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Technical session 3b: Remediation

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1 INTRODUCTION

Prof. Kamon chaired this session and introduced the framework for the session. General Reporter Dr Jefferis presented his report on the session noting that it included a fascinating and diverse array of papers though rather few actually addressed the issue of contaminated land remediation. He set out an analysis of the papers selected for the session and a comparison with the papers for the 15th ICSMGE. The 28 papers selected for the 16th ICSMGE session demonstrated the breadth of the discipline of remediation and contaminated land management. For the report he grouped the papers into five broad classes as follows:

ICSMGE Conference	16th	15th
Full-scale projects and case histories	4	1
Field investigation techniques	2	0
Laboratory investigations	11	5
Modelling including numerical modelling	4	5
Environmental protection, risk and sustainability	7	0

At the 15th ICSMGE Conference, Istanbul, 2001 there was no exactly equivalent session to the present session on remediation. The closest match was Session 5.1 Managing contaminated sites for which eleven papers were published and these could be approximately classified as in the table above. The 15th ICSMGE Conference also included a substantial and important paper by Professor Kamon entitled 'Environmental issues of geotechnical engineering'.

From this analysis of the papers, Dr Jefferis concluded that for this 2005 conference, as for the 2001 conference and many previous conferences, the largest class of papers related to laboratory investigations. There continued to be surprisingly few papers describing the performance of actual contaminated land remedial procedures.

Dr Jefferis said that in preparing a list of topics for debate in this discussion session, he had found it difficult to draw general conclusions from the diverse topics addressed in the papers and therefore preferred to ask the session delegates to consider some of the wider problems that beset contaminated land remediation. He had developed nine questions/topics which are presented in his General report on the session. It is recognised that nine questions is too many for the time available in the session and it is to be hoped that those reading the proceedings of the conference will consider the questions/topics and address them as appropriate in future publications.

2 PANEL PRESENTATIONS

After the general report, short presentations were made by the session panellists:

Prof Thomas, UK; Prof Mulligan, Canada; Dr Soga, UK;
Dr J. Kawabata, Japan; Dr Breedveld, Norway

These panel presentations helped to broaden and develop the subject of remediation prior to the general discussion.

2.1 *The Role of Predictive Models in Remediation of Contaminated Land; Prof H.R. Thomas and Dr S.C. Seetharam, Geoenvironmental Research Centre, Cardiff School of Engineering, Cardiff University, UK.*

The presentation focused on the role of predictive models in the remediation of contaminated land. It was noted that current trends in the UK are now more focused towards treatment/ natural attenuation/enhanced natural attenuation as opposed to the traditional dig and dump approach. Therefore, modelling of contaminant behaviour in the subsurface can play a significant role in remediation exercises as they are not only useful for predicting fate and transport of contaminants but also in predicting technology performance, assisting in technology selection, remediation design and system optimisation. However, for the modelling community, scientific challenges remain due to the very nature of the geosphere. Straightforward conservative models do not always provide satisfactory solutions. In relation to more complex models of contaminant behaviour, within the context of the tiered risk assessment approach followed in the UK, for example, such models are already available for use in the higher risk levels. It was postulated that these can be foreseen to make their way into more general use. At the same time, ongoing research efforts are being pursued to improve existing models – even the more complex ones (e.g. Thomas et al. 2005). This includes addressing multi-scale physical and chemical heterogeneities, sorption studies in the unsaturated zone, robust biogeochemical transport models, groundwater-surface water interaction and optimal methods in uncertainty analysis. For the geotechnical/geoenvironmental community in particular, it was suggested that major challenges will be those of inclusion of strength/stiffness effects in these approaches. Finally it was concluded that future work will also demand the incorporation of such models in the wider issues of sustainability and sustainable development (socio/economic) (e.g. Cleall et al. 2005).

