Environment Agency

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Attenuation of organic contaminants in leachate by mineral landfill liners

Science Summary SC020039-5/SS

A new report by the Environment Agency explores the adsorption and breakdown of organic pollutants typically found in UK landfill leachates as they pass through the materials commonly used to seal landfill sites and protect the underlying groundwater.

This research project, commissioned by the Environment Agency and carried out by the University of Southampton, looks at the attenuation of trace organic contaminants in landfill liners. This work will help us to improve landfill risk assessments and ensure appropriate environmental control measures at landfills.

Modern landfills are constructed with basal liner systems designed to restrict the release of pollutants to the surrounding environment. In accordance with the requirements of the Landfill Directive, these systems generally include a synthetic liner underlain by a mineral layer and a geological barrier. These liner systems act by reducing the flow of leachate from the site, with the mineral component of the liner and the geological barrier also lowering concentrations of migrating contaminants by attenuation processes such as sorption and biodegradation. However, the attenuation of organic contaminants within landfill liner systems is still poorly understood.

This project carried out a series of laboratory experiments to investigate the potential for sorption and biodegradation of organic contaminants typically found in UK landfill leachates by materials commonly used for the mineral component of liners and geological barriers (London Clay, Mercia Mudstone, Oxford Clay). In particular, the project studied Mecoprop, a herbicide commonly found in landfill leachates in the UK. Other hydrophobic organic compounds studied included naphthalene, toluene, trichlorobenzene (TCB) and trichloroethene (TCE).

The report summarises the results of the experimental programme and highlights key issues for groundwater risk assessment at landfills.

The report will be of interest to industry, regulators and academics, and may lead to better risk assessments at landfills, and hence better inform the regulation of landfills. The main results and conclusions of the research project are summarised as follows.

The experimental programme produced sorption coefficients for a range of contaminants and mineral liner materials which were often significantly different to values found in the literature. For example, sorption coefficients for Mecoprop on Oxford Clay and London Clay were three to six times greater than the maximum literature values for soils and 20 to 40 times greater than the literature values for aquifers. Sorption tests carried out on columns of mineral liner materials (a test considered to be more representative of conditions in the field) gave sorption coefficients for Mecoprop 30 per cent lower than the values found in batch tests. Furthermore, the empirical models that are often used to predict the sorption capacity of mineral liners based on the amount of natural organic matter in the liner, did not work well for all the liner materials tested. In particular, the models underestimated the actual sorption capacity of Oxford Clay, and slightly overestimated that of Mercia Mudstone. Mechanisms to explain these variations in the performance of the mineral liner materials are suggested, in particular, those based on the type (age, structure and so on) of natural organic carbon.

Tests were carried out to establish the importance of the presence of dissolved organic carbon (DOC) in leachate, using tannic acid as a surrogate for real dissolved organic carbon in batch sorption tests. The presence of tannic acid in leachate decreased the sorption of TCB and naphthalene by Oxford Clay. The effect on Mecoprop was less pronounced.

Sorption of Mecoprop, naphthalene and TCE was reversible on all clays, whereas a small fraction of the toluene and TCB sorbed by London Clay and Oxford Clay was irreversibly bound to the mineral liner material.

No evidence of anaerobic biodegradation of Mecoprop was found in any of the tests which were carried out under anaerobic conditions such as are generally found in and beneath landfills. Biodegradation of the hydrophobic organic compounds was found to be highly dependent on the bacterial population used to seed the experiments. In initial tests using synthetic leachate and a bacterial seed cultured from leachate obtained from a UK landfill known to contain a range of List I (hazardous) substances, no biodegradation of hydrophobic organic compounds was found over a period of eight months, although there was an active bacterial population producing biogas from alternative carbon sources.

However, in tests using real leachate containing a bacterial population obtained from a landfill known to biodegrade tetrachloroethene (PCE), biodegradation of TCE, toluene and TCB was observed. When this same seed was added to the synthetic leachate tests, biodegradation of TCE was also observed, albeit at a slower rate.

The results suggest that biodegradation of certain organic contaminants is possible under anaerobic conditions. However, the characteristics and activity of the bacterial community in the specific leachate are critically important in determining which contaminants are degraded. Therefore, this study cannot definitively conclude that Mecoprop or naphthalene do not degrade under anaerobic conditions in landfill liner systems.

A series of LandSim models was run to compare the effect of using retardation values selected from the literature with experimentally derived values for different mineral liner materials. LandSim is the Environment Agency's preferred model for carrying out groundwater risk assessments at landfill sites. Significant differences in predicted time of arrival and peak concentrations of List I (hazardous) contaminants at various compliance points were found, indicating the importance of using site-specific sorption data wherever possible. In particular, it is suggested that more account should be taken of the influence on sorption coefficients of the type of organic matter in mineral liners. Relying on literature values or empirical correlations to estimate sorption coefficients (and hence retardation) for predictive modelling may not give an accurate assessment of the risk of pollution. This project has shown that retardation may be over- or underestimated.

The report recommends further research, particularly on the fundamental mechanisms by which the composition of solid phase organic matter in mineral liners and geological barriers can affect sorption/desorption of hydrophobic organic compounds, and on the sorption mechanism of Mecoprop. Research is also needed to characterise the nature of dissolved organic carbon in leachates and its role in the sorption and transport of organic contaminants.

The experimental work identified differences between results produced from batch and column sorption tests. Further work should compare these two methods in order to provide landfill operators with improved practical methods of estimating sorption coefficients.

Results from the biodegradation tests suggest that biodegradation of organic contaminants in leachate can take place as long as the appropriate microbial community is present. Further work should be carried out to characterise the microbial communities found in leachates and understand the conditions required for removal of contaminants, including Mecoprop.

Finally, whilst biodegradation rates are commonly available for aerobic environments, and for soils and sediments under anaerobic conditions, there remains a lack of data for landfill environments. In particular further work is needed to determine biodegradation rates in mineral liners and geological barriers for a range of contaminants found in landfill leachates.

This summary relates to information from Science Project SC020039/5, reported in detail in the following outputs:

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