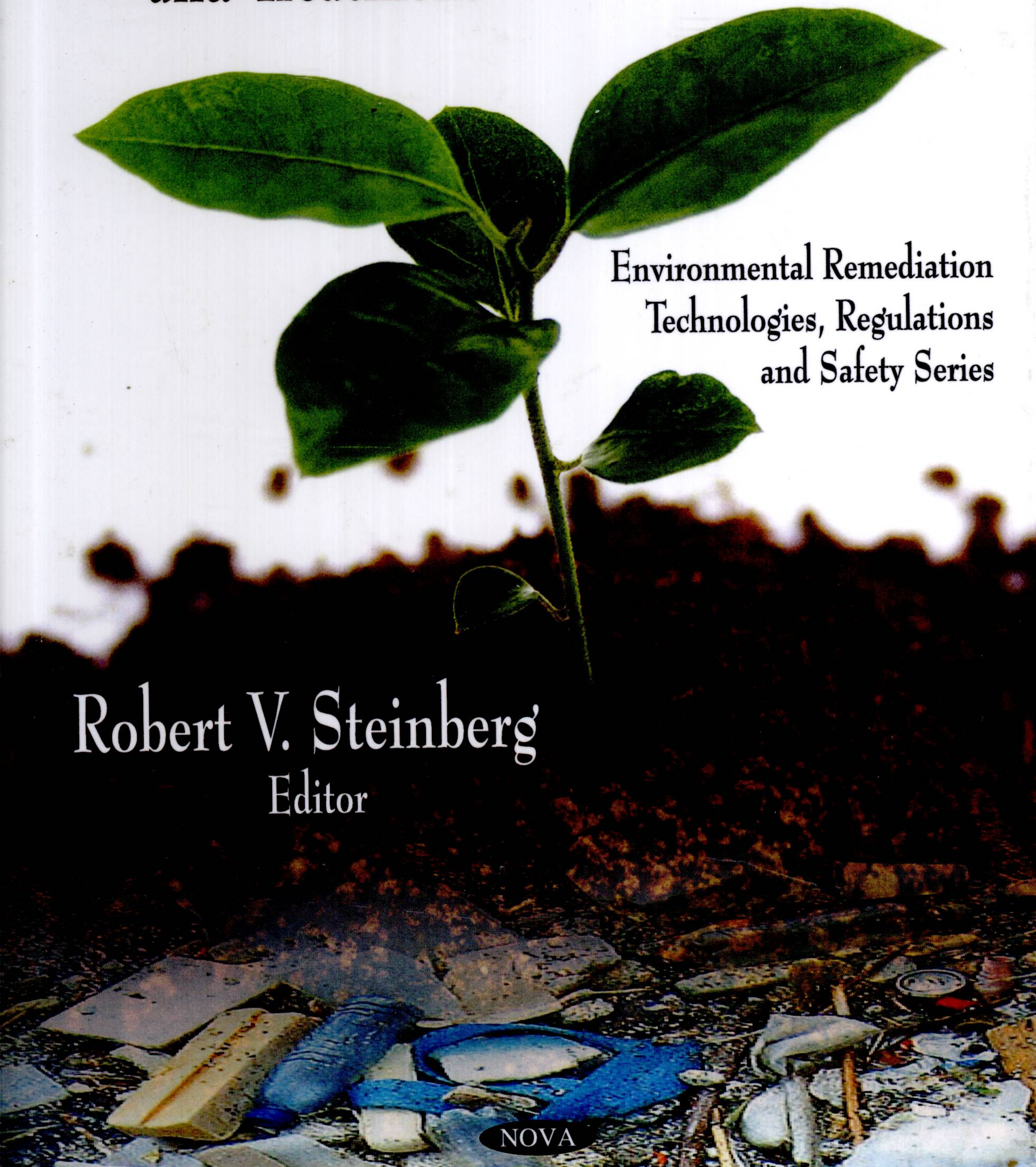
Contaminated Soils

Environmental Impact, Disposal and Treatment

Environmental Remediation Technologies, Regulations and Safety Series



Robert V. Steinberg

Editor

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ENVIRONMENTAL REMEDIATION TECHNOLOGIES,
REGULATIONS AND SAFETY SERIES