2.2 *Natural attenuation as a tool for sustainability; Prof. C.N. Mulligan, Research Chair in Environmental Eng., Concordia University, Montreal, Canada.*

As long-term environmental strategies are required to protect and enhance the environment, what role can nature play in sustainable development and specifically in a sustainable geoenvironment? Natural attenuation is being advocated for use as an integral tool in sustainable geoenvironmental practice through mitigation and management of impacts from physical and chemical stressors in the subsoil. Procedures are being developed to effectively use natural attenuation and specify macro and material-status indicators (Yong et al., 2006). The long-term performance of mechanisms and processes in the natural attenuation of pollutants must be ensured. Some of these processes are indicated in Figure 2.

Laboratory research and modelling (transport and fate) are used to evaluate the site material capability and conditions for attenuation. Yong and Mulligan (2004) proposed three main lines of evidence including site conditions, supporting laboratory research and patterns of natural attenuation. The contaminants, soil properties and hydrology, in addition to the regulatory aspects regarding evidence of natural must all be addressed.

In conclusion, natural attenuation can be used as a tool for the mitigation and management of contaminant due to the capability for contaminant and toxicity reduction. Natural attenuation can subsequently be integrated into sustainable land redevelopment schemes. If the goals and objectives of the remediation plan cannot be met by natural attenuation, as a passive approach, then a more active approach in combination with pre- or post-treatments at a site may be necessary.

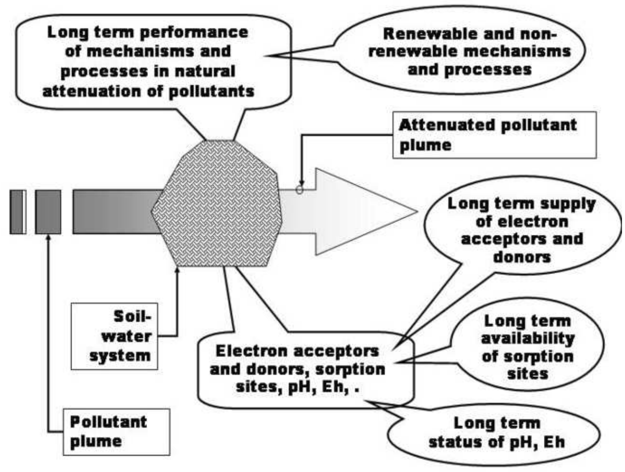


Figure 1. Sustainability of natural attenuation

2.3 *Risk after source zone remediation of NAPL contaminated site; Dr K. Soga, Dept. of Engineering, University of Cambridge, UK*

Any environmental solution for contaminated lands requires a long-term view and the selection of remediation techniques should be made as part of the life cycle assessment of the new infrastructure that will be developed. The considerations for assessment include not only potential future use of the site but also maintenance and demolition needs of the infrastructure during its lifetime. A question then arises; which remediation methods are appropriate so that the long-term risk after remediation can be predictable as well as controllable? Soga et al. (2004) reviewed source zone remediation studies available in literature and summarised the efficiencies of several in-situ remediation technologies. In Figure 1, the percentage of maximum free NAPL phase removal is plotted against the source volume of the tested area. The data has been selected from studies conducted at different experimental scales, ranging from 1-D column experiments to full-scale 3-D field tests. The efficiency problem associated with upscaling of the source zone volume is very clearly displayed. For the reported column experiments, the degree of source zone removal is limited to a small range of very high values. However, a wider range of efficiencies exists for field-scale remediation efforts. For typical field scale source saturations, on average only 60% of the DNAPL mass/volume is removed. As well as a decrease in the maximum possible remediation level moving from the 1-D column to the 3-D field situation, the range of achievable source removal efficiencies increases substantially. There exists a significant uncertainty associated with upscaling from laboratory to actual field conditions. This highlights the limited and highly variable efficiencies of current source zone remediation techniques applied in the field scale. Accepting that a significant fraction of the contamination will still remain after treatment, what level of remediation is acceptable? Considering the risk assessment procedure currently adopted in practice, attention for source zone remediation should focus on understanding and ideally quantifying the mass transfer from entrapped NAPL in the source zone into ground water flowing through the source zone before and after remediation. Recent studies show the close association between up-gradient vertical DNAPL distribution and downgradient aqueous phase contaminant concentrations (and therefore mass flux). Hence, attention should focus on quantifying the remaining source zone size after remediation in order to assess the long-term risk of NAPL contaminated sites.

