Sustainable remediation and rehabilitation of contaminated sites workshop, CEECHE 2018

Workshop Leader:
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Description:

We will present in this workshop scientific, engineering information and case studies on sustainable and innovative remediation technologies used in contaminated sites in Europe and the United States. One of the most important tasks to be performed to remediate contaminated sites is to find the proper technology to be implemented in each matrix (soil, water, etc.). Remedial actions need to provide a clear identification of the contaminants of concern (COCs) and in which matrix they are present. The next step is to link the COCs with a suitable remediation technology providing the best cost-benefit. Successful remediation has to be sustainable by relying on less energy consumption and capitalize on available and innovative material to extract, immobilize and degrade COCs. Our case studies will present experimental designs and results based scientific principles applied to contaminated sites with metals and organic by the identification of patterns of decision-making, applications and achieved results, and by evaluating the lessons learned from successfully remediated sites. Overall, this workshop will be a very useful forum to present success stories on mediation technology selection beneficial to environmental researchers in eastern Europe and worldwide.

The workshop will have three sessions. Here is the description for each session.

Session 1

Phytoremediation of Metal-Contaminated Sites with a Focus on Mine Waste Sites
Raina M. Maier, University of Arizona

Phytoremediation is an emerging technology for the remediation of metal-contaminted sites, in particular mine tailings (Mendez and Maier, 2008a and 2008b). This is a global issue for which conventional remediation technologies are costly. There are two approaches to phytoremediation of mine tailings, phytoextraction and phytostabilization. Phytoextraction involves translocation of heavy metals from mine tailings to the plant shoot biomass followed by plant harvest, while phytostabilization focuses on establishing a vegetative cap that does not shoot accumulate metals but rather immobilizes metals within the tailings. Phytoextraction is currently limited by low rates of metal removal which is a combination of low biomass production and insufficiently high metal uptake into plant tissue. Phytostabilization is currently limited by a lack of knowledge of the minimum amendments required (e.g., compost, irrigation) to support long-term plant establishment. Both strategies will be discussed within the context of two specific climate types: temperate and arid. In temperate environments, mine tailings are a source of metal leachates and acid mine drainage that contaminate nearby waterways. Mine tailings in arid regions are subject to wind dispersion and water erosion. Case study examples of phytoremediation within each of these environments will be presented. Current research suggests that phytoextraction, due to high implementation costs and long time frames, will be limited to sites that have high land values and for which metal removal is required. Phytostabilization, due to lower costs and easier implementation, will be a more commonly used approach. Complete restoration of metal-contaminated sites is an unlikely outcome for either approach.

Part 1: A generalized approach to phytoremediation:

- Step 1: Characterize selected contaminated and off-site site physical/chemical/biological characteristics to determine the site stress level
- Step 2: Identify native plants in off-site areas that thrive in the local environment
- Step 3: Evaluate plant cover (%) in off-site areas to help define reclamation success
- Step 4: If site stress level is low to moderate can likely proceed with phytoremediation
- Step 5: If site stress is moderate to high it is recommended to perform preliminary greenhouse pot studies
- Step 6: Evaluating phytoremediation success

Part 2: Case Study 1: Boston Mill Mine tailings site (a moderately stressed site)

Part 3: Case Study 2: Iron King Mine and Humboldt Smelter Superfund site (a highly stressed site)

Part 4: Case Study 3: To be defined with organizing committee

References

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Session 2

Phytoremediation of soils and groundwater contaminated with organics with a focus on plants and their associated bacteria as partners in remediation: general considerations and examples from the field.

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Phytoremediation is a promising technology for remediation of contaminated soils and (ground)waters: driven by solar energy, plants are able to 'pump' contaminations to their rhizosphere and even take them up. In the rhizosphere and during its transport throughout the plant, the present plant-associated micro-organisms can degrade organic contaminants.

Despite a number of successful field applications, phytoremediation is not yet routinely applied due to some constraints. At first, plants should tolerate the occurring contaminant levels. Further, the degradation capacity of the plant-associated micro-organisms must be high enough to prevent phytotoxicity and evapotranspiration of the contaminants to the atmosphere. To solve these constraints, a diversity of interesting traits of plant-associated bacteria can be exploited.

Plants indeed are colonised by microorganisms (both bacteria and fungi) in cell densities that are far greater than the number of plant cells. Plants have complex interactions with these microbes for numerous physiological functions. Microbial mediated functions that are important to enhance beneficial outcome include nutrient cycling, organic matter mineralisation, plant-growth promotion, disease resistance, and defence against abiotic stresses.

