A contaminant transport characterisation tool for landfill

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Introduction

Accelerating the remediation of waste by the removal of indigenous contaminants though flushing, may be an important medium-term solution to legacy landfill sites.

The variables that will affect the efficiency and success of flushing are those which act as controls on flow and transport[1], and can include waste type, geochemical and geotechnical properties, heterogeneity over a variety of scales, the volumetric flow rate of flushing and the saturation level of the wastes. There is also growing evidence that dual porosity flow and transport are significant[2].

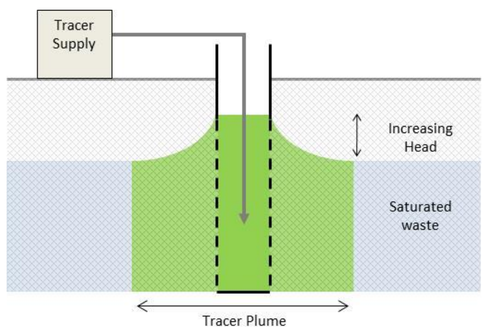
A new tool for landfill characterisation

An 'echo' test is a single-well radial pumping test in which a tracer or mix of tracers is first injected into a well and then, after a period of time, pumped back out of the same well.

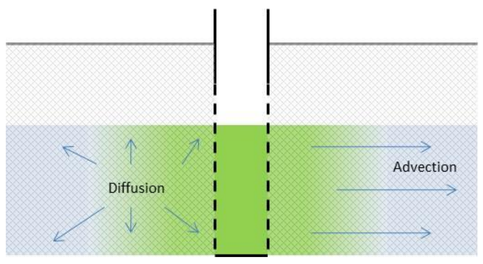
By analysing the returning concentration of the tracer during abstraction, it is possible to estimate a number of important contaminant transport properties of the waste directly around the well.

Performing a number of short-duration, single-well tests at a given landfill will, therefore, enable a picture of transport variability across a site to be built up. This information can then be used to help inform the design of a remediation strategy.

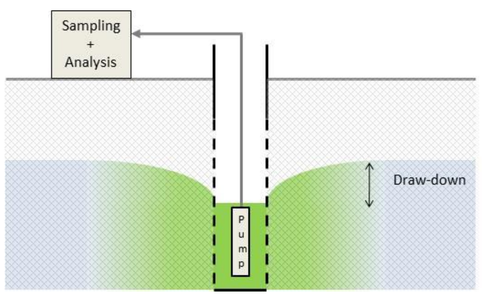
Stage 1. Injection



Stage 2. Residence



Stage 3. Retrieval



Method

An echo test is performed in three stages:

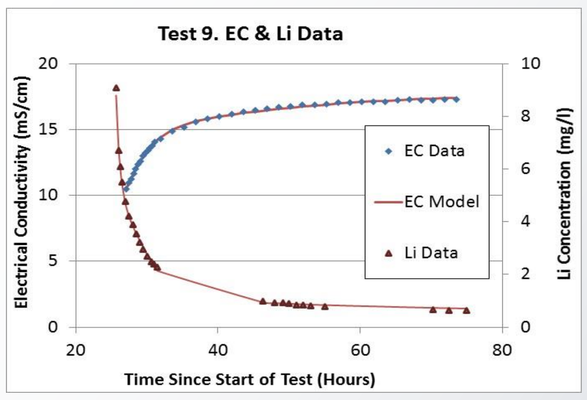
Injection - tracer or mix of tracers pumped into a well

Residence - rest period allowing advection and diffusion

Retrieval - well pumped and the returning concentration of the tracer measured

Seven field-scale echo tracer tests have been performed at four landfill sites in the UK.

The tests were carried out at different spatial scales (volume of tracer used) and with a mix of different tracers to examine the effect and significance of scaling, waste heterogeneity and the performance of different tracers in waste (Table 1).