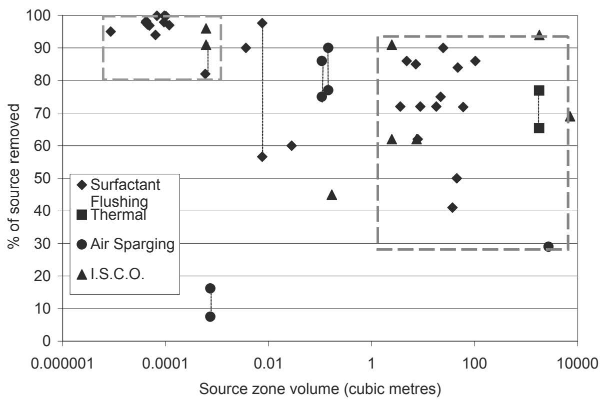


Figure 2. Removal efficiencies of selected source zone remediation technologies (Soga et al., 2004)

2.4 *New in-situ remediation techniques for VOCs' contaminated ground; Dr. J. Kawabata, Kajima Corp.,Tokyo, Japan*

Recent years have seen rapid advances in remediation technologies for ground contaminated by volatile organic compounds (VOCs) in Japan. A variety of in-situ remediation technologies has been or is being developed and applied. However, it should be recognised that effective in-situ remediation techniques should be a combination of a reliable physical and/or chemical principle and an appropriate ground improvement methodology. Recognition of this combined requirement is important when developing and applying new efficient techniques. Two unique in-situ remediation techniques for VOC contamination were introduced in the presentation; the first, a remediation method that applies a jetting technique and the second bio-sparging using a horizontal well constructed by a three-dimensional directional drilling method.

2.4.1 *Application of Jetting Method for remediation*

The jetting method has the advantage that it offers a technique for partial ground remediation of deep zones and in the reliability of the effect compared with other in-situ methods. Two procedures for the application of the technology were presented (see Figure 3):

- partial replacement of heavily contaminated clay in the ground by a heavy mortar that is mixture of clay, cement and iron sand;
- mixing zero-valent iron powder with sand in an aquifer, which creates a strongly reducing environment in an aquifer and can remediate chlorinated species such as PCE.

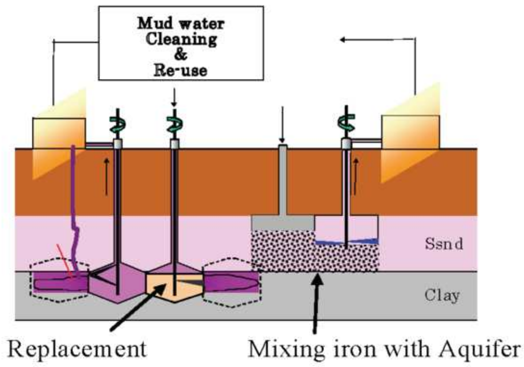


Figure 3. Application of Jetting Method for in-situ remediation

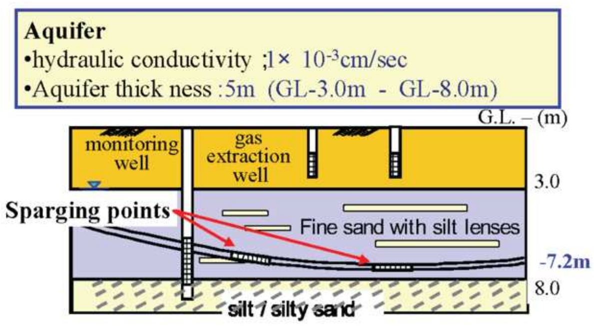
These two techniques actually have been used in remediation projects in Japan.

