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Bioremediation of Petroleum Hydrocarbons in Cold Regions

Edited by Dennis M. Filler, Ian Snape & David L. Barnes
Cambridge University Press, Cambridge, 2008.
ISBN 978-0-521-86970-6, xxiv + 273 pp. £65.

Bioremediation is the use of microorganisms to degrade pollutants in the environment. Many environmental characteristics of cold regions affect bioremediation of hydrocarbons including: permafrost, water lying above the permafrost, physiology and biochemistry of cold-tolerant microorganisms, extreme variation in daily solar radiation levels throughout the year, cold ground and air temperatures and annual freezing and thawing of the surface layers. The editors accurately describe this as a state-of-the-art guidance book to assist industry, environmental practitioners and regulators with environmental clean-up in cold climates. The unique complicating factors found in cold regions fully justify the need for a book specifically addressing the problems of bioremediation of oil pollutants under such environments.

The editors have brought together contributions from 31 experts in a wide range of scientific and engineering disciplines, to discuss the bioremediation of petroleum hydrocarbons in soils from the Arctic, Antarctica and alpine regions. Most of the contributors work in the North American Arctic or are associated with the Australian Antarctic Division (AAD), which currently leads bioremediation research in the southern polar regions. With only one exception (Anne Gunn Rike, Norway) there are no contributions from authors in the European or Russian Arctic, although research performed in these regions is reviewed. Helpfully, most chapters are structured to include an introduction, comprehensive review of the subject, information on recent advances, guidelines and recommendation and future research.

Snape *et al*., in Chapter 1, set out the extent of the hydrocarbon pollution problem within the Antarctic and in each of the Arctic nations, describing the regulations and guidelines that are in force and the extent of bioremediation undertaken. Given the size of the oil industry, the Arctic has had much more oil pollution than Antarctica, with spills of up to 126 000 tonnes not uncommon. The authors estimate that of 10^{-3} to 10^{-4}% of the terrestrial habitat in Arctic Russia could already be contaminated with petroleum. In contrast, Antarctica has experienced very many fewer spills but, due to the scarcity of ice-free coastal habitat, the proportion of terrestrial habitat contaminated by petroleum may be broadly similar to the Arctic at around 10^{-3}%. These figures may be a surprise to many, and do flag the disproportional impact of a land spill in Antarctica and highlight the necessity for effective remediation. Snape *et al*. point out that regulators in most cold regions have developed petroleum management policy based upon research in temperate regions, which may result in inappropriate management responses in cold environments. The authors go on to explain that the single most important issue for improving all aspects of petroleum pollution management would be the development of quantitative guidelines on soil quality by international collaboration between governments, industry and the academic research sector. It is unclear who can coordinate the development of quantitative guidelines across the Arctic nations, although the Arctic Monitoring and Assessment Programme (AMAP) has coordinated the collection of information on petroleum contamination across the Arctic. For Antarctica, they suggest that the Antarctic Treaty Consultative Meeting's Committee for Environmental Protection (CEP) could coordinate this work. The expansion and increasing distribution of infrastructure within Antarctica makes this work ever more important, and Antarctic operators may learn much from good (and bad) practice in the Arctic.

The following chapters describe the characteristics and properties of frozen soils and how petroleum moves through them. Recent climate change has resulted in changes in the depth of the seasonally thawed layer in both polar regions, allowing downward migration of spilled oil, reducing the rate of evaporation and physical degradation, as well as making biodegradation more difficult.

Aislabie & Foght review research into the cold-tolerant bacteria that perform the bulk of microbial hydrocarbon degradation in soils, and they describe how at least some bacteria in most cold environments possess enzymes for degradation of alkanes (alkane monooxygenase) and aromatic hydrocarbons (multicomponent aromatic dioxygenases). The proportion of hydrocarbon-degrading bacteria in soils generally increases following an oil spill, but this natural level of bioremediation depends both upon the properties of the organisms and the soil environment. Rike *et al*. describe microbial adaptations to low temperature, the impacts of temperature on biodegradation in cold soils, and provide a thorough review of cold temperature bioremediation over the past 10 years. They stress that biological remediation of contaminated soil at sub-zero temperatures is not feasible over short time scales, which may pose significant dilemmas where the summer is short and resources limited. Passive methods, such as wind energy for aeration and solar energy for heating, may need to be used but the authors emphasise that additional research is needed.

