THE GSI GROUNDWATER NEWSLETTER

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IN THIS ISSUE

Landfilling, which is likely to be the principal means of solid waste disposal in Ireland in the short and medium term, is the main topic in this **Newsletter.** Future landfills will be highly engineered and many will be artifically lined. Jim O'Callaghan (page 2) describes the benefits and problems with **flexible membrane liners.** On page 4, Jonathan Derham gives a detailed description of some of the **design requirements of a properly engineered site.** The GSI approach to landfills, which recommends **combining safe geological and hydrogeological situations with liners,** is given on page 6. Michael Rodgers highlights some of the difficulties with locating **landfills on compressible soils** on page 8. Richard Thorn (page 9) takes a European perspective and urges more reduction and recycling of wastes.

Kevin Cullen has produced a useful compilation of **Irish and EC Legislation relating to water quality and wastes** on pages 13 and 14. Any additions or corrections would be appreciated by Kevin and the GSI.

The need for properly conducted **pumping tests** on public supply wells, as an **aid in future groundwater development and protection,** is advocated on page 15.

Wisconsin is a place with many similarities to Ireland - agricultural, geological and hydrogeological. Sara Duffy (page 16) gives a summary of a recent lecture by Dr. Alex Zaporozec on groundwater in Wisconsin.

In recent months, the EC and the Department of the Environment have awarded two **contracts for research on groundwater.** These are outlined on pages 11 and 12.

Responses to any of the items in this **Newsletter** are welcome as are short articles on any groundwater topic. They should reach the GSI before 30th November.

Editor.

FLEXIBLE MEMBRANE LINERS IN LANDFILL SITES

One of the topical waste disposal issues in Ireland is the proposal currently before the European Commission for a Directive on landfilling of waste. The proposed Directive will, if adopted in its present draft format, impose stringent performance criteria on new and existing landfills.

To prevent pollution of soils and groundwater, the geological formations constituting the substratum of the landfill base and sides must comply with minimum permeability and thickness requirements. The specified standard in the draft Directive is a maximum permeability of 1×10^{-9}m/s for a saturated substratum thickness of 3m. Where these conditions are not met naturally it is stipulated that engineering measures must be taken to achieve at least the same level of protection.

Given prevalent geological conditions it is unlikely that the specified requirements will be met "naturally" in many proposed and existing landfills in Ireland. This has prompted the investigation of engineering solutions. A number of artificial sealing systems have been developed and used, apparently successfully, in lining landfills worldwide. In Ireland the one which has attracted most interest and which has actually been installed is the High Density Polyethylene (HDPE) Flexible Membrane Liner (FML).

As a landfill liner, HDPE has the advantage of being tough, good chemical resistance to leachate, is relatively easy to install, and has a very low permeability. Permeability figures given by manufacturers are in the region of 1×10^{-15}m/s However, there are some drawbacks to the use of HDPE. The material has not been in use for sufficient time to permit an accurate assessment of long-term performance. HDPE membranes have been subject to stress cracking.

In the United States, where HDPE membranes have been used extensively, it has been found that rigorous supervision is required during the installation of the HDPE sheeting. Lining sheets must be bonded together which is usually achieved by welding. The weld is a potential weak point. Researchers have found that one defect per 10 m of weld is typical in unsupervised installation[1]. In addition to weld defects the sheeting can be damaged during transportation, site storage and installation. Such damage can result in up to 25 defects per hectare. Estimates of leachate flow rates in m^3/day through defects in a HDPE liner are presented in Table 1.

The implications of such leachate flow rates are obvious. The large number of defects which can occur during installation also raise concerns about the efficiency of the double FML liner system. Recent work for the USEPA found that third party quality control is essential in order to minimise leakage and for liner systems to function as designed[2]. Giroud and Bonaparte found that QA can reduce defects in welds to one per 300m and in the sheeting to 3-5 per hectare.

In the United States the EPA, recognising the potential shortcomings of FML, have specified that the minimum level of safety acceptable for domestic waste landfills is that provided by a composite liner-an FML in direct contact with a low permeability sub-base[4]. The theory is that the sub-base will prevent or attenuate leakages through defects in the FML. As with double liner, research in the UK has found that third party quality assurance on the installation of composite systems is required to obtain maximum performance [3]. Estimated flow rates through composite liners with a single hole defect are given in Table 2.

