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The role of predictive models in remediation of contaminated land

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1 INTRODUCTION

The presentation focussed on the role of predictive models in the remediation of contaminated land. It was noted that current trends in the UK are now more focussed 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. This paper therefore briefly examines the current position in the UK with respect to the role of models in remediation exercises, discusses the state of the art in model development and identifies key research needs from the authors' perspective. The importance of considering sustainability aspects in model development has also been briefly touched upon.

2 UK SCENARIO

According to the UK Environment Agency (EA) as many as 100,000 sites may have been contaminated, which constitutes approximately 1% of UK's land area [1]. The current trends in the UK are now more focussed towards treatment/natural attenuation/enhanced natural attenuation as opposed to the traditional dig and dump approach. The EA has published the document "*Model Procedures for the Management of Land Contamination, CLR 11*", which offers the technical framework for applying a risk management process for contaminated land [1]. It demonstrates three procedures: (i) risk assessment; (ii) options appraisal, i.e. evaluating feasible remediation options and determining the most appropriate remediation strategy for the site; and (iii) implementation of the remediation strategy. Within the first procedure, i.e. "risk assessment", guidance on "tools" (models) is presented. This includes human health risk assessment models such as CLEA, SNIFFER, RBCA and RISC Human. In using these models limitations need to be clearly understood due to a number of assumptions and also those parameters that cannot be varied.

As far as groundwater is concerned, EA R&D P20 Guidance Note forms the primary guidance and advocates a tiered approach to assessment of risks. Guidance is provided with a simple analytical spreadsheet (EA remedial targets spreadsheet). Commercial packages have been developed in support of the approach; these are mainly probabilistic based, e.g. CONSIM and RAM. At higher tiers there is increasing complexity; therefore model use must be justified by the assessor. At present models like MODFLOW [2] have found increasing acceptance within the UK industry. However, the general concern is about the conservativeness of these models, including uncertainties in both model and material parameters.

3 STATE OF THE ART MODELS

Advances in the scientific understanding of soil-contaminant behaviour has led to the development of more complex models of contaminant transport capable of analysing physical, chemical, mechanical and biological problems of saturated/unsaturated soils (fully or partially coupled). Contributions have come from both the water resources and geoenvironmental engineering community. This includes models such as TOUGH2 Family [3], PHREEQC [2], etc. from the water resources community and models such as POLLUTE [4], COMPASS [5], etc. from the geotechnical engineering community. Although progress has been made, due to the physical, chemical and biological heterogeneities of the soil matrix and lack of reliable thermodynamic data for soil-contaminant interactions, significant challenges remain unresolved.

As far as human health risk assessment is concerned there are several models that exist (e.g. MEPAS, CalTOX and TRIM). However, these are static health models and can only perform health impact estimation *per se*. Human health models strongly linked to epidemiological evidence, capable of dynamic analysis and that which takes into consideration secondary human health effects are much in need [6]. The authors in collaboration with London School of Hygiene and Tropical Medicine have recently proposed an approach which will lead to an Integrated Health Impact Analysis Framework. This combines a series of mathematical models within a decision support framework [7]. These include: (i) complex pollutant transport models; (ii) exposure models; (iii) dose-response models; (iv) population health models; and (v) evaluation models of mitigation or reduction options, based on their effect or cost-effectiveness.

4 RESEARCH NEEDS

Based on a study carried out by the US Federal Agency Workshop [8], the following research needs have been identified: (i) Robust field scale reactive transport models capable of incorporating multi-scale physical and chemical heterogeneities; (ii) Sorption studies in unsaturated zone and sorption kinetics/hysteresis; (iii) Advanced algorithms to deal with kinetics of dissolution /precipitation in natural systems; (iv) Development and standardization of a new database for sorption parameters for real systems; (v) Thermodynamic database for kinetic processes similar to equilibrium reactions;

(vi) Robust biogeochemical transport models, especially to model redox sensitive processes; (vii) Groundwater – Surface water interaction models to capture risks due to intermedia contaminant transport; and (viii) Optimal methods to carry out uncertainty analysis using sophisticated models. For the geotechnical/ geoenvironmental community, a major challenge will be those of the inclusion of strength/stiffness effects.

5 SUSTAINABILITY ISSUES

Although the major challenge facing the scientific community today is to address conceptual gaps in understanding soil-contaminant behaviour and its linkages to human health and ecology, the ultimate objective of such an exercise should be aimed at achieving a sustainable geoenvironment. This means engineering, human health, social and economic aspects must be addressed within a sustainability framework. An example of such an ongoing effort is a project involving a consortium of UK institutions where a suite of engineering (groundwater, surface water and air), health, ecological and socio-economic models are integrated within a decision support framework. As stated above (section 3), an initial attempt at combining models of contaminant transport with health impact and cost effectiveness analysis has already been demonstrated [7].

6 CONCLUSIONS

This paper focussed on the role of predictive models in the remediation of contaminated land. It was noted that current trends in the UK are now more focussed 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. However, for the modelling community, scientific challenges remain due to the very nature of the geosphere. In relation to more complex models of contaminant behaviour, within the context of a tiered risk assessment approach followed in the UK, for example, such models are already available for use in the higher risk levels. It is postulated that these can be foreseen to make their way into more general use. At the same time, further ongoing research efforts are being pursued to improve existing models – even the more complex ones. For the geotechnical/geoenvironmental community in particular, it was suggested that a major challenge 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.

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