Institution: 10007822

Unit of Assessment: 12

Title of case study: Improved bioremediation of hydrocarbon contaminated soils

1. Summary of the impact (indicative maximum 100 words)

New analytical methods have been used in commercial applications for the 2012 Olympic Park to measure petroleum hydrocarbons in soil. Cranfield developed techniques, in collaboration with Eurofins, to meet the needs for contaminated land risk assessment and enable the selection of remediation strategies. Decision-support tools were developed for risk management and environmental rehabilitation of contaminated sites. The tools contribute to end-user confidence in remediation technology, reduced remediation costs and minimised waste disposal to landfill with subsequent savings in CO_2 emissions. Our research laid a road map to demonstrate risk reduction and provided practical and cost efficient soil quality management tools.

2. Underpinning research (indicative maximum 500 words)

The focus of our research has been to tackle the protection and recovery of soils contaminated by complex hydrocarbon mixtures, a key challenge for industrialised countries, because of its consequences for water resources and land use [G1,2,5,6]. Our research draws on Cranfield's analytical and environmental modelling expertise with a substantive contribution to the practice of sustainable remediation.

We have pioneered the detailed chemical examination of heavy oil residues by reference to risk concepts, dramatically improving on the rudimentary analytical parameters used in risk assessment in the mid 1990's. Early work secured novel analytical insights on gas chromatography to characterise complex weathered contaminated soil-oil matrices and allowed the development of new analytical indices of biotransformation. This set the theoretical groundwork for an industrial research consortium addressing the risk-based bioremediation of weathered hydrocarbon waste in 2004 [G5]. This enabled us to construct innovative decision-support tools for contaminated sites such as the Remediation Decision Support Tool for stakeholders (BP, Shell, National Grid) [G5] and service providers (Remedios Ltd) [P3,G5] and the fugacity[1] based multimedia fate and transport tool [C1,2,G3,4,5].

Specifically, we addressed the partitioning of complex hydrocarbon mixtures within the soil-oil matrix of contaminated soils using authentic wastes and we characterised the fate and transport of the contaminants in question, a key requirement for estimating risks to human health and the environment [P1,3]. We also quantified the biotransformation half-lives in the residual oil phase [P2,4,6]. These are rarely, if ever, measured or even predicted [P2], and overly-conservative estimates had been resulting in over- stringent soil assessment criteria with considerable cost implications for remediation - a waste of resource and a missed opportunity to recover land quality [C2]. Our research corrected this and has the potential to save between £3.2 million and £12.4 million per year in remediating derelict land for development in the UK [C1,3,4]. It further provided a 'fit for purpose' assessment of the fate of hydrocarbon complex mixtures and risk-critical

[1] Fugacity is an effective pressure, equal to the pressure of an ideal gas which has the same chemical potential as the real gas.

compounds in soils allowing realistic remediation objectives to be set [P2] supporting swifter, risk-based remediation.

The detailed evaluation of different hydrocarbon fractions has further helped the appraisal of residual hydrocarbon levels that can be left safely at remediated sites without posing unacceptable risk [P2,5]. This ensures environmental protection and the recovery of soil quality for reuse [P1,3,6].

Our work and reputation in this area have led to contributions on environmental decision-making in general, better regulation and risk policy via drafting the national consultation and regulatory guidance on the assessment of risks from hydrocarbon-contaminated soils for the Environment Agency of England and Wales in 2005 [G2, C1].

Key researchers	Post details*	Dates involved	Research
Dr Frederic Coulon	Lecturer	2006-date	All of the above
Dr Mick Whelan	Lecturer	2010-2012	Modelling
Dr Cedric Kechavarzi	Lecturer	2010-2012	Partitioning, fate of fractions
Prof Simon J.T. Pollard	Professor	2004-date	All of the above

* highest grade in period given

3. References to the research (indicative maximum of six references)

Evidence of quality - Peer reviewed journal papers

P1 Wu G. [e], Kechavarzi C., Li X. [e], Sui H. [e], Pollard S.J.T., Coulon F. (2012). Influence of mature compost amendment on total and bioavailable polycyclic aromatic hydrocarbons in contaminated soils. Chemosphere. 90: 2240-2246 doi: 10.1016/j.chemosphere.2012.10.003

P2* Coulon F., Whelan M.J., Paton G.I. [b], Semple K.T. [a], Villa R. , Pollard S.J.T. (2010) Multimedia fate of total petroleum hydrocarbon fractions in the soil:oil matrix of constructed biopiles. Chemosphere. 81: 1454-1462. doi: 10.1016/j.chemosphere.2010.08.057

P3 Coulon F., Al Awadi M. [b], Cowie W. [b], Mardlin D. [b], Pollard S., Cunningham C., Risdon G. [c], Arthur P. [a], Semple K.T. [a], Paton G.I. [b] (2010) When is a soil remediated? Comparison of biopiled and windrowed soils contaminated with bunker-fuel in a full-scale trial. Environmental Pollution. 158: 3032-3040 doi: 10.1016/j.envpol.2010.06.001

P4 Coulon F., Orsi R., Turner C., Walton C., Daly P. [d], Pollard S.J.T. (2009) Understanding the fate and transport of petroleum hydrocarbons from coal tar within gasholders. Environment International. 39: 248-252 doi: 10.1016/j.envint.2008.06.005

P5* Risdon G. [c], Pollard S.J.T., Brassington K.J., McEwan J.N. [c], Paton G. [b], Semple K. [a], Coulon F. (2008) Development of an analytical procedure for weathered hydrocarbon contaminated soils within a UK risk-based framework. Analytical Chemistry. 80: 7090-7096 DOI: 10.1021/ac800698g

