Environment Agency

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# Optimising biopile processes for weathered hydrocarbons within a risk management framework (PROMISE)

## Science summary SC040076/SS

A collaborative project supported by the Environment Agency explored the best ways of assessing and treating soil polluted with weathered hydrocarbons.

The aim of this project was to assess the *ex situ* biological treatment (biopile and turned windrow) of contaminated soil in order to understand the environmental and human health risks associated with heavier hydrocarbon fractions, and to develop guidelines to manage those risks effectively. The outcomes of this project will be of interest to the contaminated land sector, including consultants and environmental regulators.

Key outcomes of the project are outlined below.

### Total petroleum hydrocarbon (TPH) analysis

An ultrasonic extraction method was developed for recovery of TPH from contaminated soils. The method has an extraction efficiency above 90 per cent, requires less time, uses less solvent, and is less likely to lead to thermal degradation of analytes than traditional extraction methods. The extraction permits subsequent analysis, without a concentration step, for carbon banding C8 to C40, aliphatic/aromatic split and identification of risk indicator compounds typically down to 10 mg/kg in soil.

### Biological and ecotoxicity assessment

A range of bioassay techniques was used in combination with chemical analyses to explore how the hydrocarbons were transformed during bioremediation. The bioassays were selected for their ease of use and ability to cover the response of different soil organisms, such as earthworms and bacteria, to bioremediation.

The study found that the progress of bioremediation cannot be measured by a single parameter, and that measures are needed to assess the bioavailability of contaminants and their metabolites and the ability of a microbial population to break them down. An ecological end-point for remediation also needs to be established, that is, the level to which soil should be treated.

Respiration data has traditionally been used to follow microbial activity through biodegradation. However, our study found that most of the microbial activity reflects the utilisation of readily available carbon, and that the more refractory carbon, including weathered hydrocarbon compounds, remains unused.

The study found that a drop in contaminant levels does not necessarily indicate a decrease in soil toxicity, as toxic intermediates and incomplete degradation products can contribute to the overall toxicity of the soil.

### Fugacity modelling

The propensity for a substance to transfer from one phase to another can be predicted using its fugacity (related to partial pressure). The importance of the non aqueous phase liquid (NAPL) for partitioning of hydrophobic organic contaminants in soil is understood, but is rarely incorporated into exposure assessment tools. This project developed Level I and II fugacity models that included four phases within the soil matrix, namely: air, water, mineral soil and residual NAPL.

The models predicted the propensity for petroleum hydrocarbons to partition into the soil and NAPL phases and that degradation was the dominant removal mechanism in biopile systems, except for lighter fractions such as benzene and toluene. Only benzene was predicted to have any significant concentration in the aqueous phase.

### Diagnostic toolkit

The above approaches were incorporated into a diagnostic process, combining chemical, biological and ecotoxicological analyses to improve our confidence in the risk assessment and remediation approaches for dealing with weathered hydrocarbon-polluted soil.

### Pilot trials

A six month pilot study was carried out to compare windrow turning and biopile methods for treating soil contaminated with bunker fuel.

The windrows were found to outperform biopiles in that a lower end-point concentration was achieved after a shorter duration. The windrows were also associated with greater soil recovery as there were positive responses to the ecotoxicological tests. Furthermore, the regular turning of the windrows meant that the soil became more friable and easier to work with while the biopiles became compacted.

**Decision support tool**

A decision support tool was developed to support a risk-based approach to sites contaminated with weathered hydrocarbons where biopiling and/or turned windrows are proposed as a treatment option. The tool continues to evolve and has now been extended to other remediation technologies. The tool is available at:

http://www.abdn.ac.uk/remediation-dst/

**Dissemination of findings**

Workshops were held at Melton Mowbray and Edinburgh University in February 2008, to share the project's findings with contaminated land researchers and professionals. Twenty seven research publications and presentations have also been delivered from this project and continue to be submitted for peer-review. The most notable publications to date are:

Brassington, K.J., Hough, R.L., Paton, G.I., Semple, K.T., Risdon, G., Crossley, J., Hay, I., Askari, K. and Pollard, S.J.T. 2007. Weathered hydrocarbon wastes: A risk management primer. CRC Reviews in Environmental Science and Technology. 37: 199-232.

Risdon *et al.* 2008. Development of an analytical procedure for weathered hydrocarbon contaminated soils within a UK risk-based framework. Analytical Chemistry 80 (18), 7090-7096.

Pollard *et al.* 2008. Fugacity modelling to predict the distribution of organic contaminants in the soil:oil matrix of constructed biopiles. Chemosphere 71, 1432-1439.

Coulon *et al.* Multimedia fate of total petroleum hydrocarbon fractions in the soil:oil matrix of constructed biopiles. (in preparation for Env Sci Technol or Chemosphere)

Paton et al. When is a soil remediated? End-point comparisons of biopiled and windrowed soils contaminated with bunker-fuel. (in prep. for Environmental Pollution Journal)

The work has given us greater insight into the fate and behaviour of weathered hydrocarbons in soil. The findings have been used to refine the level of analytical, biological and ecotoxicological testing needed to demonstrate the success of biopiling and turned windrow technology within a risk-based management framework.

The project was led by Cranfield University and included the following partners: Aberdeen University, BP International, Environment Agency, Lancaster University, National Grid Property, PERA Innovation, Remedios, Shell Global Solutions and TES Bretby.

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This summary relates to information from Science Project SC040076, reported in detail at the following web site:

http://www.cranfield.ac.uk/sas/resource/research/promise/index.jsp

**Internal Status:** Released to all regions
**External Status:** Publicly available

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