Advanced Science and Technology for Biological Decontamination of Sites Affected by Chemical and Radiological Nuclear Agents

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Advanced Science and Technology for Biological Decontamination of Sites Affected by Chemical and Radiological Nuclear Agents

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PREFACE

Pollution of soils and waters by human activities is an important and widespread problem. This pollution by, organic and inorganic substances can affect individual organisms, human populations, and ecosystems, each in its own unique way. In particular former military installations, often used for weapons production and nuclear power plants represent a ongoing and substantial threat to environment and human health because of the specific pollutants that can be released: Solvents, explosives, fuels, radionuclides, heavy metals, and metalloids all have been identified in the environment around these installations. Remediation technologies for these contaminated sites have been developed based on conventional systems utilising physical and chemical treatments, such as excavation and incineration, pump-and-treat methods, ultraviolet oxidation, soil washing, etc.

These approaches are usually very expensive, and can involve the removal of large amounts of soil or water, which often leads to resources depletion and limitation in the future utilisation of the site. Recently, new decontamination approaches, based on living organisms, in particular micro-organisms and plants, have been researched and developed as a more sustainable alternative because they have lower costs, reduced environmental impacts, and increased public acceptance. Development of biological decontamination techniques has been carried out in several laboratories and research institutions worldwide, and practical applications on contaminated sites have been recorded in several countries. In the USA and Canada several commercial companies have been utilizing these approaches for years, alongside conventional techniques, with great success:; a good examples can be found is in the U.S. EPA Superfund Innovative Technology Evaluation Program. In the European Union commercialization of phytotechnologies and bioremediation technologies is still scant, even though groups of high-level scientists are actively involved in research on this very topic. Constraints to the application of biological decontamination technologies can be attributed to the legislation and to the lack of endpoint requirements for cleanup, to lack of economic considerations about costs and benefits, and to the limited knowledge of long-term environmental effects.

There is a strong need to train of new professionals in commercial or governmental initiatives, and teach them mastery the scientific background of biological decontamination and specific features of "in-field" applications. As the most relevant pollution problems are localised in the less developed countries, training per se may not suffice.

A complete capacity building policy is needed, that encompasses training, infrastructure, as well as human and financial resources necessary to implement these new technologies. Capacity building can be obtained by bringing together both scientists and experts in the field, finalized to the application of biological decontamination, in order to favor the merging of specific expertise.

These specialists are an important technical resource for governmental institutions with a mission in environmental protection, and can serve as a training resource postgraduates and post-docs who are willing to improve their professional knowledge with practical experience and education. Commercial companies and enterprises already acting or willing to move into this sector can benefit from the initiative as well.

The environmental movement is gaining acceptance and importance in many countries, particularly in those countries which have originated after the collapse of the former USSR.Many of these former Soviet Bloc countries have been left with a plethora of environmental problems arising from antiquated manufacturing processes. Built without pollution control equipment to problems arising from the careless disposal of chemicals and petroleum products, to disposal of excess military ordinance.

While there are no precise data on extent of environmental contamination in Eastern Europe, it has been estimated that the former USSR countries may contain 200,000 of these disposal sites. Western Europe, North America and other developed have made a concerted effort to identify and define their waste disposal sites, and are actively remediating them.

The NATO ASI "Advanced Science and Technology for Biological Decontamination of Sites Affected by Chemical and Radiological Nuclear Agents" held in Zhytomyr (Ukraine) on 17-28 August 2005 addressed the topics of biological decontamination of pollution related to chemical, radiological and nuclear agents. The main objectives of the initiative were: (i) to train participants for principles of scientific and technology of biological decontamination, bioremediation and phytoremediation, with particular emphasis on sites contaminated by radionuclides and chemical substances connected with explosives, ammunitions and fuels; (ii) to

describe and discuss the present state-of-the-art, the latest developments, and the further advances required for commercial applications; (iii) to stimulate future interactions and collaborations in this technologically important field of study.

The purpose of the ASI was to bring together lecturers of worldwide renown in this subject and let them meet with interested stakeholders and end-users, coming from academy, research, public administration, military institutions, and private companies. Participants came from 18 countries, representing Asia, Africa, most of Europe and North America.

The ASI was organized to provide detailed, advanced, and thought provoking information about possible decontamination approaches, alternative technologies, cost effectiveness, feasibility, with the support of literature data, personal experience of lecturers, and case studies.

The chapters in this book represent the result of the lectures and of the following discussions with participants and stakeholders.

