

## **Groundwater Response Matrix for Landfills**

### **Background**

Groundwater in Ireland is protected under European Community and national legislation. Local authorities and the Environmental Protection Agency (EPA) have responsibility for enforcing this legislation. The Geological Survey of Ireland (GSI) in conjunction with the Department of Environment and Local Government (DoELG) and the EPA have developed a methodology for the preparation of groundwater protection schemes to assist the statutory authorities and others to meet their responsibility to protect groundwater (DoELG/EPA/GSI, 1999). This methodology incorporates land surface zoning and groundwater protection responses.

These groundwater protection responses are concerned with the site selection process for landfills and the associated design, operation and monitoring of landfill sites. These responses outline the likely acceptability of landfills in each groundwater protection zone (as described in Groundwater Protection Schemes (DoELG/EPA/GSI, 1999)) and the recommended level of response/restriction, which depends on the groundwater vulnerability, the value of the groundwater and the contaminant loading.

In general terms this guidance is for the siting of landfills for non-hazardous wastes. The principles involved may also be applied to the selection process for landfill sites for hazardous and inert waste.

A significant factor in siting all landfills is the protection of groundwater, which is an important resource and source of water supply in Ireland, particularly in rural areas.

The geology and hydrogeology of any region have a major bearing on: (i) the availability of suitable areas for landfill sites; (ii) the level of natural protection for groundwater from contamination by landfill leachate; and (iii) the design, operation and monitoring of landfills.

Groundwater protection schemes, supported by detailed investigations, provide hydrogeological information for landfill site selection. They are used to identify areas where landfills should normally be excluded and areas where they are less likely to pose a risk to groundwater. The groundwater protection responses outlined here require that new landfills should not generally be developed on regionally important aquifers.

Developers of landfills should have regard to both the resource potential and the vulnerability of the underlying and adjacent aquifers. The groundwater protection responses combine both of these factors in a matrix which facilitates rational decisions on the acceptability or otherwise of a landfill from a hydrogeological point of view.

The risk to groundwater from the landfilling of waste is mainly influenced by:

- the nature of the waste;
- the leachate composition;
- the volume of leachate generated;
- the groundwater vulnerability; • the proximity of a groundwater source;
- the value of the groundwater resource;
- the landfill design; and

- the landfill operation and management practices.

In general the pollution risk is greatest in source protection areas and on regionally important aquifers.

The topsoil and subsoil, depending on their type, permeability and thickness, play a critical role in preventing groundwater contamination and mitigating the impact of many potential pollutants. They act as a protecting filtering layer over groundwater.

Guidance presented in these responses should be used to assist in the selection, design and management of landfill sites, and is based on the precautionary principle. The concept of risk management should be used in the decision making process for the selection of new landfill sites.

These groundwater protection responses should be read in conjunction with Groundwater Protection Schemes (DoELG/EPA/GSI, 1999).

### **Landfilling of Waste: a Hazard for Groundwater**

The generation of leachate is one of the main hazards to groundwater from the disposal of waste by landfilling. Good site selection, design and operation assist in minimising the risk of pollution. Leachate from landfills for non-hazardous waste is a highly polluting liquid and its composition is dependent on the nature of the waste within the landfill. The pollution potential can be evaluated by calculating the volume and predicting the composition of leachate that will be generated.

The volume of leachate depends principally on the area of the landfill, the meteorological and hydrogeological factors and the effectiveness of the capping. It is essential that the volume of leachate generated be kept to a minimum. The design and operation of the landfill should ensure that the ingress of groundwater and surface water is minimised and controlled.

Leachate composition varies due to a number of different factors such as the age and type of waste and operational practices at the site.

The conditions within a landfill vary over time from aerobic to anaerobic thus allowing different chemical reactions to take place. Most landfill leachates have high BOD, COD, ammonia, chloride, sodium, potassium, hardness and boron levels. Ammonia is a contaminant which may be used as an indicator of contamination, particularly in terms of surface water, as it can be toxic to fish at low concentrations (1 mg/l). Chloride is a mobile constituent which is often used as an indicator of contamination. The leachate from landfills for non-hazardous waste may produce reducing conditions beneath the landfill, allowing the solution of iron and manganese from the underlying deposits.

Leachates from landfill sites for non-hazardous waste often contain complex organic compounds, chlorinated hydrocarbons and metals at concentrations which pose a threat to groundwater and surface waters. Solvents and other synthetic organic chemicals are a significant hazard, being of environmental significance at very low concentrations and resistant to degradation. Moreover, they may be transformed in some cases into more hazardous compounds.

Landfills have the potential to produce leachate for several hundred years.

### **Groundwater Protection Response Matrix for Landfills**

The reader is referred to the full text in Groundwater Protection Schemes (DoELG/EPA/GSI, 1999) for an explanation of the role of groundwater protection responses in a groundwater protection scheme.