Given the advantages of HDPE flexible membrane liner it is certain that they will play an increasing role in containment engineering in Ireland. Landfill operators considering their usage should be aware of the potential drawbacks. The level of safety provided by FMLs is enhanced when incorporated into a composite liner system and, most importantly, by the implementation of third party quality control during installation.

It is not the purpose of this article to question the capability of contractors involved in installation of HDPE liners in landfills in Ireland. Reputable contractors recognise the

Table 1

Rates of flow of leachate (m^3/day) through defects in a HDPE membrane liner with groundwater level at or below the underside of the liner

Defect	Hole Diameter (mm)	Depth of Leachate Above Liner 300mm	1m
Pinhole	0.3	0.025	0.084
Hole	2	0.395	0.816
Hole	11.28 (1 sq. cm.)	12.577	22.962

(Thomas, R. 1991)

Table 2

Rates of flow of leachate (m^3/day) through a single defect in composite liners comprising flexible membrane and low permeability soil with groundwater level at or below the underside of the soil liner.

		GOOD CONTACT		POOR CONTACT	
High Conductivity of soil layer m/s	Diameter of hole mm	Depth of Leachate 300mm	1m	Depth of Leachate 300mm	1m.
1×10^{-7}	2	0.063	0.186	0.344	1.016
1×10^{-7}	11.28	0.089	0.262	0.486	1.436
1×10^{-8}	2	0.011	0.034	0.062	0.185
1×10^{-8}	11.28	0.016	0.048	0.088	0.261
1×10^{-9}	2	0.002	0.006	0.012	0.034
1×10^{-9}	11.28	0.003	0.009	0.016	0.048

(Thomas, R. 1991)

need for third party quality assurance and are happy to comply with QA programmes. Whatever the liner system, be it single, double or composite, if it contains an FML component it is critical to insist on a tightly specified QA programme to ensure maximum liner performance.

References

(1) Giroud J.P. and Bonaparte, R. 1989. Leakage through liners constructed with Geomembranes, Geotextiles and Geomembranes Vol. 8.

(2) Bonaparte, R. and Gross, B.A. 1990. Field behaviour of double liner systems, Waste Containment Systems, Geotechnical Publication No. 20 ASCE, New York.

(3) Thomas, R. 1991. Quality Control in Containment Engineering. Institute of Waste Management LXXXI No. 11.

(4) Resource Conservation and Recovery Act 1991. Subtitle D Final Role for Municipal Solid Waste Landfills.

Jim O'Callaghan, WESTON-FTA Ltd.,

THE 90's LANDFILL - A BLUEPRINT

We know of the E.C. Landfill Directive and have, in recent times, become familiar with the new techniques and terminology of waste disposal facility engineering (FML, HDPE, VLDOE, composite, permeabilities etc.).

I do not intend to argue here the advantages or disadvantages of each of the current design formulas i.e. double lined, double composite, mineral only, etc. However, a composite design (mineral liner directly overlain by HDPE), which involves the combination of the chemical stability of HDPE with the self healing ability and robustness of a mineral liner, has in England, as was the case in Germany and the USA, surfaced as one of the most accepted and practicable means to achieve containment. In Greater Manchester composite systems have been the standard of the Waste Regulation Authorities (WRA's) for three years. Approximately ten composite lined facilities have been constructed in this period. Consequently, much experience has been gained. The composite system in these cases extends over the whole of the base of the cell and up to a minimum 2m above the floor of the cell. Side wall containment design varies depending upon the risk factor, internal drainage system and operator preference.
Some designs use an engineered clay wall only, others employ a HDPE FML barrier only. This option for variation is only permitted when certain other engineering works are included in the design.

To simply say lets build it composite is not enough. There are certain basic design requirements which must be fulfilled if this system is to be expected to work to its best potential, provide the necessary assurances and have an acceptable design life.

Formation Level

Must have suitable bearing capacity (min. 90% proctor). Under drainage may be essential if groundwater is considered a problem. This drainage should drain to a limited number of points which could be monitored prior to discharge.

Mineral Liner

For natural clays a minimum 1m of mineral where permeability $\leq 1\times10^{-9}$ m/s. For processed clays (eg. Bentonite) a minimum of 0.5m of mineral where permeability $\leq 1\times10^{-12}$ m/s. In the case of a natural clay liner, it must be placed to within 95% of its maximum dry density. The clay content (< 0.002 mm) must exceed 10%; the liquid limit must not exceed 90 and the plasticity index must not exceed 65 (National Rivers Authority N.W. Region - Earthworks on Landfills Sites, July 1989). The placement of clay liner must be carried out to an appropriate standard (e.g.