2.4.2 *A case study of bio-Sparging with using horizontal wells*

In-situ bioremediation is one of the techniques that is attracting growing attention because of its cost-effectiveness and its reduced carbon dioxide emission compared with techniques that require excavation.

In bio-sparging, air is injected into the contaminated aquifer to remove VOCs physically from the ground and to increase the dissolved oxygen (DO) content. Nutrients are also injected to enhance the activity of aerobic micro-organisms. Figure 4 shows the profile of the site which was the subject of this study. Horizontal injection wells were installed with a three--dimensional directional drilling system. Advantages of horizontal wells are applicability to ground contamination under buildings and a larger area of influence than in the vertical well method (and hence greater cost effectiveness) .

Air/Bio-sparging was performed for a year in this study. The benzene concentration in the groundwater in a 100-square-metre area around the injection well was reduced to a level of one tenth of the initial concentration after three months of treatment. However the rate of reduction of concentration then suddenly decreased and became "stable." By applying bio-sparging after that, the remediation speed was remarkably accelerated again. The concentration became one-hundredth of the initial concentration after 4 months of bio-sparging operation (see Figure 5). The bio-effect became dominant at a low level of concentration. The effectiveness of bio-sparging using horizontal wells was clearly verified by the results of this case study.



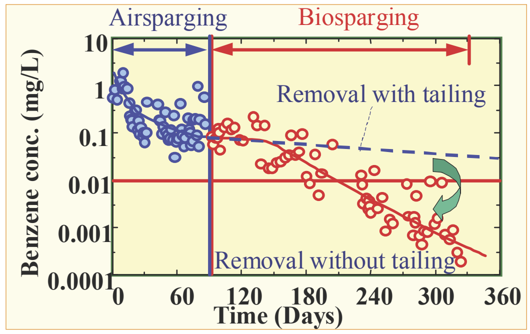


Figure 5. Effect of Air/Bio sparging at this site

2.5 *Contaminated sediments – Chemical stability directs remediation; Prof. G.D. Breedveld, Norwegian Geotechnical Institute, Oslo, Norway*

There is no doubt that sediments in estuaries and coastal zones are highly contaminated throughout the world, especially near urbanized and industrial areas. However, the question arises as to what an optimal sediment management strategy would be, given the environmental setting.

The key question which has to be addressed is the long-term stability of the contaminants stored in the sediments, with respect to both physical and chemical changes in the environment. These changes might be the result of natural processes as well as anthropogenic activities (e.g. construction works, redevelopment and remediation).

Sorption to the organic sediment fraction has been considered a major factor controlling the environmental fate of organic pollutants and as such has been at the basis of environmental risk assessment. In recent years the role of residues of incomplete combustion like soot, coke and charcoal, commonly termed "black carbon" (BC), has received considerable attention. These studies showed that sorption to the BC phase is much stronger than expected. A proper understanding of these sorptive processes and potential release mechanisms allows a new approach to sediment management. Based on a proper understanding of the chemical stability of contaminants, novel remediation techniques can be developed to reduce release to the aquatic environment and thereby minimize ecological effects.

3 DISCUSSION

The discussion opened with a debate on toxicity of contaminants. The state of knowledge on toxicity was queried. It was recognised that the main role of the contaminated land engineer is to assess the dose of contamination that a receptor might receive and that the harm done to that receptor is more a matter for the toxicologist in respect of human health though expert input also will be required on ecotoxicology. It was recognised that databases exist on toxicity and that these are valuable to the engineer assessing contaminated land. However, databases do not necessarily convey the subtlety of the problem and the maintenance of a dialogue between those responsible for the assessment of dose and those considering response (generally harm though some chemicals can bring benefits) is important.

New legislation such as the EU Registration, Evaluation and Authorisation of Chemicals (REACH) regulations may bring benefits in reducing future pollution by making users aware of toxicity. However, requiring ever more toxicological data comes at the cost of tests on living species. Furthermore, this still leaves the problem of extrapolating from animal tests to humans as human exposure studies are rare and tend to be limited to accidental, workplace or criminal exposure.

