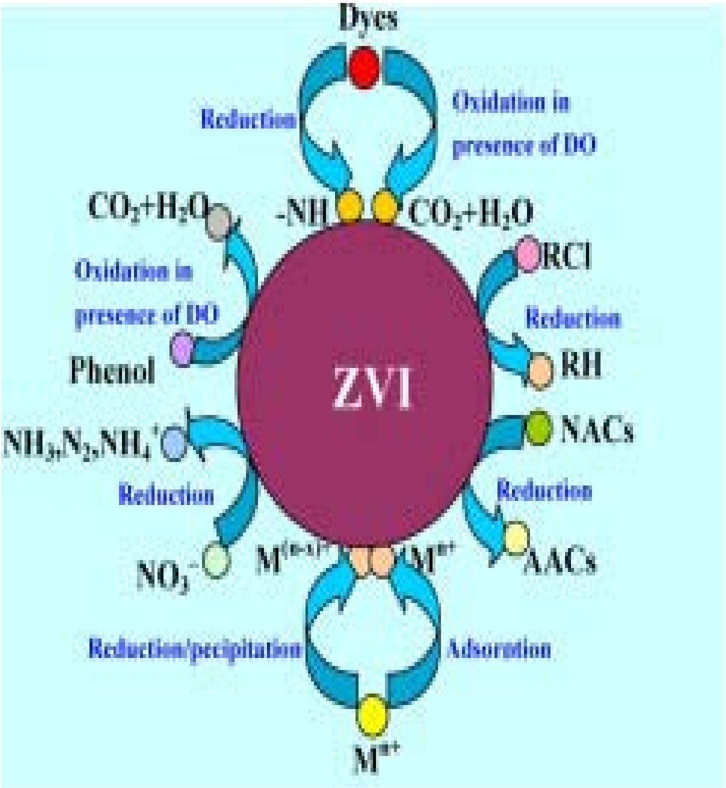


Adsorption/desorption profile of CO_2, NO_x, SO_2 on carbon nanotubes at 25^oC.

- A CNT is a rolled up graphene sheet in the form of cylinder which is one atom thick.
- CNTs have more than 3 times the adsorption capacity of activated carbon for dioxins.
- CNTs could be used as an adsorbent for the removal of NO_x, SO_2 and CO_2 at room temperature.

Yunus , et al.,(2012) Environmental Technology Reviews, 1:1, 136-148

Zero-valent iron (ZVI)



- The use of zero-valent iron (ZVI) for the treatment of toxic contaminants in groundwater and wastewater has received wide attention.
- ZVI (including nanoscale zero-valent iron (nZVI)) is effective for the removal of:

(a) chlorinated organic compounds,

(b) nitroaromatic compounds,

(c) arsenic,

(d) heavy metals,

(e) nitrate,

(f) dyes, and

(g) phenol.

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Summary

- Remediation of environmental pollutants involves a variety of *in-situ* and *ex-situ* techniques, ranging from physical, chemical, biological to advanced engineering technologies.
- The necessity to develop newer cost-effective, environmentally friendly, and reliable remedial techniques is high.
- The new technologies can be integrated with existing ones to improve the performance and overcome limitations of the existing remedial options.
- In order to pave the way for a healthy environment for future generations to enjoy, more challenging research focusing on the limitations of the existing as well as emerging remediation technologies during field-scale applications is demanded.

Summary

- Bioremediation has grown into a green, attractive and promising alternative to traditional physico-chemical techniques for the remediation at a contaminated site.
- Bioremediation can be more cost-effective and it can selectively degrade the pollutants without damaging the site or its indigenous flora and fauna.
- However, bioremediation technologies have had limited applications due to the constraints imposed by substrate and environmental variability, and the limited biodegradative potential and viability of naturally occurring microorganisms

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Thank you