An essential supportive role played by plant-associated microbiota involves the degradation and detoxification of xenobiotic compounds. As soil microorganisms are the primary agents for the mineralisation of organic compounds and nutrient cycling, they may also convert contaminants to stable and/or less toxic products. This activity may be greater in the plant rhizosphere because plants provide microbial habitats and nutrients that are rapidly utilised by the microbes for growth. Microorganisms residing inside plant tissues (endophytes), or on aerial plant parts (phyllosphere) can help to stabilise and/or transform contaminants that have been translocated, which may reduce toxicity and the extent of volatilisation of pollutants to the environment.

Biodegradative microorganisms have to compete for resources with other inhabitants of the plant niche, and biodegradation can be independent of effects on plant growth. For each individual field case, many aspects of the plant-microbiome interactions should be thoroughly investigated and optimised to achieve the desired outcome.

Successful application of phytoremediation was demonstrated in several field cases (BTEX, diesel and TCE contamination). On these sites, poplar trees were planted in the contamination plume and groundwater concentrations and possible evapotranspiration to the atmosphere were monitored. To explore if and how the plant-associated bacteria assist their host to better tolerate and to degrade the contaminants and to prevent evapotranspiration of the original contaminants and their degradation intermediates, soil, rhizosphere, roots and shoots of hybrid poplars were sampled in order to isolate bacteria able to grow in the presence of and to biodegrade BTEX, diesel and TCE. All cultivable bacteria were tested for their capacity to produce various plant growth promoting traits. Strains with the highest degradation rates were selected for genome sequencing (Ion Torrent). The availability/uptake of many organics can be stimulated by bacteria producing *e.g.* surfactants, siderophores and organic acids. Bacteria equipped with the appropriate degradation pathway(s) can strongly improve the degradation efficiency.

On a TCE-contaminated site, poplar trees were *in situ* inoculated with TCE-degrading endophytes. Three months later, a 90%-reduced TCE evapotranspiration was observed. Further investigations revealed that this reduction was not only achieved by an enrichment of the inoculated strain, but also by of transfer of the degradation genes from the inoculated strain to strains from the natural abundant community.

Field Case 1: BTEX contaminated groundwater on the site of a car producing factory
Field Case 2: Diesel contamination on the site of a car producing factory
Field Case 3: TCE contaminated groundwater on the site of a container producing factory

References:

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Session 3

Innovative and sustainable use of materials to aid in the remediation technologies of contaminated water and sediments

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Background

The beneficial use of materials is a key component of Sustainable Materials Management, which uses the best environmental practices of materials management to ensure resources for the future generations. The BU of industrial materials reduces the use of raw materials, bringing down the cost of the purchase of those materials; but also, reduces the energy consumption because the raw material doesn't need to be produced or transported. At the same time, the premise is that the final product will hold similar or better quality than the conventional raw material used for the application. Hence, the resource optimization contributes to the protection of the environment while not reducing the quality of the produced goods.
This principle of beneficial use of materials has been applied to the remediation technologies used to treat contaminated water and sediments to improve their sustainability and to reduce the cost of their application. In several cases, the materials to be used come from the same region where the application will be held, avoiding the use of transportation and reducing carbon foot prints.

Case studies:

1. **Use of waste materials in mining-impacted water remediation.**

Bioremediation of mining-impacted water often is carried out in anaerobic bioreactors, where the sulfates are reduced to sulfides in a microbially-induced reaction, causing metal precipitation. The bacteria used to induce this reaction uses a substrate as carbon donors and as housing for their growth. The substrate is typically composed of cheap materials available around the mine sites: wood chips, sawdust, hay, limestone, etc. One of the promising materials used in substrate is crushed crab shells, which had shown effective in removing metals and sulfates in high rates (Al-Abed et al. 2017)

2. **Titanium nanomaterials used for arsenic adsorption.**

The use of titanium dioxide nanoparticles (amorphous and crystalline) to remove arsenic from contaminated water has been proven as effective (Jegadeesan et al. 2010). The cost of the TiO_2 is usually high because of the cost of the titanium. The beneficial use of titanium waste materials to generate the nanoparticles could increase the financial and energy gain of this water remediation technology.

3. **The use of reactive activated carbon (RAC) impregnated with palladized iron nanoparticles to remove PCBs from sediments.**

PCBs present in contaminated sediments are sequestrated and dechlorinated with the use of the palladized iron nanoparticles in a RAC (Choi et al. 2015). The source of iron to be used in this applications can be scrap metal or other waste, while the source of activated carbon could be walnut shells, coconut shells, bagasse, or other wastes.

References

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