PREFACE

Phytoremediation, the use of plants and their associated microorganisms to remediate contaminated soils or (ground) water, concerns a range of *in situ*, solar-powered remediation technologies involving minimal site disturbance and maintenance with low implementation costs and high public acceptance. Since conventional (mostly civil-engineering based) remediation options for polluted soils and (ground) water currently available are frequently expensive (and at the same time environmentally invasive), phytoremediation often turns out to be a valuable alternative, especially for managing large areas with diffuse pollution. However, large-scale implementation of phytoremediation often faces a number of obstacles, including the levels of contaminants (being toxic for the organisms involved in remediation), the bioavailability of the contaminants (being too low) and, in certain cases, evapotranspiration of volatile organic pollutants from soil or groundwater to the atmosphere. The current volume contains several reviews addressing the potential for exploiting plants and their associated microorganisms to improve phytoremediation of trace metals and organic contaminants.

In general, remediation technologies, whether in place or *ex situ*, either remove the contaminants ('decontamination or clean-up'), or reduce the risk posed by the contaminants by reducing exposure ('immobilization or stabilization'). One 'gentle' plant-based site stabilization approach suitable for heavily contaminated sites is phytostabilization, aimed to decrease soil pollutant availability and spreading using plants or a combination of plants and soil amendments. Indeed, although some soils may be completely bare, due to extreme metal phytotoxicity, spontaneous development of metal tolerant vegetations has been seen in many cases (Chapter 1). Naturally occurring metalliferous soils are known to harbour unique vegetation types. Human-created metalliferous sites may become colonized by similar types of metal-tolerant plant communities. Such metal-tolerant communities often contain metal hyperaccumulators and constitute an excellent resource of species for rehabilitation or phytoremediation of degraded land (Chapters 1 and 5). Hyperaccumulators are excellent candidates for metal phytoextraction and phytomining (Chapter 5), which are based on trace element removal from the polluted substrate by concentrating them in harvestable plant parts. In general, a trace element phytoextraction protocol consists of (1) cultivation of the appropriate plant/crop species on the contaminated site; (2) removal of harvestable trace element–enriched biomass from the site; and (3) post harvest treatments (*i.e.*, composting, compacting, thermal treatment, etc.) to reduce volume and/or weight of biomass for disposal as a hazardous waste, or for its recycling to recover the trace elements that may have an economic value.

Metal uptake in plants does not only depend on the availability of the metals in soil and the expression of detoxification genes and metal transporters by the plant itself, but also on the plant-associated microbiota. Like other plant species, hyperaccumulator plants harbour a high diversity of bacteria and fungi in their rhizosphere and endosphere (Chapters 2 and 4), some of which were shown to have potential for assisting plants to grow in metal-contaminated soil and regulating plant metal uptake (Chapter 3). Some unique microbial groups that are highly abundant in heavily contaminated sites have been identified using next generation sequencing techniques and might have great potential for enhancing the efficiency of metal phytoextraction (Chapter 2). Also a profound knowledge of molecular and cellular mechanisms of toxicity and tolerance against toxic concentrations of metals is crucial to optimize phytoremediation strategies to clean up contaminated soils (Chapter 6).

In contrast to metals, organic contaminants can efficiently be degraded by the cooperation of plants and their associated microorganisms, generally termed rhizo- and phytodegradation. Since recently several reviews were published on rhizo- and phytodegradation of organic solvents and fuels, the review presented here concentrates on organic pesticides (Chapter 7).

More recently, the potential of air phytoremediation has received increased attention. Air pollution has become a global problem. Most of the pollution is of anthropogenic origin. Plants with their enormous biologically active surface area can be considered as crucial partners to combat this type of pollution. Plants themselves developed very efficient defence mechanisms against atmospheric pollutants, which can also be exploited to improve air quality. It is thus possible to exploit higher plants with their microbiome for the removal of airborne pollutants (including particulate matter) in outdoor and often also indoor locations (Chapter 8). Some of these pollutants are included by plants in their own metabolism, while others are sequestered. In some plant species, the processes of removing pollutants from the air are conducted in a very efficient way.

In conclusion, use of plants and their associated microbiome harbours great potential for remediation of polluted soils, (ground) water and air. Nevertheless, local environmental (and other) conditions need to be carefully investigated to define the most optimal implementation of phytoremediation.

Jaco Vangronsveld and Ann Cuypers

In conclusion, use of plants and their associated microbiome harbours great potential for remediation of polluted soils, (ground) water and air. Nevertheless, local environmental (and other) conditions need to be carefully investigated to define the most optimal implementation of phytoremediation.

Jaco Vangronsveld and Ann Cuypers