White *et al*. describe the methods and challenges associated with extraction and quantification of petroleum in soils, while in Chapter 7, Snape *et al*. skilfully put the wide range of studies that have assessed the treatability of contaminated soils into context. In particular, the excellent summary of treatability studies detailed in Table 7.2 should be highlighted. Walworth & Ferguson review the beneficial effects (and the potential pitfalls) of adding nutrients to enhance bioremediation. Unusually, they provide clear recommendations for fertiliser use, including addition of no more than 2000 mg of nitrogen kg^{-1} soil water added, regardless of contaminant concentration, or use of slow release nutrient sources.

Field scientists and engineers may find the final three chapters of the book most useful as they discuss practical methods for the bioremediation of hydrocarbons *in situ* and *ex situ*, and provide useful case studies from both polar regions. Walworth *et al*. describe the goal of cold-climate landfarming to be the alleviation of other environmental limitations (e.g. moisture, oxygen, nutrients) such that temperature becomes the limiting factor to bioremediation. Once these limitations are reduced, the soil-microbial-contaminant system can take advantage of natural seasonal warming of soils. If natural heating is insufficient to permit bioremediation at the desired rate, then thermally enhanced bioremediation (TEB) may be a solution, as discussed in Chapter 10 by Filler *et al*. As well as describing theoretical details, they provide case studies and information on designing a TEB system, including integration of oxygenation, fertilisation and thermal insulation systems. However, the cost of transporting fuel to Antarctic may make energy-hungry TEB systems prohibitively expensive. The final chapter discusses emerging technologies in soil bioremediation and groundwater treatment, and it is clear that systems exist for cleaning up oil-spills effectively in cold regions. However, what may be lacking in some parts of the Arctic and Antarctica is sufficient investment and political will to make large-scale bioremediation a reality.

The editors have successfully amassed much relevant information for researchers, engineers and policy makers. In particular, the authors make the case for more formal integration of legislation within regions and across cold regions as a whole, and have emphasised the need for more research on enhancing bioremediation under the wide variety of environmental conditions found in cold regions. The authors deserve much credit for guiding us skilfully through such a complex subject, for presenting information from diverse disciplines in an easily understood manner and for generating practical guidance based on solid field and research experience.

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Permafrost Soils

Edited by Rosa Margesin
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This book, perhaps inappropriately titled *Permafrost Soils*, is edited by Dr Rosa Margesin from the Institute of Microbiology, University of Innsbruck, Austria. The book is part of a soil biology series published under the auspices of the Amity Institute of Microbial Sciences, India. Rather than "Permafrost Soils," the book could more appropriately be titled "Biology of Permafrost-Affected Soils."

The book is divided into six parts, including i) properties of permafrost, ii) biodiversity, iii) biological activity, iv) global warming and permafrost, v) contaminants in permafrost, and vi) permafrost and extraterrestrial habitats. The 21 chapters generally have been prepared by experts in the field. Russian contributions are particularly noteworthy. The book heavily emphasizes microbiology. The chapters average 16 pages and are followed by extensive lists of citations. The tables and figures are clear but include only three poor-quality colour images. It is unfortunate that no effort was made to introduce or summarize each part to provide cohesiveness within the book.

Many interesting findings are reported, including the existence of old DNA and ancient protozoa in permafrost (two chapters) and the unexpected diversity of microbial communities in permafrost (several chapters). The chapter on genomic insights into cold adaption of permafrost bacteria (Bakermans *et al*.) was particularly interesting.

In addition to its emphasis on soil biology, the book differs from *Crysols: Permafrost-Affected Soils*, (edited by J.M. Kimble; published in 2004 by Springer) with its treatment on potential impacts of global warming on permafrost-affected soils. The five chapters in this part address global warming and thermokarst (Murton), mountain permafrost (Haeberli & Gruber), methane production (Wagner & Liebner), dissolved organic carbon release (Prokushkin *et al*.), and foundations of buildings (Shur & Goering). The book ends with a fascinating chapter on terrestrial permafrost models and analogues of Martian habitats and inhabitants (Demidov & Gilichinsky).

In summary, *Permafrost Soils* complements previously published books on permafrost-affected soil with its emphasis on soil microbiology.

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