Department of Transport Specification Series 600 - Earthworks). The clay surface must not be allowed to become desiccated or over-saturated. Appropriate compaction plant must be used to achieve effective marrying between lifts as well as target density. No drainage etc. should be brought through a mineral seal if at all possible.

Any clay material intended for use in a mineral liner should have the following tests carried out on it in order to demonstrate that it can achieve the above criteria and to establish the optimum conditions for emplacement:

i) natural moisture content;
ii) liquid and plastic limits;
iii) particle size distribution;
iv) density, moisture content compaction relationship;
v) moisture content, degree of compaction (on re-compacted sample) and permeability relationship; and
vi) specific gravity of solid fraction.

With the exception of the permeability tests all the above tests should be carried out on a frequency of c. 1 per 1000m^3 of source material. Permeability tests should be carried out at a frequency of c. 1 per 3000m^3 of source.

Post compaction conformance testing should be carried out on a minimum frequency of c. 1 per 400m^3 of completed liner (e.g. c. 6 samples per 250mm lift per hectare). These samples should be tested for:

i) in-situ density;
ii) moisture content;
iii) liquid and plastic limits; and
iv) particle size distribution.

During the placement works a NTG (Nuclear Test Gauge) (calibrated on pre-testing results) can be used to indicate that the material is approximating its design specification. This allows confident and rapid progression of works pending laboratory confirmation.
These frequencies are only a guide, appropriate modifications should be made where quality and consistency of source material varies or where in-situ clay is to be used to form the seal. In the latter case, a minimum of 3m of sand lens free clay should be established.

Flexible Membrane Liner

Preferably HDPE, and minimum 2mm thick. It must be laid in intimate contact with the mineral liner. All delivered rolls should have appropriate factory certification. The surface of the mineral liner should be smooth and free of all debris likely to cause damage to the FML.

Installation should be carried out by manufacturer-approved installers and in the absence of Government standards the installation specification should equal or exceed the manufacturers installation QA document. (All reputable sheet manufacturers produce such documents). All areas to be welded must be clean and dry, all welds must be 100% tested including destructive tests. Full details of all QC procedures can be found in the aforementioned installation documents.

The installers should accept in writing the surface of the mineral liner as being suitable. Calculations must be made to demonstrate the trench dimensions and fill suitable to anchor the sheet with an appropriate factor of safety.

If leachate chambers are to be built into the site, careful and calculated consideration must be given to any design e.g. load distribution, sacrificial layers of HDPE etc. Pipework penetrating the FML must be avoided.

Samples of the sheet must be taken and submitted to an independent laboratory for confirmatory testing e.g. density, thickness, tensile properties etc.

Folds and scratches must be avoided as these enhance the development of "environmental stress" related failure of the sheet. The FML on completion must be covered with minimum 300mm of protective layer (e.g. sand, silt). This material should be approved in writing by the sheet installers. A heavy grade geotextile could be a suitable alternative, provided it is appropriately tested.

Leachate Collection System

This consists of a full drainage blanket (minimum 250mm thick) with twin walled perforated pipes laid in it. The aggregate/hardcore of the blanket must be fines free as well as being chemically and structurally stable. The permeability of this medium should be no less than 1 x 10^{-4}m/s and it should be able to pass through a 100mm mesh.

The floor of the cell should have a slope no less than 1:50. The leachate collection pipes are laid in minor depressions in the FML protective layer which are lined with a strip of geotextile to stop blinding of the pipes by the FML protective layer. The drainage blanket is then placed over the pipes and FML protective layer.

Where possible the primary leachate collection pipes should plunge at the same angle as the slope of the cell floor. The secondary leachate collection pipes should be laid out in such a manner so as to limit the travel distance of leachate in the blanket to 50m or less before a pipe is intersected. The secondary drains should have a plunge of no less than 1:100.

The leachate collection system detailed above is confined to the base of the site. However, any leachate collection systems should, as far as is possible, be maintainable. Therefore the leachate collection pipes are brought up the inside walls of the cell (with aggregate surround) to the surface in order to permit rodding or jetting. This design also permits ventilation of landfill gas. No geotextile should be used between the waste and drainage blanket. Finally the maximum permitted head of leachate anywhere on the FML is 1m. Monitoring pipes should be located in the wastes remote from the sump and not close to a leachate drain so as to monitor the effectiveness of the system.