CONTAMINATED SOILS: ENVIRONMENTAL IMPACT, DISPOSAL AND TREATMENT

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CONTAMINATED SOILS: ENVIRONMENTAL IMPACT, DISPOSAL AND TREATMENT

PREFACE

Soil contamination is caused by the presence of man-made chemicals or other alteration in the natural soil environment. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage. The concern over soil contamination stems primarily from health risks, both of direct contact and from secondary contamination of water supplies. It is in North America and Western Europe that the extent of contaminated land is most well known, with many countries in these areas having a legal framework to identify and deal with this environmental problem; this however may well be just the tip of the iceberg with developing countries very likely to be the next generation of new soil contamination cases. This new book gathers the latest research from around the globe in this field.

Chapter 1 - Organic and metallic contaminants can accumulate in soils where they may remain strongly bound to mineral and organic matter, limiting their removal. Phytoextraction is the use of plants to mobilise, capture and take up contaminants from soil. Plant roots, driven by transpiration, draw in water and dissolved substances that can be transported to the aerial biomass, forming the basis for a natural remediation system. Contaminant removal processes can be enhanced by the application of amendments to promote plant growth, increase contaminant bioavailability, reduce soil toxicity or improve intrinsic plant uptake mechanisms. Potential chemical amendments include chelating agents, organic and amino acids, surfactants, hormones and inorganic compounds. In addition, biosolids, minerals, compost and industrial wastes can be applied as bulk amendments. Biological amendments include inoculations of microorganisms, as well as compounds naturally released by plant roots. Differing uptake routes and mechanisms for organic and ionic contaminants exist within plant tissues, which may be altered in the presence of soil amendments.

Complications arise when amendment-mediated mobilisation of contaminants from soil increases the bioavailability of substances to levels that are potentially toxic for plants and soil biota. Additionally, rapid leaching of contaminants from the soil can result in plumes of mobilised contaminants migrating further afield. Predicting the influence of soil amendments on contaminant uptake by plants has proved challenging due to the diversity of physical, chemical and biological processes to be considered in addition to the inherent variability that exists in natural systems. This chapter presents an overview of plant physiology and the routes of contaminant uptake as well as the potential benefits and limitations of using soil amendments to enhance phytoextraction. While amendments can offer some benefits for contaminant removal from soil, their influence is often dependent on factors such as site conditions, contaminants present and plant species involved. Implementation of phytoremediation technologies, as with other remediation approaches, remains site-specific and therefore requires an understanding of these factors.

Chapter 2 - Radioecological geoinfomational systems (RadGIS), that form a basis of a radioecological cadastre for territories of Soviet nuclear complex on the Yenisey river (Zheleznogorsk), the Tom river (Tomsk-7), the Techa river (Mayak) and are necessary to assess radiation environment and to establish priorities in ecological policy, are discussed.

Radioactive contamination in the plants' vicinity has been formed during some decades starting in the late 1940s. A special structure of a geoinformational system to provide a radioecological estimation of the territories with nuclear complex has been developed. Information on radioactive contamination of individual landscape components (soil, vegetation, bottom sediments, etc.) is supplemented by information on landscape complexes in whole. Presented are data of large-scale mapping of flood-plain landscapes of the Techa River based on the field-radiometry survey.

Central for the Tomsk-7 region is an analysis of the accident of April 6, 1993 accounting for a radionuclide release into the environment. Radioecological GIS for the adjacent territory has been created, with the topographic maps of 1:200000. The radiational situation of the territory is characterised by radioecological data bases (airborne gamma survey, data of contamination of snow, soil, vegetation, surface and underground waters, bottom sediments).

As to the town of Zheleznogorsk (theYenisey river), of special concern was assessment of radioecological situation in the Yenisey river floodplain in the zone of influence of the Mining & Chemical Combine (MCC). Presented are results of reconstruction of radionuclide situation at the initial period (the 1960s) of contamination of floodplain landscapes owing to discharge of radiocontaminated waste; as well as information on radioactive contamination that includes published experimental data of radionuclide contamination of the Yenisey river floodplain (soil, bottom sediments and water) of research conducted in 1991-2000, and a set of landscape and lithologic maps characterising special distribution of artificial radionuclides.

