In Situ Soil and Groundwater Remediation: Theory and Practice

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Preface

You have just opened the new, updated edition of the book 'In Situ Soil and Groundwater Remediation: Theory and Practice'. Congratulations. It is genuinely worth reading. In this time where almost everyone uses the internet and Wikipedia, publishing a standard text book on in situ soil and groundwater remediation fills me with pride.

About 30 years ago John Vijgen, first head of the Soil and groundwater remediation department at TAUW and a visionary man, recruited me for the task of developing innovative techniques as an alternative for remediation by excavation. While cooperating with Frank Spuij and Charles Pijls, authors of the first edition of this book, this is how I started my professional career.

Since then, 25 years have passed and the pioneering days are over. Learning by trial and error, young engineers became experts and in situ remediation became a mature working field. In this book, the knowledge and experience they acquired is presented in a very accessible way. This drive for knowledge transfer is characteristic for the people in this field.

I am proud of what has been achieved in more than 25 years and grateful that we have continued to have clients giving us the trust to keep innovating and testing new technologies at their sites. Clients who dared to invest, stick out their necks and share in the publication of the results. We treasure our long-term relationship with them.

Another crucial factor for the success of in situ remediation was the open mindset of the authorities who dared to accept innovative, unproven technologies and were able to make the transition towards risk-based strategies. It was the interaction between problem owners, competent authorities, and TAUW that made this book possible.

But above all I am proud of the authors of this book. Dedicated people who wrote this book in their own time. They are members of the TAUW family who wrote history by their dedication to in situ remediation and who are internationally recognised experts in their field. A big thank you is in place. They represent the true nature and value of TAUW.

Annemieke Nijhof, former CEO of TAUW Group

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1 Introduction

Some 4.6 billion years ago Earth was created by agglomeration of matter from our solar system. Our planet could not sustain life during its early stages because of its hot, constantly (and violently) reshaped surface. As Earth slowly started to cool down, a crust of solid rock was formed on its surface. Water on our planet originated from either ice traveling via incoming comets and asteroids or from internal mineral hydrate sources; water remained at the surface, which played a key role in the development of life. Water affected the top layer of the surface and redistributed it. On the skin of the earth, life developed in the water and later on in the top few meters of the newly shaped soil. Life soon spread throughout the whole planet. In modern times, humankind developed and quickly inhabited the surface, and in the process changed the face of the earth.

Soil and (ground)water played a vital role in the development of life on earth. It is the basis of our own existence and of all life that has developed on land. At the beginning of human development, civilisations came and went due to their use and misuse of land. The management of land was crucial to survival. Peoples that were able to manage land by irrigation and who had become acquainted with agriculture, developed more quickly than others. Those who were not able to manage land because of local conditions, depended on seasonal weather fluctuations and sustained life in close connection with nature, with all its benefits and drawbacks. Over the last 250 years, the predominantly western, agricultural civilisation has developed into an industrialized one, during which land resources have increasingly been exploited. Accessible natural resources such as coal and iron and later oil formed the basis of the industrialisation process. The mining and use of petroleum hydrocarbons as well as salt electrolytically converted into chlorine, formed the basis of modern chemical industry. The chemical industry and the energy sector produce chemicals that are distributed all over the world as a result of their widespread demand. In some parts of the world exhaustive use of resources has severely disrupted ecosystem development.

The industrial development has been beneficial to many in the developed world and has improved the quality of life. With the industrialisation and the intensive use of soil, the appreciation of soil in developed societies also changed. And as civilisations grew, building space and the environment became a valuable commodity. Environmental awareness developed in the last decades of the 20th century when it became all too clear that air and water were to be seen as vital elements of our ecosystem. That what is beneath us – the soil – was of lesser interest. We have travelled more than 7 billion km into space with the Voyager missions, but we have remarkably little knowledge of the soil beneath us.

Chemical production processes and the abundant use and spillage of chemicals have caused substantial damage to the soil. Dumping chemical waste in soil was an accepted method of disposal. Nobody thought of the difficulties of reversing this process, nor of the fundamentally different approach that is required for soil clean up compared to contaminated air and water treatment.

When it became apparent that our housing environment was threatened by soil contamination, concerns arose about the heritage that our modern industrialized society was going to leave behind. The well-known Lekkerkerk case of 1980 in The Netherlands – soil and groundwater underneath some 300 houses in the small town of Lekkerkerk were strongly contaminated and the entire area was excavated at huge costs – triggered contaminated soil and groundwater policy development throughout

Western Europe, including the question of liability. The 'polluter pays, unless ....' principle was introduced and policies were developed to enable a quick and complete cleanup of contamination. The Dutch ABC values became a worldwide reference for assessing soil and groundwater contamination and remediation. The first soil remediation techniques, usually consisting of excavation of impacted soil, sheet pile isolation and pump & treat, were based on principles of civil and construction engineering. Although these are fairly reliable and robust technologies, they are in many cases impracticable and prohibitively expensive.

The scandals that ensued, triggered assessment activities, which established that most historic and current industrial activities both pose a risk to, and have caused soil contamination. Soil contamination at a discernable scale is at least as old as the Romans, who left us with copper contamination in the soil as a result of their urban and military activities: copper was used as a base metal in bronze for the production of weaponry, kettles and coins. It became clear quickly that the full recovery of all soil contamination using traditional civil technologies would be impractical. As an alternative, in situ treatment technologies were developed. These technologies are based on chemical, physical and biological principles that are able to remove, degrade or immobilise contaminants. By changing the environmental conditions and introducing air, energy or specific chemicals into the soil, in situ practitioners can influence the behaviour of contaminants and bacteria.

In situ technologies have been applied in soil remediation for more than 25 years now. Some of them have developed into state-of-the art techniques. However, because of the slow rate of biological and diffusion processes in soil, the limited accessibility and heterogeneity of the subsurface, and the impossibility to imitate soil processes on a large scale in the laboratory, the learning process is slow compared to other fields of science. Knowledge transfer is therefore a vital element in accelerating the development and acceptance of new strategies and technologies: conferences and publications enable the transfer of new insights and experiences.

The objective of this book is to supply the interested reader, scholar and student with an overview of the theoretical backgrounds, the current state of the art and the practical application of in situ soil and groundwater remediation technologies. It provides consultants with a reference to assess the feasibility of technologies and applicable strategies, practitioners with an insight into relevant processes, and authorities with examples of applications and points of attention for design, implementation and operation.

We believe it is of utmost importance to understand the processes that govern contaminant fate and transport in soil and groundwater. Chapters 2 to 5 of this book therefore start with a theoretical description of the processes that determine the distribution of contaminants over the various soil compartments and their physico-chemical and biological behaviour in soil. In Chapter 6 an overview of technologies is presented while in Chapters 7 to 9 the individual in situ technologies are described in more detail. State-of-the-art technologies and relatively new developments are described based on their removal characteristics. In Chapter 10 the practical application of the technologies and their combination into complete remediation strategies is described. Chapter 11 presents real-life cases to demonstrate the effectiveness and limitations of in situ technologies. Finally Chapter 12 presents a high level overview of lessons learned in more than 25 years remediation practice.