Should the liner system ever fail (gradual or catastrophic), it is essential to have an effective leachate collection system which would remove leachate quickly and prevent build up of head on the liner. The above system should provide such assurances.

Construction Quality Assurance

All elements of design work, construction and testing must be assessed, supervised and checked by an independent appropriately qualified consultant. Any method statement from an operator detailing design, methods of construction, pre-testing of materials, etc. must be checked and endorsed by the independent consultants prior to works. The consultants must provide the relevant authority, on completion of the facility, a final validation report for all works.

This "Blueprint" for landfills is not some fanciful regulators dream. In Greater Manchester County today such facilities have and are being built. Should any individual or party be interested in visiting one of these facilities, I would be happy to arrange it. (Contact GSI for address and telephone No.).

Jonathan Derham, Greater Manchester Waste Regulation Authority.

(Jonathan is a geology graduate from UCC. He carried out postgraduate research on bedrock geology at UCG before becoming a Landfill Scientific Officer in Manchester. **Editor**).

GSI APPROACH TO LANDFILL SITE SELECTION

Introduction

Many factors influence the location of landfill sites. However, the geological and hydrogeological aspects are among the most critical - landfills are located on or in geological deposits and groundwater is not only a major resource which must be protected but is a means of transmitting pollutants to wells and surface water. As the national geosciences centre, the Geological Survey of Ireland (GSI) receives many requests for advice and information and is in a unique position to provide recommendations on the geological, hydrogeological and groundwater protection aspects of landfill site selection.

Background Factors

The approach and recommendations of the GSI are influenced by the following factors:

1. Municipal wastes in landfills produce a noxious leachate which can cause significant pollution to water. In particular, the leachate may contain volatile organic carbon (VOC's) constituents, such as solvents, which are highly mobile and can cause pollution of groundwater at very low concentrations - parts per billion.

2. The leachate must be contained on the site and prevented from entering groundwater. The proposed EC Landfill Directive requires a substratum thickness for the landfill base and sides of 3m of material with a maximum permeability coefficient of 1×10^{-9}m/s.

3. In recent years landfilling techniques have improved greatly particularly with the use of artificial liners, such as HDPE (high density polyethylene) and sand-bentonite composite. Although these liners significantly enhance the containment on sites, there are difficulties with their use:

(i) With regard to geomembrane liners Parkinson (1991) states "... it is generally agreed that all such liners leak to some degree". Giroud and Bonaparte (1989) suggest the presence of 2-50 holes per hectare, depending on the quality control, with two-thirds of the holes associated with the seam.

(ii) Depending on artificial and technological methods such as HDPE means reliance on consistent high quality standards of material and installation. This is difficult to ensure.

(iii) The design and installation of a liner system is likely to be undertaken by specific experts in these areas; experts who realise the consequences of leakages and who would be likely to maintain high quality control over the relatively short period of time that the liner is being installed. However, the operation of the site, which lasts for years, is more difficult to control, and ensuring that the liner is not punctured is difficult to achieve.

(iv) Recent research has suggested that although intact HDPE is effectively impermeable to water, it has a reasonable permeation rate for certain chemicals, such as solvents (HAXO and LAHEY, 1988). Also untreated bentonite may be vulnerable to certain landfill leachates.

(v) A liner must be capable of providing containment over the extended period of leachate generation - many decades and probably more than 100 years - in modern containment sites. However, it has been suggested (Mather, 1991) that the long term behaviour of synthetic materials over this time span has not yet been demonstrated, particularly the welds between panels and liner materials.

Approach and Recommendations

1. It is probable that only a small proportion of the country contains rocks with a sufficiently low permeability to meet the requirements of the proposed EC Landfill Directive. Consequently, artificial liners will be necessary in many instances. However, dependence on artificial liners alone to contain leachate creates risks for the environment and to humans.

2. Clayey tills (or boulder clays) and clays (such as lake clays) are the best geological deposits for providing containment and for attenuating pollutants. Peat also has a low permeability and a high cation exchange capacity. However, peatland areas may be difficult to engineer as cover material is not usually present nearby.