P6* Pollard S.J.T., Hough R.L., Kim K-H[f], Bellarby J. [b], Paton G. [b], Semple K. [a], Coulon F. (2008) Fugacity modelling to predict the distribution of organic contaminants in the soil:oil matrix of constructed biopiles. Chemosphere. 71: 1432-1439. doi: 10.1016/j.chemosphere.2007.12.007

Key

a Lancaster University, UK
b Aberdeen University/Remedios Ltd, UK
c EGS, UK
d National Grid, UK
e Tianjin University, China

f University of Seoul, South Korea

* 3 identified references that best indicate the quality of the research

Evidence of quality – Research grants

G1 EPSRC / Waste and Action Resource Programme (Life III Environment programme; No. OBF009) – Innovative uses for quality composts within the landscape and regeneration sectors, 2008 – 2011; value £95k - PI: Dr R Sakrabani CI's: Dr C. Kechavarzi, Dr F Coulon

G2 The Environment Agency of England and Wales (SC070055): Evaluating and improving the effectiveness of our risk-based decisions – January - September 2008; value £50k - PI: Prof S.J.T. Pollard

G3 National Grid UK (No. 1193): Field measurement of vapour emissions from gas holders - April-September 2007; value £14.5k - PI: Dr F Coulon

G4 Shell Global Solutions, Shell Research (No. 5010978): Biotransformation of weathered hydrocarbons at contaminated sites – 2004-2007, value £80k – PI: Prof S.J.T. Pollard

G5 BBSRC/BERR/EA BIOREM_35 Link project: PROMISE (BB/B512432/1): Optimising biopile processes for weathered hydrocarbons within a risk management framework - 2004 - 2008, value £916k - PI: Prof S.J.T Pollard

4. Details of the impact (indicative maximum 750 words)

Cranfield's work in hydrocarbon remediation has produced new practical analytical methods with applications in industry. We have created a roadmap for risk reduction and promoted soil remediation, and made the methods widely available through commercially available toolkits.

Our work has improved the technical capability of our industrial partner Eurofins EGS (formerly TES Bretby). The company grew by 70% during the later stages of this project following the award of the 2012 Olympics Park testing contract in London. The company is confident to have achieved the objective of 2% increased analytical sales. The company estimated an overall of £200k per annum saving on their hydrocarbon analysis costs including: (i) reduced use of solvents, saving £100k per annum, (especially due to reduced use of chlorinated solvents by 90%); (ii) improved laboratory throughput (4 fold faster than using previous methods): £80k per annum on-going saving) and; (iii) reduced quality control failures by either incomplete extraction of surrogates or cross contamination (Estimate £20k per annum on-going saving) [C5].

The UK Standing Committee of Analysts 'Blue book 2012' of accredited analytical methods for petroleum hydrocarbons now includes the analytical method [P5] developed under the BBSRC Bioremediation Link programme 2004-2008 [G5]. This addresses ISO17025 for TPH analysis, banding and class separation, and complies with the Environment Agency's Monitoring Certification Scheme (mCERTs)).

Our research laid out a road map of the logical steps involved in the demonstration of risk reduction within process-optimised technology and provided a set of practical and cost efficient soil quality management tools in 2008 [C1,3,4]. As with many large companies, BP International [G5], Shell UK [G4] or NationalGrid [G3] (our industrial partners) engage a range of consultants to carry out site investigations, design remedial strategies and to carry them out. However there has been a lack of continuity in strategy and transparency except when single contractor has worked on numerous sites, which the roadmap has addressed. By promoting a greater understanding of the

remediation technologies, both internally and externally, we have aided strategic decisions of our industrial partner, Remedios Ltd [C1] on their future direction in terms of the ex-situ remediation market in 2009 [P3].

Our application of fugacity-based multimedia models [P2, 4 & 6] for predicting the phase distribution and concentrations of organic contaminants during remediation treatment has been used to address the key issues of identifying the source of risk, the perception of risk and the appropriate societal response to this problem [C1,2]. Particularly our combined hazard and risk diagnostic strategy approach demonstrated that information obtained could meaningfully be used to assess constraints of bioremediation and most significantly help to avoid unnecessary expenditure [C1,2,4].

Our research led to a decision-support tool kit with our industrial partner Remedios Ltd in 2008 [P3; C1]. The tool kit was initially designed for sites contaminated with weathered hydrocarbons focusing on sites characterisation and risk-based approach where biopiling and/or turned windrows were proposed as a treatment option. Cranfield broadened the tool kit to all remediation technologies for contaminated lands and waters with the perspectives of facilitating and assisting in a transparent decision making process. The tool is available at: http://www.abdn.ac.uk/remediation-dst/.

Our technical contribution has been published via CL:AIRE website in 2010 which ensured (i) a targeted delivery to *ca.* 4500 contaminated land practitioners and advisors, (ii) effective knowledge transfer to the remediation and consulting community [C3,6].

5. Sources to corroborate the impact (indicative maximum of 10 references)

C1 Contact: Remedios Ltd, Managing Director

C2 Contact: Australian Antarctic Division, Programme Leader

C3 Contact: Director, Contaminated Land: Application in real environments (CL:AIRE), UK

C4 Contact: HSE Manager, Shell Global Solutions, Shell Research, UK

C5 Contact: Eurofins, Managing Director

C6 PROMISE report on bioremediation on CL:AIRE website http://www.claire.co.uk/index.php?option=com_resource&controller=article&article=46&category_id=3&Itemid=61