The siting, design, operation and monitoring of landfills must comply with the guidelines outlined in the EPA's Landfill manuals except where such facilities hold a waste licence issued by the EPA. A Waste Licence is required for all landfills.

From the point of view of reducing the risk to groundwater, it is recommended that all landfills be located in, or as near as possible to, the zone in the bottom right hand corner of the matrix. The appropriate response to the risk of groundwater contamination is given by the assigned response category (R) appropriate to each protection zone (Table 1).

**Response Matrix for Landfills**

| VULNERABILITY RATING | SOURCE PROTECTION AREA |                 | RESOURCE PROTECTION<br>Aquifer Category |                 |                       |                 |                   |                 |
|----------------------|------------------------|-----------------|-----------------------------------------|-----------------|-----------------------|-----------------|-------------------|-----------------|
|                      |                        |                 | Regionally Important (R)                |                 | Locally Important (L) |                 | Poor Aquifers (P) |                 |
|                      | Inner                  | Outer           | Rk                                      | Rf/Rg           | Lm/Lg                 | Ll              | Pl                | Pu              |
| <b>Extreme (E)</b>   | R4                     | R4              | R4                                      | R4              | R3 <sup>2</sup>       | R2 <sup>2</sup> | R2 <sup>2</sup>   | R2 <sup>1</sup> |
| <b>High (H)</b>      | R4                     | R4              | R4                                      | R4              | R3 <sup>1</sup>       | R2 <sup>1</sup> | R2 <sup>1</sup>   | R1              |
| <b>Moderate (M)</b>  | R4                     | R4              | R4                                      | R3 <sup>1</sup> | R2 <sup>2</sup>       | R2 <sup>1</sup> | R2 <sup>1</sup>   | R1              |
| <b>Low (L)</b>       | R4                     | R3 <sup>1</sup> | R3 <sup>1</sup>                         | R3 <sup>1</sup> | R1                    | R1              | R1                | R1              |

In all cases standards prescribed in the EPA Landfill Site Design Manual (EPA, 1999) or conditions of a waste licence will apply.

**R1** Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence.

**R2<sup>1</sup>** Acceptable subject to guidance in the EPA Landfill Design Manual or conditions of a waste licence.

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down- gradient of the site and to the projected future development of the aquifer.

**R2<sup>2</sup>** Acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence.

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down- gradient of the site and to the projected future development of the aquifer.
- Groundwater control measures such as cut-off walls or interceptor drains may be necessary to control high water table or the head of leachate may be required to be maintained at a level lower than the water table depending on site conditions.

**R3<sup>1</sup>** Not generally acceptable, unless it can be shown that:

- the groundwater in the aquifer is confined; or

- there will be no significant impact on the groundwater; and
- it is not practicable to find a site in a lower risk area.

**R3<sup>2</sup>** Not generally acceptable, unless it can be shown that:

- there is a minimum consistent thickness of 3 metres of low permeability subsoil present;
- there will be no significant impact on the groundwater; and
- it is not practicable to find a site in a lower risk area.

**R4** Not acceptable.

### **Regionally Important Aquifers**

The siting of landfills on or near regionally important aquifers should only be considered:

- Where the hydraulic gradient (relative to the leachate level at the base of the landfill) is upwards for a substantial proportion of each year (confined aquifer situation).
- Where the proposed landfill is located in the discharge area of an aquifer. In this case surface water may be more at risk.
- Where a map showing a regionally important aquifer includes low permeability zones or units which cannot be delineated using existing geological and hydrogeological information but which can be found by site investigations. Location of a landfill site on such a unit may be acceptable provided leakage to the permeable zones or units is insignificant.
- Where the wastes types are restricted and the waste acceptance procedures employed are in accordance with the criteria specified by the EPA.

### **Investigations**

Special attention should be given to checking for the presence of more permeable zones, such as faults, particularly in fractured bedrock aquifers. Geophysical surveys may be used to identify zones which should be investigated further by drilling to determine their vertical and lateral extent. Hydrogeological tests should also be carried out to define the local and regional effects of the zones. Investigations should be carried out in accordance with the EPA's Landfill Manual Investigations for Landfills, 1995.

### **References**

DoELG/EPA/GSI, 1999. Groundwater Protection Schemes. Department of the Environment and Local Government, Environment Protection Agency and Geological Survey of Ireland.

EPA, 1995. Landfill Manual: Investigations for Landfills. Environmental Protection Agency.

EPA, 1995. Landfill Manual: Landfill Monitoring. Environmental Protection Agency.

EPA, 1997. Landfill Manual: Landfill Operational Practices. Environmental Protection Agency.

EPA, 1999. Landfill Manual: Landfill Site Design. Environmental Protection Agency.