3. The optimum area in Ireland is considered to be a greenfield site, underlain by thick low permeability till which in turn is underlain by low permeability bedrock. Artificial liners may or may not be needed depending on the permeability and thickness of the till. The advantages of this situation are as follows:

(i) There are no significant groundwater resources underlying the site and so groundwater is not at risk in the event of liner leakages.

(ii) The pollutants cannot migrate away underground as they would be contained and to some degree at least, attenuated in the clays. If a slight leak occurred through a liner, pollution should be minimal and the risk to the environment would be low. In contrast, if a leak occurred through a liner underlain by sand and gravel or permeable limestone, attenuation would be minimal, pollution would

be likely and the environment is at risk.
(iii) Till can be used as cover material -both for daily and final cover. This helps to reduce litter, birds, rats, fires and leachate.
(iv) The till can be used to build bunds around the waste and around the site, thus helping to control leachate and gas migration and reduce visual intrusion.
(v) The site is more readily defensible.

4. It is recommended that liners should be used as a means of containment only where the geological materials provide some additional containment and protection. Adopting this approach reduces the risks to the environment as far as is practicable and consequently would encourage public confidence in selected sites.

5. Limestone quarries and gravel pits are generally risky sites and are not recommended even when engineered as containment sites, except in exceptional circumstances (e.g. where the gravel is underlain by till).

6. It is recommended that landfill sites should not be located on major aquifers (about 30% of the country) as they pose a significant risk to the groundwater resource.

7. The location of optimum areas and the ranking of areas requires the availability of regional maps and information on the geology and hydrogeology. It is recommended that, as far as practicable, a planned regional approach, rather than site specific approach, should be adopted in the initial stages, preferably as part of a groundwater protection scheme.

8. It is concluded that sound engineering of landfill sites requires the proper assessment and use of the natural geological materials combined with modern technological advances such as liners, in order to reduce the risks to the environment.

The approach and recommendations outlined are based on the experience of GSI staff, the available information on the science and engineering of landfills, and on general principles which are designed to protect groundwater and enable good planning practices.

They are under regular review and consequently the views of waste disposal experts, hydrogeologists and local authority engineers are welcome.

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Mather, J.D. 1991. Current landfill design - a short term engineering solution with a long-term environmental cost. Proceedings of Conference "The Planning and Engineering of Landfills". The Midland Geotechnical Society, Birmingham.
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Donal Daly, Geological Survey of Ireland.

LANDFILL DISPOSAL OF WASTE ON COMPRESSIBLE SOILS

Great care should be exercised in the construction of a waste disposal facility on soft compressible saturated soils which are common in Ireland. The behaviour of these soils is very different to the behaviour of stiff soils under load. The procedures adopted for the construction of a waste disposal facility on stiff soils may not always be suitable for soft compressible saturated soils. The reasons for the non-suitability of these procedures for soft soils include the following:

1. If a low permeability barrier of a clay layer and a synthetic liner are used to prevent leachate from contaminating the groundwater it may also have the effect of preventing drainage of water from the underlying soils. Excess pore water pressure will be generated in the underlying soils as the waste is applied in the facility. Drainage of water from soil causes dissipation of this pressure. Unless there is pore water pressure dissipation there can be no increase in the shear strength of the underlying soils. It could happen that the stresses applied by the waste would exceed the strengths of the soils and barrier leading to a failure. This in turn could lead to a major pollution problem. It would be necessary to analyse the stability of such a construction taking into consideration the strengths and permeabilities of the underlying soils and barrier.

2. The construction of the containment bund or embankment around the landfill site may lead to problems of stability and settlement. These problems are the same problems encountered in the construction of road embankments on these soils.

3. Large strains are common in the compressible soils found in Ireland. Peats can have strains of the order of 40% for a load of 60kN/m2 which is equivalent to 6m of well-compacted waste fill. In order words, a 3m thick layer of peat could settle 1.2m under a 6m high waste fill. These large strains could damage the clay layer and the synthetic liner.

4. If large settlements occur the invert level of the containment facility may be below the water table in the surrounding ground.

The above points along with others would need to be examined in the design and construction of a landfill disposal facility on soft soils.

Michael Rodgers, Department of Civil Engineering, UCG.