The main achievements of the school and of this book have been:

- The increased understanding of the global subject of phytoremediation-bioremediation
- The sharing of practical inside and very specialised information on subjects like decontamination of radionuclides and ammunitions or propellants
- The discussion about the need of a holistic approach with integration of different expertise: scientific, technological, legal and juridical, economical
- The understanding of the role played by all stake-holders in the cleanup process, including: scientists, economists, managers, regulators, public
- The discussion of the use of conventional vs. non conventional technologies
- The identification of faults and drawbacks in the remediation process, as well as of strengths and advantages of these processes
- The need for a policy of communication of the results achieved to stakeholders and to national and supranational regulators
- The relevance of capacity building and training,

Site characterisation procedures and related measures are addressed by Michael Pupeza (Golder Associates Srl, Italy), Oleksandr Orlov (Ukrainian Scientific-Research Institute of Forestry and Agro-Forest Amelioration, Ukraine) and Anja Hebner (BioPlanta GmbH, Germany). In particular they

consider and discuss problems connected with sampling and assessment of sites contaminated by radionuclides and explosives. Pollution problems generated by the Chernobyl accident are addressed considering the contamination incurred to the forest ecosystems and the hazards to human health.

The main processes of bioremediation are addressed starting from the site conditions, analyzing the microbial features, both genetic and physiological-biochemical, in the chapter provided by Ludo Diels (Flemish Institute for Technological Research, Belgium). These basic biological considerations led further on to analyze and elucidate case studies that compared together bioremediation with conventional remediation techniques. Authors brought also their experience in technologies based on chemical reactions and construction of physical barriers, discussed alongside with examples of bioremediation. Specific cases of explosives and radionuclides decontamination were also addressed, citing European and non-European experience. New contaminants of interest are also addressed, such as the MTBE (methyl-tert-butyl-ether).

The basic biochemical mechanisms of phytoremediation are explained by Stanislaw Gawronski (Warsaw Agricultural University, Poland), considering also the differences between plant and microbial metabolism of contaminants, together with a record of the natural and cultivated plants more frequently used for decontamination. The role of genetics and genetic engineering in increasing the knowledge on detoxification processes and to produce and obtain more specific types of decontaminating plants is explained in the chapter by Nelson Marmiroli.

Practical implementation of remediation technologies is addressed starting from feasibility studies at the laboratory level, to pilot scale experiments and large scale tests. Several examples of applications are provided by researchers and private companies' representatives, both for decontamination of explosives and of radionuclides, in particular with a significant contribution by Dave Russell (Global Environmental Operations, Inc., USA), Petr Soudek and Tomas Vanek (Academy of Sciences of Czech Republic) and Christian Kunze (WISUTEC WISMUT Umwelttechnik GmbH, Germany). Constructed wetlands are prominent among successful applications and the chapters bring several examples. A straightforward analysis of case studies leads to identification of advantages and limitations of constructed wetlands technology.

The book is supplemented by the contributions of Wolf-Uwe Marr (Bundesministerium der Verteidigung, Germany) and Andrei Kozeltsev (Ministry of Natural Resources, Russian Federation) addressing the

relationships between legislators and regulators on one side, and on the other side scientists and private companies acting in remediation.

The "state-of-the-art" as it emerges from the book, is that bioremediation and phytoremediation are both applied, in most cases, without a precise and detailed knowledge of all molecular mechanisms occurring within cells. This can have consequences on several aspects, and especially concerning decisions to be taken case-by-case according to site characteristics, type of pollutant(s) and endpoints to be reached.

Some main considerations deserve mentioning:

1. There is a great necessity of understanding the basic aspects of microorganism and plant physiology, biochemistry and genetics, because only from sound scientific knowledge may in future derive the possibility to drive these technologies on more applied aspects.
2. Interactions between plants and microorganisms in remediation must be studied further and with greater attention, because in many contaminated sites they both can be beneficial if applied simultaneously,, and synergy may enhance the individual site cleanup and reduce costs.. This holistic approach considers interactions in the environment, not only between organisms, but also between contaminants, and between biotic and abiotic factors.
3. Interaction of scientists and technicians with state and governmental agencies, regulators, economists, and evaluators is of paramount importance. The need to communicate and understand each other by sharing goals and objectives and develop priorities for successful implementation of biological decontamination practices.
4. Eastern European participants and scientists are convinced that phytoremediation and bioremediation can be a more sustainable solution to their environmental problems and are willing to learn more and to apply them extensively in the field.
5. The need for greater cooperation between public and private sectors can be accomplished by integrating basic academic and private technological research into a set of common social goals and priorities.
6. The promotion of a better understanding and cooperation between countries, in particular Western and Eastern European countries, favors and encourages a free access to guidance materials and basic

information on contaminated sites and previous decontamination attempts, and promotes further application of these effective and valuable techniques.

7. The support of increased capacity building of personnel, resources and infrastructures is required with a particular emphasis on young scientists and female- scientists.

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