Chapter 3 - Remediation of contaminated soils is one of the most important environmental issues. Chemical soil degradation affects 12% of all degraded soils in the world, totalling 2billions hectares. Soil contamination is not only a social and sanitary issue, but has also an economic concern, since it implies major costs related to decreasing productivity and monetary evaluation of the contaminated sites. Costs related to remediation of contaminated soils (particularly with heavy metals), moreover, are very high.

Many of the organic substances contribute to contaminate ecosystems and are very poisonous to living organisms and to human health. Correspondingly, many metals, when present at high concentration in the environment, are critical or toxic to plants and animals, and may enter the food chain and therefore affect humans.

In areas affected by high contamination, direct and indirect health hazards require urgent restoration, regardless of the remediation technology selected for the site. In other cases, such as land with non-hazardous contaminant levels, remediation may eliminate or reduce the environmental hazard and contribute to the valorisation of green areas, public services, and arable land otherwise not utilizable.

Metal contamination persistence and little knowledge of mechanisms regulating the interaction soil-metal and the sorption of contaminants by living organisms make soil remediation particularly difficult and expensive. Any of the current technologies are actually effective and applicable at wide scale. The most utilized technical solutions are clearly inadequate for cleaning large areas of moderately contaminated land, where soft and (environmental) friendly technologies are needed to restore soil fertility, in such a way that they could be utilized for agriculture or public/residential green areas. Therefore, in recent years the interest of both public Authorities and private Companies towards innovative methodologies for decontamination and restoration of contaminated sites is increasing.

Phytoremediation is an emerging technology that holds great potential in cleaning up contaminants that: 1) are near the surface, 2) are relatively non-leachable, 3) pose little imminent risk to human health or the environment, and 4) cover large surface areas. Moreover, it is cost-effective in comparison to current technologies, and environmental friendly.

Most of the available data, until now, has come from microcosm experiments; full scale experiments could help in assessing the feasibility of phytoremediation, and its effective contribution to clean-up contaminated soils. However, phytoremediation is not yet ready for full scale application, despite favourable initial cost projections, which indicate expansion of clean-up market to be likely in next years.

Research should be addressed to find out new highly efficient accumulator plants, and related cultivation technologies, and this research must account for the spatial and temporal variability of complex systems that include mixtures of contaminants and organisms.

Chapter 4 - It is generally recognized that the knowledge of the total concentrations is not sufficient to understand the behaviour of metals in soils and to predict their availability and mobility, which influence their release and their interaction with other environmental compartments. These characteristics are usually investigated with single or sequential extraction procedures. Single extractions are commonly performed with complexing agents, diluted acids or electrolytes, and in many applications are aimed at the estimation of the most potentially mobile metal fraction and/or of the proportion amenable for plant uptake. In sequential extraction procedures, the soil under investigation is treated with reagents of different chemical properties, which are usually applied in order of increasing strength and give rise to the leaching of metals and to the partitioning of their total content into different fractions; sequential extraction results provide information on metal association to soil components and help to predict the risks associated to metal contamination.

This chapter deals with the state-of-the-art of single and sequential extraction techniques, with reference to the following topics: the types and properties of extracting reagents; batch and dynamic flow-through procedures; the possible drawbacks and limitations; other approaches to metal extraction, such as kinetic procedures and leaching with non-specific reagents. Examples of applications of single and sequential extractions to the investigation and management of metal-polluted soils are reported throughout the chapter and a case study on metal availability in polluted soils in Piedmont (Italy) is described in detail.