TOXIC WASTES IN EUROPE - PARLIAMENT, PEOPLE, POLITICS, PROBLEMS AND POTENTIAL

6 - Potential

Patrick Johnston in the last issue of *The GSI Groundwater Newsletter* spelt out clearly the real costs associated with landfill of wastes, the most widely used method of waste disposal throughout Europe. If, to the cost of operating landfill sites is added the value of much of the "waste" landfilled, then clearly real attempts to recycle, reuse and reduce wastes are needed.

It was estimated in 1984 [1] that between 70% and 80% of all waste residue produced could be reused in one form or another, whereas between 90% and 99% of waste was being destroyed or simply disposed of in tips. In the intervening period little appears to have changed, for example, in the UK only 5% of domestic waste is currently being recycled [2]. There are hopeful signs that attention is being devoted to the potential to reduce, recycle and prevent waste. This is particularly so in the area of industrial waste. The US Congressional Office of Technology Assessment estimated in 1986 that about 50% of industrial waste could be cut through technology available at that stage [3]. A European Parliament Committee [4] in 1989 reported that there was considerable potential for reductions in some hazardous wastes produced in Germany (Table 1).

However, much remains to be done. Although pollution prevention is an old concept, the replacement of the traditional end-of-pipe approach to environmental protection with a strategy that embraces pollution prevention poses considerable threats, uncertainties, new work practices and technical and management challenges, all of which must be tackled. Nonetheless, the enthusiasm with which

Table 1

Potential for the Prevention of Some Hazardous Wastes in Germany

	Amount produced (1983) (1000t)	Reduction (in %) 1989	1999
Waste containing sulphur	2,160	60-65	80
Waste containing oil	490	low	40-50
Varnish and paint waste	250	low	60-70
Organic solvents	313	low-20	60-80
Electroplating waste	190	low	60-70
Salt residues	125	50	100
Remainder	1,342	low	low
Total	4,870	30-35	50-60

In some instances the potential is being realised as is shown in Table 2.

Table 2.

Some Examples of Successful Industrial Waste Reduction

Industry	Method	% Reduction	Payback Time
Photographic processing	Electrolytic recovery, ion exchange, adsorption	85% of developer 95% fixer, silver, solvent	<1.0 year
Leather making	ion-exchange, adsorption	99% of chromium	2.5 years
Paint, coatings	Pneumatic cleaning process	100% of solvent, paint	<1.0 year
Equipment manufacturing	Ultrafiltration	100% of solvent, oil 98% of paint	2.0 years

(Source Reference 3).

recycling and waste reduction initiatives are being embraced by consumers in many parts of the developed world bodes well for the future.

In Ireland, the irony is that while initiatives such as The Recycling 2000 effort in Dublin are being undertaken with some degree of enthusiasm there is at least one local authority that is ceasing refuse collection services, for financial reasons, in rural areas from the end of May 1992 without an alternative being in place.

So not alone is an opportunity being lost to pay more than lip service to the challenges of recycling and reuse but it is likely that the problem of fly tipping will be exacerbated.

1. **European Parliament (1984)** Report of the Committee of Inquiry into the Treatment of Toxic and Dangerous Substances by the European Community and its Member States. Document 1-109/84. PE 89.163/fin. 48pp.

2. **Dumbleton, B. (1991)** Consumer

waste recycling: is it viable? *Pollution Prevention*, 1(7), December, 19-23.
3. **Hirschorn, J.S. (1991)** The technological potential: Industrial pollution prevention. *Pollution Prevention*, 1(1), February, 17-25.
4. **European Parliament Committee on Energy, Research and Technology STOA Project (1989)** Hazardous Waste Management Beyond 1992. English Version. 24pp.

Richard Thorn, Sligo RTC.

VOLATILE ORGANICS STRIDE PROJECT

In association with EOLAS and CSA, K.T. Cullen & Co. Ltd's proposal to undertake the STRIDE project entitled "Trace Organic Contaminants in Irish Groundwater" has been selected and approved by the DOE. The project commenced on August 1st, 1992 and will span one year to completion.

The term "organic contaminants" comprises all water-soluble volatile organic compounds which are either non-naturally occurring or are present in non-naturally occurring concentrations. "Trace" refers to concentrations up to an upper solubility limit of approximately 5000 mg/l (ppm). By simplistic definition "groundwater" encompasses all naturally-occurring water below the land surface.

