Science Project: Contaminant fluxes from hydraulic containment landfills
Summary SC0310/S

Hydraulic containment is the practice of operating a landfill with a lower leachate level than the external groundwater head. The hydraulic gradient into the landfill therefore causes groundwater to enter the landfill, and prevents advective movement of leachate, and therefore contaminants, from the waste into groundwater. However, there remains potential for contaminants to diffuse out of the landfill, especially since the advective velocities permitted through low permeability liners are low. In 2001 it was estimated that there were between 40 and 50 such landfills in the UK.

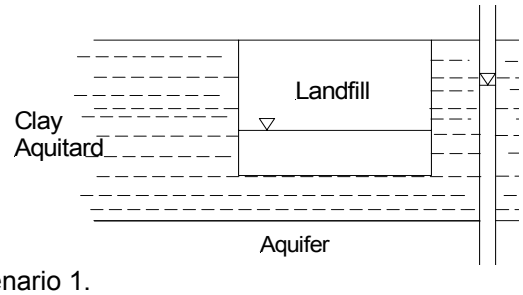
This report has been written to contribute to the understanding of the significance of contaminant diffusion across landfill liners, particularly liners in sites operated using hydraulic containment. It is not a design manual for hydraulic containment landfills and does not advocate the construction of such sites. The report, and accompanying spreadsheet tool, may be used to aid decision-making for landfill risk assessments within the framework set out in the Environment Agency's guidance on *Hydrogeological Risk Assessments for Landfills*.

The report contains a literature review relating to diffusion across mineral liners and other low permeability materials used in landfill basal and sidewall liners and artificially established geological barriers. The report presents a list to illustrate the range of values for certain key parameters for the hydrogeological risk assessment of hydraulic containment landfills; this is not intended as a database of acceptable values for any specific risk assessment since values obtained from detailed site-specific or laboratory investigation will always be preferred for UK hydrogeological risk assessments.

The literature review firstly discusses the various types of landfill lining system that have been used in UK hydraulic containment landfills, particularly issues regarding delamination of composite liners under such conditions. Diffusion and other solute transport processes that occur in porous media are described with particular reference to their role in solute transport within low permeability mineral (e.g. clay) barriers. Solute transport through composite liners is also discussed, including transport through defects and intact geomembrane.

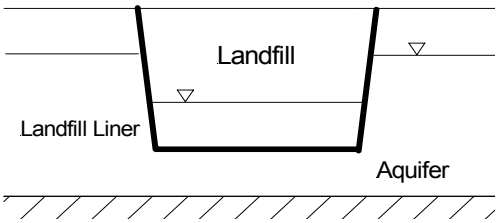
A spreadsheet tool has been developed to help assess the impact on groundwater of landfills operated under hydraulic containment. It computes diffusive fluxes from hydraulic containment landfills for the following three scenarios. Landfills corresponding to these scenarios may not be compliant with the Landfill Regulations, but it should be noted that these scenarios have been created to allow the spreadsheet tool to support the assessment of existing, as well as new landfill cells.

Scenario 1: A landfill without an artificial sealing liner, but which has been excavated in a low permeability clay stratum above a confined aquifer. This can also be used as a conservative approximation to simulate a new landfill site with an artificially constructed clay liner and *in situ* geological barrier by consideration of each component alone.



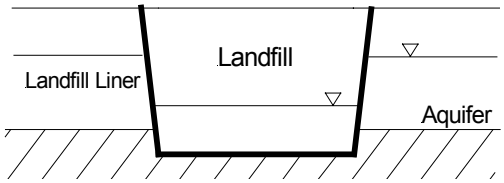
Scenario 1.

Scenario 2: A landfill with an artificially formed geological barrier and artificial sealing liner (e.g. geomembrane composite, compacted clay or geosynthetic clay liner) constructed wholly within a permeable formation.



Scenario 2.

Scenario 3: A landfill with an artificially formed geological barrier and artificial sealing liner (e.g. geomembrane composite, compacted clay, geosynthetic clay liner) constructed in a permeable formation but with a low permeability base.



Scenario 3.

The spreadsheet model is a scoping tool that computes diffusive contaminant fluxes from hydraulic containment landfills, and their concentrations in groundwater (or pore water at the outer edge of the liner for List I substances). It is pre-configured to use landfill geometries that comply with the three scenarios described above. Diffusion, dispersion, retardation and decay processes can be modelled where appropriate.

A user manual has been compiled that explains how to use the spreadsheet model, and how to interpret the results. Two key aspects of the performance of hydraulically contained landfills are predicted by the spreadsheet for typical parameters. These are summarised below:

- In landfills with mineral liners a balance is struck between the water flux into the landfill and contaminant concentrations outside the landfills. As the hydraulic conductivity of the liner is decreased, the water flux decreases, but so does the inward velocity. Hence, for a given effective diffusivity, solutes can more readily diffuse through clay liners with the lowest hydraulic conductivities since the advective flux of water into the site is decreased. Conversely, as the hydraulic conductivity of the liner increases, increased advective flux will lead to greater volumes of leachate being generated.
- Organic contaminants relatively readily diffuse through polymer geomembrane liners. Advective flow within a zone of influence beneath defects can limit the concentration at the base of the mineral liner. However, beneath intact geomembrane away from the defects, pore water is immobile and the contaminant diffuses through the mineral liner. Therefore, given appropriate transport properties, organic compounds can diffuse through a composite liner with a defect-free geomembrane more readily than through one with many defects.

The results of the literature review and spreadsheet calculations confirm that diffusion can cause significant flux of contaminants out of landfill sites, even against an inward advective flow of groundwater. Hydraulic containment landfills therefore have the potential to cause pollution if they are not designed, constructed and operated in an appropriate manner.

This report, and the accompanying spreadsheet model, will help Environment Agency staff, landfill operators and consultants to assess the impact of new and existing hydraulic containment landfill sites on groundwater quality.

This Summary relates to information from Science Project SC0310 reported in detail in the following output(s):-

Science Report SC0310/SR
Contaminant fluxes from hydraulic containment landfills – a review

ISBN Number 1844323153 **September 2004**
Product Code: SCHO0904BHXX-E-P

Internal Status: Released to Regions
External Status: Released to Public

Project Managers
Heather MacLeod & Dr Hugh Potter, Science Group

Research Contractor
Environmental Simulations International Ltd,
Shrewsbury. www.esinternational.com

This project was funded by our Science Group, which provides scientific knowledge, tools and techniques to enable us to protect and manage the environment as effectively as possible.

Further copies of this and the above report are available from our National Customer Contact Centre by emailing enquiries@environment-agency.gov.uk or by telephoning 08708 506506.