Sample test data and model fit

Test No.	Site No.	Waste + Saturated Depth (m)	Tracer Type	Vol. of Tracer (m^3)	Test Duration (Days)	σ	t_{cf} (Hours)	t_{cb} (Hours)
3	A	5.5 / 2.3	Water	2.1	2	4.7	0.2	4.9
4	B	7.3 / 4.6	Water	2.0	2	5.4	1.4	41.6
5	B	9.0 / 2.8	Water	1.1	2	8.7	0.1	5.5
6a	C	10.0 / 2.2	Water	6000	190	12.3	114	17,189
6b			Lithium	228	21	15.6	20	4849
6c			D2O	8	15	17.5	1.1	327
7a	C	10.0 / 2.2	Water + Lithium	6	10	6.2	8.0	303
7b						7.0	8.1	342
8	D*	26.3 / 14.5	Lithium	6	5	4.5	2.5	50.0
9a	D*	26.3 / 14.6	Water + Lithium	6	3	4.2	2.3	41.8
9b						4.5	4.8	99.4

Table 1 – Echo test and tracer information

DP-PULSE

Test data has been analysed using a 1D numerical model called **DP-PULSE**, by fitting concentration vs time data for each of the tracer recovery curves[3].

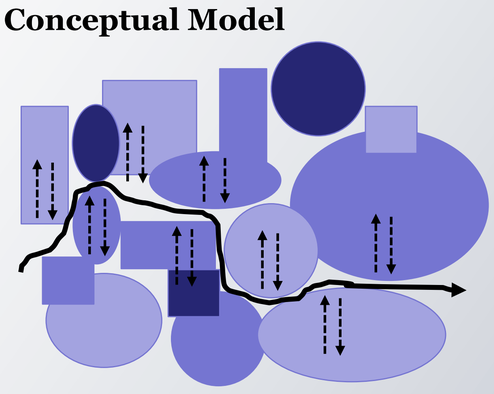
The model assumes a dominant solute transport mechanism of advection within a **mobile zone** and diffusion into a single **immobile zone** which can be characterised by a single spatially homogeneous diffusion time. The significant parameters derived from the model are:

t_{cf} - diffusion time for a region with the same volume as the mobile region of the formation

t_{cb} - the block diffusion time

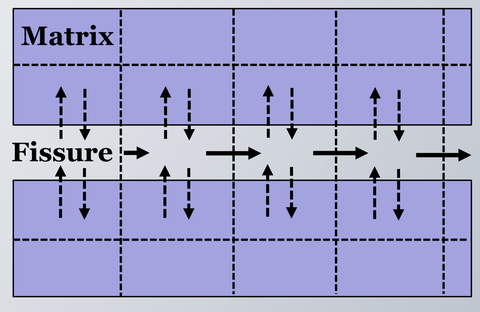
σ - the ratio of the immobile and mobile porosities

Conceptual Model



Diffusion between fissure and matrix
Advective flow from cell to cell in fissure

Representation in DP'PULSE



Conclusions

The transport parameters derived are relatively consistent between tests. σ falls within the range 4.2-17.5 and t_{cf} 0.1-114 hours.

In terms of calculated t_{cb}, the differences are rather larger (5-1106 hours), possibly related to the volume of waste tested, and may demonstrate an underlying power-law relationship relating to the spatial scale of the test.

If verified, this scaling relationship would allow affordable small-scale tests to be useful in predicting larger scale flushing operations.

EPSRC
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[1] **Beaven, R.P, Woodman, N. and Barker, J.** (2005) End-member flushing models for 'saturated' waste *Proceedings Sardinia 2005, S. Margherita di Pula, Cagliari*
[2] **Beaven, R.P. & Barker, J.A.** (2010) Scientific and management concepts in landfill flushing, *Proceedings of Waste 2010, Stratford-upon-Avon*
[3] **Rosqvist, N. H., & Destouni, D.** (2000) Solute transport through preferential pathways in municipal solid waste, *Journal of Contaminant Hydrology 46, 46*, 39-60