Irish groundwaters are threatened by numerous organic contaminants both of a point and diffuse nature. Petrol, diesel, fuel oil, pesticides, herbicides, solvents, dry cleaning compounds, paint, timber preservatives, dyes, process chemicals, leachates, and effluents name but a few of the substances composed of volatile organic compounds. Potential sources of these contaminants are widely distributed in Ireland and are for the most part unmonitored. A list of such potential sources would include the following: petrol stations, diesel tanks (including home heating oil), fuel oil depots, landfills, chemical and pharmaceutical plants, agricultural practices, auto service stations, paint (body) shops, dry cleaners, road and rail networks, tanneries, aquaculture, waste treatment facilities, and timber treatment plants.

The presence of volatile organic compounds can render the quality of groundwater below a potable standard. Human and/or animal ingestion of trace organic-contaminated groundwater can result in symptoms of acute or chronic toxicity; in addition many compounds such as benzene, anthracene, pyrene, and bromochloroforms (trihalomethanes) are designated carcinogens and bioaccumulative in living tissue.

The objectives of this project are to *identify, quantify, and determine the incidence of trace* organic compounds in Irish groundwaters. The initial phase consists of three simultaneous desk studies conducted in order to determine the controlling chemical, analytical, and hydrogeological parameters respectively. Once these parameters have been established it is intended to undertake two field investigations: a pilot study of a specific aquifer; and a representative nationwide study of trace organics in all of the major aquifers. The project will culminate in the production of a report documenting the entire research project and presenting its findings and conclusions.

From experience of groundwater quality in Ireland it is anticipated that the conclusion of this investigation will be that trace organic contaminants will not be present in the majority of the major and minor aquifers in Ireland. However it is further anticipated that specifically vulnerable areas where intensive agriculture, fuel storage, industrial activity, waste disposal, and/or other such activities, are taking place will show a localised incidence of trace organic contamination.

Shane M. Bennet, K.T. Cullen & Co. Ltd.

EC/DOE STRIDE CONTRACT AWARDED FOR GROUNDWATER PROTECTION STUDIES IN THE WEST OF IRELAND

A syndicate consisting of Sligo RTC, the Geological Survey of Ireland (GSI), Trinity College Dublin (TCD) (Environmental Sciences Unit, Natural Resources Development Centre and the Department of Civil, Structural and Environmental Engineering), Galway, Mayo and Roscommon County Councils and the Regional Laboratory in Castlebar has recently been awarded a research contract to undertake groundwater studies in the west of Ireland.

The project, which will be coordinated at Sligo RTC, will update the aquifer protection scheme for County Galway, completed in 1985 by the GSI, will complete the scheme for Mayo, prepared in draft form by the GSI and Sligo RTC in 1990 and will prepare a scheme for Roscommon. The schemes will be prepared using both AutoCad facilities and Geographic Information System (GIS) technology.

In addition to the preparation of the aquifer protection schemes the project will carry out detailed groundwater vulnerability investigations at 12 to 15 groundwater sources in the three counties, will attempt to relate water quality variability to aquifer vulnerability and will undertake well head protection area studies involving modelling pollutant transport in groundwater and in the overlying unconsolidated deposits.

The total research contract is worth £244,000 and will run from August 1992 to early 1994. The project will employ four research students/research assistants.

Richard Thorn, Sligo RTC.

HARDNESS OR SCALE INHIBITORS: HOW WELL DO THEY WORK?

In recent years hardness or scale inhibitors have been marketed as installations which prevent scale from forming in areas of hard water - areas that cover much of the country. These inhibitors,as their name suggests, do not remove the hardness but prevent precipitation of lime scale.

Consequently, they are cheaper than softeners, require no maintenance or chemical replenishment and maintain the benefits and taste of drinking hard water.

How successful are they? Do they always work? If you have any experiences or knowledge which would answer these questions, please write in to the **Newsletter.**

Donal Daly, Geological Survey of Ireland.

Irish & Community Legislation
Relating To Water Quality (August 1992)