Chapter 5 - Heavy metal and trace element contamination has been increasingly of concern on a global scale. Toxic metals/metalloids, such as cadmium (Cd), mercury (Hg), arsenic (As) chromium (Cr), nickel (Ni), copper (Cu), lead (Pb), zinc (Zn), etc., have been significantly released into the environment through both natural and anthropogenic activities since the industrial revolution, and they pose a major human health problem. Compared to traditional remediation technologies for metal/ metalloid-contaminated soils, phytoremediation is a cost-effective, environmental-friendly, and public accepted approach to clean up contaminants from soils. This chapter discusses the feasibility of using plants for metal/metalloid-contaminated soil cleanup by reviewing both laboratory and commercial scale phytoremediation as reported in the literature. In the field of phytoremediation of heavy metal/metalloid-contaminated soils, phytoextraction is the most effective strategy; it uses hyperaccumulator plants to remove heavy metals/metalloids from soils permanently. Currently, over 400 hyperaccumulator plants have been identified for accumulating various heavy metals/ metalloid all over the world. The mechanisms by which plants hyperaccumulate heavy metals will be also discussed. In addition, phytostabilization, using plants to concentrate metals/metalloid around roots to limit metal mobility and bioavaiability in soil, will be also reviewed. For soils contaminated by Hg and Se, phytovolatilization may be used. Finally, this chapter will also discuss the handling requirements, proper disposal, and management of the by-products produced by phytoremediation processes.

Chapter 6 - Protecting and improving the quality of our environment today are considered as one of the top of global concerns that requires innovative design solutions that establish compliance with ever-expanding and more stringent regulations. Environment modelling with computational fluid dynamics (CFD) methods help us tackle our environmental flow problems in the most efficient and cost-effective way. CFD complements physical modelling and other experimental techniques by providing a detailed look into our environmental problems, including complex physical processes such as chemical reactions, degradation, mass transfer, and multiphase flows. The added insight and understanding gained from environment modelling gives us confidence in our design proposals, avoiding the added costs of over-sizing and over-specification, while reducing risk. In many cases, we can build and analyze virtual models at a fraction of the time and cost of physical modelling. This allows us to investigate more options and "what if" scenarios than ever before. Moreover, CFD modelling provides insights into our environmental problems that would be too costly or simply prohibitive by experimental techniques alone.

In this chapter, CFD model has been developed and employed to predict the transport of hydrocarbons contaminants in the soil around a disposal pit of produced water at oilfield, and then simulate the bioremediation process for a selected studied area under the controlling of effecting conditions; application of nutrients, hydrocarbon utilizing bacteria (HUB) population count, and surfactants treatment. A coupled transient CFD model is presented for the simulation of the flow of water, air and the contaminant transport through unsaturated soil including the effects of chemical reactions and bioremediation process. Satisfied results have been obtained by applying this model. The values calculated by the model were consistent with the experimental results. The results were based to build up an effective plan of the bioremediation of hydrocarbon contaminated soil. This technique is applicable for accomplishment of restoration programs for many contaminated site.

Chapter 7 - In situ bioremediation of contaminated subsurface soil or groundwater is an effective, economical and eco-friendly alternative to chemical and physical remediation technologies. However, several factors can reduce its effectiveness and limit the rate of in-situ biodegradation. These factors include the low availability of molecular oxygen for aerobic degradation, absence of contaminant-degrading bacteria, low bioavailability of hydrophobic contaminants, heterogeneous sub-surface conditions, and lack of trace nutrients. Several treatment technologies (such as air sparging, bioventing and injection of surfactant or other amendments into soil) have been developed to address some of these limitations, but a flexible approach to address all of the limitations has been lacking. This article presents an overview of these technologies and their advantages and limitations, followed by a detailed discussion of the bioactive microbubble dispersion as an emerging technique that can enhance in situ bioremediation by comprehensively addressing all of the primary limiting factors. Applying microbubble dispersion to contaminated soils stimulates in-situ contaminant degradation by delivering contaminant-degrading microorganisms and trace nutrients to maintain microbial activity, enhancing contaminant bioavailability using surfactants, providing oxygen to maintain aerobic bioactivity, and improved penetration and distribution of the above ingredients in the contaminated region resulting from the buoyancy of small bubbles in the dispersion. This chapter reviews the methods for generating microbubble dispersion, the types of surfactants used and their properties, and the characteristics and factors affecting dispersion properties (e.g. stability and quality). In addition, a number of bench- and field-scale experiments are discussed to illustrate the benefits of applying this technique to enhance in-situ bioremediation.

Chapter 8 - The contamination of soils, groundwater and surface waters by hydrophobic compounds is currently a significant concern throughout the world. Many of these compounds are a threat to both human health and the environment. Soil is the main, ultimate sink for most organic contaminants. Soil pollution may be due to industrial accidents (spills leaks, and leaking underground storage tanks) and anthropogenic activities (agrochemical treatments, forest and agricultural fires, fossil fuel combustions) and represents a long term source of environmental contamination (Wong et al., 2009).

