Evaluating echo tests as a contaminant transport characterisation tool

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Introduction

Accelerating the remediation of landfilled 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 contaminant flushing, discussed by Beaven *et al*. (2005), are those which act as controls on flow and transport. These may 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.

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 short period of time, pumped back out of the same well (e.g. Lessof & Konikow, 1997). By simulating the concentration of the tracer as it is abstracted, 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 tests at a given landfill will enable a picture of transport variability within a site to be built up. This information can then be used to help inform the design of a remediation strategy.

7 tests were carried out at four different landfills in the UK. The tests were carried out at different scales, using a mix of tracers to examine the effect and significance of scaling and waste heterogeneity. Details of the tests are given in Table 1.

Results and Analysis

A 1D model, DP-PULSE has been fitted to concentration versus time data for each of the tracer recovery curves by minimising the sum of square errors between the data and the model. Further details of the mathematical and model representation of dual porosity systems and its practical application to different landfill flushing scenarios, is discussed in Beaven & Barker (2010).

Within the model, the formation is assumed to conform to a double-porosity medium, characterized by a time (t_{cf}) and a porosity ratio (σ) where t_{cf} is a characteristic time for diffusion in a region of the same volume as the mobile region of the formation and σ is the ratio of the immobile and mobile porosities. Using these two parameters, the block diffusion time, t_{cb}, can also be derived. The code can fit up to four parameters: t_{cf}, σ, C_b and V, where C_b is the background (i.e. prior) solute concentration which is assumed to be constant throughout the waste (in both mobile and immobile water) and V is the effective well volume (assuming that the well is a mixing cell), which may differ from the internal well volume. Fitted and derived parameters are given in Table 1.

The transport parameters σ and t_{cf} are relatively consistent between tests, with averages (and SDs) of 8.2 (5) and 14.7 (32) hours respectively. σ falls within the range 4.2-17.5 and t_{cf} was in the range 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 (i.e. the volume of tracer injected). The data possibly show an underlying power-law relationship relating the spatial scale of the test to t_{cb}. If verified, this scaling relationship would allow affordable small-scale tests to be useful in predicting larger scale flushing operations.

Echo tests are potentially of value in characterising landfill flushing behaviour because they are a relatively rapid way to characterise horizontal transport. As well as informing design for flushing by injection and withdrawal at individual wells, the processes and parameters thereby established might also be applicable to horizontal flushing models (e.g. between lines of wells or dipoles). The tests are relatively inexpensive and simple to perform, and produce immediate measurements which can be taken by in situ probes and logged automatically.
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Table 1. Echo test and tracer information

Test No.	Site No.	Waste + Saturated Depth (m)	Tracer Type	Volume 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

*Tests performed in the same well

References

Beaven, R.P, Woodman, N. and Barker, J. (2005) End-member flushing models for 'saturated' waste *Proceedings Sardinia 2005, S. Margherita di Pula, Cagliari, Italy*

Beaven, R.P. & Barker, J.A. (2010) Scientific and management concepts in landfill flushing, *Proceedings of Waste 2010, Stratford-upon-Avon*

Lessof, S. C. & Konikow, L. F. (1997) Ambiguity in measuring matrix diffusion with single-well injection/recovery tracer tests, *Ground water, 35, p166-176*