PLENARY LECTURES

Metallophytes: a biodiversity and phytotechnological resource for soil decontamination, phytomining and mine site restoration

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Metallophytes – plants which have evolved on metal-enriched soils – have key 'values' that must drive research on their unique properties, and ultimately their conservation. The ability of metallophytes to tolerate extreme metal concentrations commends them as the optimal choice for ecological restoration of mineral wastes and metal-contaminated sites. Metallophytes, and in particular metal-hyperaccumulating plants, have also spawned several novel phytotechnologies, including phytoremediation, phytoextraction and phytomining. Other new potentials for exploiting their unique properties are emerging such as the use of metal-enriched biomass or ash in chemical catalysis.

Action towards conserving the global metallophyte resource base is imperative because many species are under threat of extinction primarily through mineral exploration and mining activities but also from the restoration of ancient mining sites and metalliferous soils. This concern was identified as a priority in the Mining, Minerals and Sustainable Development (MMSD) project of the Global Mining Initiative in 2002, but positive responses from the minerals industry have been slow. The last decade has however seen an ever-increasing interest in metal-tolerant and metal-accumulating plants both from an academic standpoint and their use in restoration and phytostabilization. Few studies have highlighted the need to conserve these species. This presentation will identify future research directions and the need for the conservation and utilization of the global metallophyte biodiversity.

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Heavy metal tolerance of plants

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Few plant species, termed metallophytes, can grow on heavy metal soils. The metallophytes occurring in Central Europe belong to different taxonomic affiliations. Heavy metal tolerance of plants is thus a clear-cut example of convergence in biology. A separation between pseudometallophytes (plants that occur on heavy metal soils but also elsewhere) and strict metallophytes (only on heavy metal soils) does not make sense, since all metallophytes that are found naturally only on heavy metal heaps in the plains of Central Europe can be grown in non-polluted garden soils. A botanist can immediately recognize a site as being polluted by heavy metals by the occurrence of heavy metal plants. The adaptations of the metallophytes to the adverse conditions of heavy metal soils differ from one plant species to the next. There is no general tolerance of plants to heavy metals, and adaptation to a toxic concentration is heavy metal specific. Toxicity of heavy metals to plant cell constituents and responses of plant cells to cope with excess of heavy metals will be discussed. Heavy metals may affect plant cells by binding to functional SH-groups of enzymes or may generate reactive oxygen radicals that destroy cell constituents. Interactions with symbiotic microorganisms such as mycorrhizal fungi will only briefly be mentioned in the presentation. Current research on heavy metal tolerance and hyperaccumulation of plants focuses on the two model species *Cardaminopsis (Arabidopsis) halleri* and *Thlaspi caerulescens*. On the molecular level, heavy metal tolerance of plants might have arisen by gene duplications and modified regulations of their expressions rather than the development of new genes generated by extensive sequence alterations. The identification of gene regions that code for the tolerance against a heavy metal is currently in the centre of research in the field.

Knowledge explosion in phytotechnologies – boosting environmental cleanup and bioeconomy

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Industrialization and extraction of natural resources have resulted in large scale environmental contamination and pollution. Large amounts of toxic waste have been dispersed in thousands of contaminated sites spread across the globe. Thus every one of us is being exposed to contamination from past and present industrial practices, emissions in natural resources (air, water and soil) even in the most remote regions. These pollutants belong to two main classes: inorganic and organic. The challenge is to develop innovative and cost-effective solutions to decontaminate polluted environments, to make them safe for human habitation and consumption, and to protect the functioning of the ecosystems which support life. Much progress has been made in developed countries like UK, USA, Canada, Australia, Japan and European countries. However, there is an urgent need to evaluate the exciting developments coming out of various laboratories.

Phytotechnologies involve plant diversity for mitigation (and wherever possible complete elimination) of the noxious effects caused by environmental pollutants in a given site. It operates through the principles of biogeochemical cycling. If the process occurs in the same place affected by pollution then it is called in-situ bioremediation. In contrast, deliberate relocation of the contaminated material (soil and water) to a different place to accelerate biocatalysis is referred to as ex-situ bioremediation. As of todate about 20,000 articles have been published on various aspects of phytotechnologies starting with only 11 in 1989. Thus, there has been a steep rise in scientific investigations and a real knowledge explosion in this field of research.

Phytotechnologies include the application of appropriate biodiversity for in-situ risk reduction in contaminated soil, sediments and ground water. Microflora associated with plants; endophytic bacteria, rhizosphere bacteria and mycorrhizae are reported to accelerate phytotechnologies. Use of phytoremediated phytomass for phytoproducts and bossting bioeconomy via cogeneration of value additions and value chain products are also dealt in this lecture. Use of phytomass from phytotechnology for phytoproducts and boosting bioeconomy via cogeneration of value additions and value chain products are dealt in this lecture.

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A role for plant-associated bacteria in metal mobilization and uptake by plants and phytoextraction?

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In metal-enriched habitats around the world, a high diversity of metal hyperaccumulating plant species was found. These metal hyperaccumulators received much attention for their potential exploitation in phytoremediation processes, but also as unusual, extreme habitats for their associated bacterial flora. This paper will briefly focus on the research topics that have been addressed to date on bacteria associated with metallophytes and aims to offer a state of the art and to present possible future directions for research which could potentially be applied in technologies for sustainable use and remediation of contaminated land.

Phytoextraction uses trace element-accumulating plants that concentrate the pollutants in their tissues. Pollutants can subsequently be removed by harvesting these plants. The success of phytoextraction depends on trace element availability to the plant roots and the ability of the plant to take up and translocate and accumulate trace elements in the shoots. Current phytoextraction practices either make use of hyperaccumulators or of fast-growing high biomass plants, but may also make use of soil amendments, which increase trace element availability in the soil. Focus will be on the role of plant-associated bacteria to enhance trace element availability in the rhizosphere. The kind of bacteria typically found in association with trace element -tolerating or -accumulating plants will be discussed. Further we will review how bacteria can contribute to improve trace element uptake by plants and even plant tolerance to metals and thus the efficiency and rate of phytoextraction. This enhanced trace element uptake can be attributed to a microbial modification of the absorptive properties of the roots such as increasing the root length and surface area and numbers of root hairs, and/or by increasing the plant availability of trace elements in the rhizosphere and the subsequent translocation to shoots via beneficial effects on plant growth, trace element complexation and alleviation of phytotoxicity. An analysis of data from literature shows that effects of bacterial inoculation on phytoextraction efficiency are currently inconsistent. Some key processes in plant-bacteria interactions and colonization by inoculated strains still need to be unraveled more in detail to allow full-scale application of bacteria assisted phytoremediation of trace element contaminated soils.