Chapter 9 - Among the xenobiotics entering the environment as a result of human activities, some of the most dangerous are war gases, including mustard gas. After its introduction into the environment, mustard gas undergoes degradation arising from chemical hydrolysis. Contamination of soil with mustard gas hydrolysis products (MGHPs) cause significant changes in soil microbial population and biological activity. MGHP-contaminated soils are highly toxic, and the biochemical processes proceed more slowly in these soils. Microorganisms from different taxonomic groups exhibit suppression of growth by mustard gas hydrolysis products. The highest sensitivity to MGHPs was exhibited by the micromycetes; the most resistant to MGHPs were bacteria. The primary target of the negative impact of MGHPs is the cell membrane. Cell permeability of bacteria, micromycetes and actinomycetes increases along with toxicant concentration. Compared with micromycetes and actinomycetes, bacterial cells suffered a smaller loss of metabolites after the addition of MGHPs. Increase of permeability was associated with a growth in the amount of unsaturated fatty acids. Bacteria from the genera *Pseudomonas* and *Rhodococcus* were isolated from MGHP-contaminated soils. The main properties of these microorganisms were their tolerance to mustard gas hydrolysis products and the ability to utilize the major product of hydrolysis, thiodiglycol, as the sole source of carbon and energy. Thiodiglycol degradation may follow two metabolic pathways, one of which yields [(2-hydroxyethyl)thio]acetic, thiodiglycolic, and thioglycolic acids; and the other, β-mercaptoethanol, which is further transformed to thioglycolic acid. Treatment of MGHP-contaminated soils with MGHP-degrading bacteria accelerates the degradation of thiodiglycol and decreases the toxicity of the contaminated soils.

Chapter 10 - Surfactant-enhanced soil washing has become a very important option for the remediation of soils contaminated with a variety of compounds and elements, *i.e.,* petroleum hydrocarbons, pesticides, dense nonaqueus-phase liquids, metals, and others. Soil washing enhanced by surfactants is a feasible remediation technique when there is no chance for biodegradation-based methodologies. When time and/or space are scarce, soil washing is an excellent cost/benefit option. This chapter reviews the state of the art for surfactant enhanced soil washing developments at laboratory, pilot plant, and real scale levels. Aspects such as the selection of the best surfactant and doses and the use of natural surfactants, alone or in combination with synthetic ones, are discussed. On the other hand, aspects concerning operational practice, such as the relationship between the initial concentration of contaminants in soils and removal efficiency, a rule of the thumb for calculating how many washing steps are necessary to get a desired final contaminant concentration, and the experience developed in the washing tons of contaminated soils, are presented also. Finally, aspects related with the design of an industrial washing process and estimation of costs are reviewed and discussed.

Once that soils have been washed, an effluent containing petroleum hydrocarbons, surfactants, and small amounts of salts, humic acids, and other molecules lixiviated from the soil is originated. A very general approximation is to produce 3-5 liters of wastewaters per kilogram of washed soil. It is necessary to treat the produced wastewaters in order to: 1) recycle them to the washing process or 2) at the end of the process, to release it to be drained. Many techniques have been reported for the treatment of these wastewaters, such as coagulation-flocculation, biological systems, and other physicochemical processes. Recently, advanced oxidation processes have shown a great potential for the treatment of these wastewater streams, in combination with other treatments (such as coagulation-flocculation or biological processes). It is important to remark that information regarding the produced wastewater quality and volume is very scarce. This chapter pretends to approach the integrated process of wastewater generation and treatment of the produced effluents, based on the experience at a pilot plant and with real scale field work. Technical and economic features are also reviewed and discussed.