The discussion then moved to the continuing evolution of legislation relating to the management of pollution. As an example of developing and rigorous regulation, the pollution from landfills was queried. The thesis was advanced that many landfills present minimal pollution risk. However, this was countered with the view that although some old landfills filled with largely inert material may now present no hazard, modern very large landfills represent major sources of pollution. If such landfills are not properly regulated and engineered at the outset, dilution and dispersion can in no way be relied on to manage any contaminant plumes emanating from them. It was concluded that engineers should be encouraged to take a proactive position in the development of new legislation – and many do. It is inappropriate for the engineer to complain of changes to legislation if she/he is not prepared to take a pro-active position in its development. In this respect, one must ask: should engineers have been more active in warning of the pollution potential of methyl tertbutyl ether (MTBE) prior to its major use as an oxidant in petrol and is resulting widespread occurrence as a groundwater pollutant. Also should they have been more active in developing appropriate management systems for it, once in use.

Engineers also need to do a better job in informing the public regarding their work and in the provision of project specific data so that stakeholders can make informed decisions and be less susceptible to paranoia driven by often poorly informed scare stories. This will avoid wasted time and resources in public hearings on contentious projects.

Information was presented on on-site toxicity testing using bioluminescent bacteria (Cybersense, 2004; Hart, 2004). These procedures allow rapid on-site testing of toxicity that can be undertaken by the engineer without the need for a toxicologist (though of course, toxicological experience is encompassed in the development of the test and interpretation of the results). Such testing shows good correlation between bioluminescence assessed toxicity and current regulatory control levels suggesting that current levels are realistic in relation to effects. However, interestingly toxicity is found in significant minority of samples tested where it is not found in laboratory testing. This suggests that the response to Question 9 of the General report "Are laboratory measurements always the 'gold standard. Do we understand / enquire enough about extraction procedures and the performance of laboratory analytical regimes?" is 'not always'. The engineer must be aware of test protocols and be prepared to question both laboratory, on-site and in-situ protocols. Those responsible for the assessment and management of contaminated land must be aware of the methodologies by which all the test data were produced and the regulatory context within which they are to be used.

Discussion then moved to natural attenuation and in particular how to convince regulators to use natural attenuation. It was concluded that requirements include the development of adequate monitoring programmes to prove the existence of natural attention through location of monitoring wells, supporting laboratory tests and the use of modelling to predict transport and fate of contaminants plus supporting laboratory tests. It was stated that there is a need for regulators, practitioners and other professionals to have a deeper understanding of the assimilative processes occurring within soils – to enable a better understanding of natural attenuation of soil.

In relation to a question on how to develop acceptance of new technologies it was stated that large scale demonstrator projects are needed to prove the technologies and allow them to be accepted by regulators. The U.S.A. and Canada have used this approach successfully.

4 CONCLUSIONS

This was a substantial session based on a wide ranging slate of papers and it resulted in a wide ranging discussion. However, this was a discussion which focused on the role of the engineer in pollution management and the development of pollution control legislation rather than a discussion of technical issues.

In this conclusion, the general report wishes to repeat his concern set out in his general report. Although the session was on 'remediation' there were few papers on full scale remediation projects. It is to be hoped that more will be reported in future conferences. From the session discussion, informal discussions during the conference undertaken by the session reporter and his personal experience it is clear that remediation is being undertaken on very many challenging sites using highly innovative procedures but why are there so few reports of our successes or even of our occasional failures?

Much formerly contaminated land has now been redeveloped. Indeed many readers of this report may live on formerly contaminated land – especially if they live in England were there is a Government target (enthusiastically achieved by developers) that 65% of new hosing should be on contaminated land. We need to get it right and to demonstrate that we are doing so. We also need to tell the stakeholders that we can and are doing it.

The discussion leader wishes to thank all those who attended and contributed to the session and in particular Professors Peck, Krishna Reddy, Manassero and Sarsby for their active involvement in the discussion.

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