Chapter 11 - The article focuses on the discussion of impact of aluminum production aero-emissions, mainly NaF, on individual components and agroecosystems. Within the framework of the experiments agroecosystem soil-microorganisms-plants-atmosphere (plant cultivation option) was considered as a functional model, in which interacting components are combined (integrated) by nitrogen and carbon fluxes. Negative impact of high pollution level on soil physical and chemical properties was demonstrated to show more intensely on gray forest soil than on alluvial soil. Increase of fluorides mobility degree ($F_{water\text{-}soluble} : F_{total}$, %) and exchange sodium accumulation reduces soil buffer qualities in respect of fluorides pollution, facilitates alkalinization, which affects functioning of other components and agroecosystem as a whole. Relatively stable state of alluvial soil properties ensured adaptive potential of both soil microbe complex and spring wheat crops. In agroecosystems on gray forest soil, particularly characterized by high pollution level, there were identified significant disturbances in nitrogen cycle (^{15}N label was used) and carbon, which showed in enhancement of mineralization (**M**) accompanied by increase of net-mineralization (**N-M**) and reduction of re-immobilization (RI). Integral evaluation of agroecosystems functioning and environmental load based on parameters of NM:RI and nitrogen and carbon recirculation in intra-soil cycle (RI:M,%), showed that, for instance, with water-soluble fluorides content in soils amounting to 6-9 MPC agroecosystem on gray forest soil functioned in the regime of resistance, on the alluvial soil – in the regime of stress. In the conditions of equally high level of fluorides accumulation in the soils agroecosystem functioning regime changed only on gray forest soil (adaptation exhaustion; "critical" level of impact), staying the same on alluvial soil, at which environmental load corresponded to "permissible" level, as well as on unpolluted gray forest soil. Agroecosystems resistance on alluvial soil ensured good balance of NM and RI fluxes, which contributed to optimization of nitrogen and carbon metabolic pool thanks to intensity of their transformation, including recirculation. Functioning and sustainability of agroecosystems is connected with both responsive (adaptive) reactions to pollution of individual components, and to their co-operative interactions. However, it is soil that plays primary role in the formation of agroecosystems sustainability.

Chapter 12 - Polycyclic aromatic hydrocarbons (PAHs) are widely spread as pollutants in soils and waters and are composing a relevant health risk for humans. They can be degraded when used as energy and carbon sources by heterothrophic microorganisms, and the microbial degradation metabolic pathways are well known. However, given their high hydrophobicity, they are adsorbed onto mineral and organic fractions of soil and pass very slowly to the aqueous phase; thus, their bioavailability is limited, and biodegradation in natural attenuation happens very slowly. The high molecular weight PAHs are the most recalcitrant and they persist in soil for long time. Several studies have been carried out to accelerate and intensify PAHs remediation by low-impact technologies, such as the biological ones, mainly aimed at stimulating the activity of soil microorganisms by maintaining/protecting the natural characteristics of soil. In addition, they are cheaper and more socially acceptable than chemical and physical processes. However, the bioremediation of PAH-contaminated soils is controlled by a number of pollutant features and of environmental factors, which are reviewed in this paper, such as the pollutant bioavailability, the availability of oxygen, water and nutrients, the presence of other toxic compounds and the plant-soil interactions.

The bioremediation of PAH impacted sites can be carried out through *ex situ* schemes or *in situ*. In *ex situ* treatements, the most critical environmental conditions are temperature, moisture, oxygen and nutrients availability, soil mixing, etc and they can be easily controlled and optimized to accelerate the process. In *in situ* bioremediation, one of the best and innovative way to further enhance the pollutant biodegradation is rhizoremediation, in which plants roots can degrade the pollutants, boost the activity of indigenous microorganisms in charge for PAH biodegradation and play an important active role on soil fertilization.

Chapter 13 - Arbuscular mycorrhizal fungi (AMF) are symbiotic fungi colonizing the roots of most land plants. Apart from nutritional effects, AMF are also able to protect their host plants against environmental stresses. The variation in the morphological parameters and molecular diversity of AMF in a naturally heavy metal (HM) polluted site and their relationship with soil physico-chemical properties were investigated in the Anguran Zn and Pb mining region (Zanjan province, Iran). A total of 35 plots were selected to represent different levels of HM contamination along a transect away from the mine pit. Within each plot, a composite sample of root and rhizospheric soil from several individuals of the respective dominant indigenous plant was collected. The soil samples were analyzed for their physico-chemical properties, mycorrhizal colonization parameters and AMF spores. The AMF diversity colonizing the roots of an indigenous plant species, *Veronica rechingeri*, at different levels of Zn and Pb was assessed based on the ITS rDNA fragment amplification and sequencing. Native *Glomus mosseae* and *G. intraradices* isolates were used as inoculum for a greenhouse experiment designed to evaluate the effectiveness of indigenous AMF isolates in phytoremediation of zinc-polluted soils using maize as a bioassay plant.

Our data showed that with decreasing concentration of Zn and Pb, AMF abundance increased along the transect. AMF spore numbers were more affected by Zn and Pb concentrations than root colonization. Molecular analysis of mycorrhizal roots of *Veronica rechingeri* revealed seven different AMF sequence types all within the genus *Glomus*. Correspondence analyses showed that the number of AMF sequence types decreased with increasing level of HM contamination. Some AMF sequence types were only found at sites with the highest or the lowest HM soil contents. Evaluation of the remediation potential of native AMF isolates indicated that *G. mosseae* was the most effective fungal species in Zn extraction and translocation, while *G. intraradices* had the highest effectiveness for accumulation of Zn in the roots at high soil pollution levels. Our results showed that the mycorrhizal colonization levels of indigenous plants, availability of AMF spores and AMF diversity and community structure of colonized plants are affected by the levels of heavy metal contamination. Isolation, propagation and use of stress-adapted AMF ecotypes in such heavy metal polluted areas are promising biotechnological tools in remediation and revegetation programs.

Chapter 14 - The physiologically-based extraction test (PBET) is being applied to soil from contaminated land sites to assess the environmental risk to humans. Various procedures have evolved based on the use of simulated gastric and intestinal juices. This chapter evaluates one approach to assess the environmental risk to humans from soil contaminated with metals. Soil samples have been obtained from contaminated sites in N.E. England with a historic legacy of pollution from heavy metals. Initial work will assess the total metal content of soils using microwave acid digestion followed by inductively coupled plasma mass spectrometry. A PBET test is evaluated and undertaken on the soils. The results highlight the additional, or supplementary information, provided by PBET and the role bioaccessibility data might play in a site specific risk assessment.

Chapter 15 - In a world in rapid change, emergency responders are faced with new types of challenges, and decision makers need to ensure that all factors of importance are taken appropriately into account when optimising a restoration strategy for, e.g., a radioactively contaminated soil area. Examples are given describing how different processes can affect the physicochemical form of radionuclides, both before and after deposition in a soil area following an airborne release, and thereby influence the need for introduction of countermeasures. Three different problems in connection with the need for measurements to guide restoration of contaminated soil areas are highlighted, and a new publication with detailed method-specific information on each of a range of countermeasures for radioactively contaminated areas (including soil) is introduced.

Chapter 16 - It is not generally known that the first serious failure of nuclear power plant (NPP) technology with loss of human lives occurred in NPP Jaslovské Bohunice (Czechoslovakia) in January 1976. A year later the second accident finally broken reactor A1 with large radioactive contamination of nearby environment. The authors have used phytotoxic and cytogenetic "in situ" plant tests extended by analyses of pollen grains. Results were confronted with results of standard laboratory plant tests. Although the dose of some samples of radioactive soil was relatively high (322 $kBq\ kg^{-1}$) no any significant impact on the biological level of tested both wild and laboratory plant species was observed. Possible explanation (such as adaptation and resistance) is discussed.

Chapter 17 - In natural water and subsurface soils, chromium occurs in two major oxidation states: III and VI. Cr(VI) is approximately 1,000-fold more cytotoxic and mutagenic than Cr(III). As the application of Cr is extensive in several industries, chromium-associated pollution is an increasing problem. Biological transformation of Cr(VI) to Cr(III) by enzymatic reduction is a means of chromium decontamination. This biological reduction may provide a less costly and environmentally friendly approach to remediation. Actinomycetes are the dominant population in soil. Their metabolic diversity and the particular growth characteristics indicate them as agents for bioremediation.

A Cr(VI)-resistant actinomycete strain, *Streptomyces* sp. MC1, has the ability to reduce Cr(VI) present in a synthetic medium, soil extract and soil sample. Also, *Streptomyces* sp. MC1 has demonstrated the ability to accumulate Cr(III).

Chromate reductase activity of *Streptomyces* sp. MC1 is an enzyme associated principally with the biomass; it is constitutive and requires an electron donor (NAD(P)H). It is active over a wide range of pH level (5–8) and temperature (19–39°C), with optimum conditions of 30°C and pH 7.

Because the chromate reductase of *Streptomyces* sp. MC1 is present in supernatant, pellet and cell free extract, it could be utilized in processes of bioremediation in systems incompatible with cell reproduction, frequent conditions in contaminated environments.

Streptomyces sp. MC1 or its compounds could be used for Cr(VI) reduction and removal in biotechnological processes applied to environmental samples.

Chapter 18 - Tanker oil spills seriously affect the environment and organisms are damaged by contamination of the water and coastal areas. The monetary cost of decontamination is very high. Native bacteria in sands (soils) of the seashores can be used to remove the oil from the seashore. When appropriate nutrients are supplied, this process is called biostimulation (BS). Another bioaugmentation (BA) process, in which isolated microorganisms and their mixtures can be used as degraders of xenobiotics, is considered to be more promising. Autochthonous bioaugmentation (ABA) is a new bioremediation technology to clean up thinly and broadly petroleum contaminated seashores. In ABA, petroleum-degrading consortia must be acquired and prepared in advance by enriching microorganisms derived from the decontamination site. In this study the authors aim to use ABA at seashores in Hokkaido Island, Japan, which faces the Okhotsk Sea, and Sakhalin Island, Russia, where large oil fields are being developed. Crude oil-degrading microbial consortia of sea sands collected at seashores of Abashiri City, Hokkaido, were enriched using liquid and solid (sand) media supplemented with minimal salts medium (MSM) and crude oil. When unsterilized sand from the same place was inoculated with two types of microbial consortia, degradation of crude oil was greater in the consortium prepared by cultivation in sand (consortium 2) than in that prepared by liquid cultivation (consortium 1). The extent of degradation of crude oil by consortium 1 was almost the same as that by BS. Polymerase chain reaction-denaturing gradient gel electrophoresis (PCR-DGGE) analysis targeting 16S rRNA genes of the bacterial consortia showed that consortium 2 included several faint DGGE bands suspected to be those derived from crude oil degraders. However, BS consortium and consortium 1 included three very predominant bands, through which proliferation of some of degraders found in the consortium 2 are probably depressed. These results suggest that various types of bacteria are involved in the degradation of crude oil in soil and that proliferation of these bacteria might be hindered by the occurrence of extremely predominant strains. For a more practical application of ABA, microbial sources should be acquired from the site to be decontaminated and consortia or isolates should be prepared under the same cultivation conditions as those where BA will be conducted.

Chapter 19 - The use of wastewater for agricultural irrigation is steadily increasing world-wide and, due to shortages of fresh water, is common today in most arid regions of the world. Application of treated wastewater for agricultural irrigation may result in soil exposure to pathogens, creating potential public health problems. A variety of human pathogens are present in raw sewage water. Although their concentrations decrease during the wastewater reclamation process, the secondary treated effluents most commonly used for irrigation today still contain bacterial human pathogens. A range of bacterial pathogens, introduced through contaminated irrigation water or manure, are capable of surviving for long periods in soil and water where they have the potential to contaminate crops in the field. Therefore, there is a risk of direct contamination of crops by human pathogens from the treated effluents used for irrigation, as well as a risk of indirect contamination of the crops from contaminated soil at the agricultural site. Contradictory to previous notions, recent studies have demonstrated that human pathogens can enter plants through their roots and translocate and survive in edible, aerial plant tissues. The practical implications of these new findings for food safety are still not clear, but no doubt reflect the pathogenic microorganisms' ability to survive and multiply in the irrigated soil, in the water, and in the harvested edible crop.

Chapter 20 - This contribution contains an explanation of possible application of Life Cycle Assessment for modeling of environmental benefits of remediation technologies. According to general experience, any technological process can be represented by material and energy inputs and outputs, from which several of them are connected into environment. Any remediation technique can be viewed as such a process, which goal is, of course, to improve present environmental status of contaminated site, but which represent some environmental burden, too. The important question for realization of remediation technologies is if their environmental benefits are higher than burdens. Life Cycle Assessment concept can offer a conceptional tool for this kind of evaluation.

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