Year of Implementation	General Title	Reference Number
1942	**Water Supplies Act**	**No. 1 of 1942**
1977	**Local Government (Water Pollution) Act**	**No. 1 of 1977**
1978	Regulations	SI No. 108 of 1978
	(Transfer of Appeals) Order, 1978	SI No. 96 of 1978
1983	(Transfer of Appeals) Order, 1978 (Amendment Order, 1983)	SI No. 37 of 1983
1985	(Control of Cadmium Discharges) Regulations	SI No. 294 of 1985
1985	(Fees) Regulations	SI No. 115 of 1985
1986	(Control of Hexachlorocyclohexane and Mercury Discharges) Regulations	SI No. 55 of 1986
1990	**Local Government (Water Pollution) (Amendment) Act, 1990.**	**No. 21 of 1990**
1975	**Council Directive on the Quality of Surface Water for Human Consumption**	**75/440/EEC**
1989	(See Council Directive 79/869/EEC below)	SI No. 294 of 1989
1975	**Council Directive Concerning the Quality of Bathing Water**	**76/160/EEC**
1988	(Quality of Bathing Water) Regulations	SI No. 84 of 1988
1988	(Quality of Bathing Water) (Amendment) Regulations	SI No. 99 of 1989
1976	**Council Directive on Pollution of the Aquatic Environment**	**76/464/EEC**
1978	**Council Directive on the Quality of Fresh Waters to Support Fish Life**	**78/659/EEC**
1988	(Quality of Salmon Waters) Regulations	SI No. 293 of 1988
1979	**Council Directive on Sampling of Surface Water for Human Consumption**	**79/869/EEC**
1989	(Quality of Surface Water Intended for Drinking Water) Regulations	SI No. 294 of 1989
1979	**Council Directive on the Quality Required for Shell Fish Waters**	**79/923EEC**
1979	**Council Directive on Groundwater Protection**	**80/68/EEC**
1980	**Council Directive on Natural Mineral Waters**	**80/777/EEC**
1986	(Natural Mineral Water) Regulations	SI No. 11 of 1986
1980	**Council Directive on Quality of Water for Human Consumption**	**80/778/EEC**
	(Quality of Water Intended for Human Consumption) Regulations	SI No. 81 of 1988
1982	**Council Directive on Mercury Discharges**	**82/176/EEC**
1983	**Council Directive on Cadmium Discharges**	**83/513/EEC**
1986	**Council Directive on Discharges of Certain List 1 Substances**	**86/280/EEC**
1987	**Council Directive on Nitrates from Agricultural Sources**	**91/626/EEC**

Irish & Community Legislation Relating to Waste (August 1992)

Year of Implementation	General Title	Reference Number
1878	**Public Health (Ireland) Act**	——
1981	**Dumping at Sea**	No. 8 of 1981
1982	**Litter Act**	No. 11 of 1982
1967	**Council Directive on Classification, Packaging & Labelling of Dangerous Substances**	67/548/EEC
1979	(Dangerous Substances)(Classification, Packaging & Labelling) Regulations	SI No. 383 of 1979
1988	(Dangerous Substances)(Classification, Packaging & Labelling) (Amendment) Regul.	SI No. 47 of 1988
1989	(Dangerous Substances)(Classification, Packaging & Labelling) (Amendment) Regul.	SI No. 228 of 1989
1975	**Council Directive on the Disposal of Waste Oils**	75/439/EEC
1984	(Waste Oils) Regulations	SI No. 107 of 1984
1975	**Council Directive on Waste**	75/442/EEC
1979	(Waste) Regulations	SI No. 390 of 1979
1991	Amending Directive	91/156/EEC
1976	**Council Directive on the Disposal of PCB's**	76/403/EEC
1984	(Waste) Regulations	SI No. 108 of 1984
1978	**Council Directive on Toxic & Dangerous Waste**	78/319/EEC
	(Toxic & Dangerous Waste) Regulations	SI No. 33 of 1982
1978	**Council Directive on Waste from the Titanium Dioxide Industry**	78/176/EEC
1983	Amending Directive	83/29/EEC
1984	**Council Directive on the Transfrontier Shipment of Hazardous Waste**	84/631/EEC
1986	Amending Directive	85/469/EEC
1986	Amending Directive	86/279/EEC
1985	Amending Directive	87/112/EEC
1988	(Transfrontier Shipment of Hazardous Waste) Regulations	SI No. 248 of 1988
1987	**Council Directive on Environmental Pollution by Asbestos**	87/217/EEC
1990	(Asbestos Waste) Regulations	SI No. 30 of 1990
1986	**Council Directive on Sewage Sludge in Agriculture**	86/278/EEC
1991	(Use of Sewage Sludge in Agriculture) Regulations	SI No. 183 of 1991
1989	**Council Directive on Emissions from New Waste Incineration Plants**	89/369/EEC
1989	**Council Directive on Emissions from Waste Incineration Plants**	84/429/EEC
1990	**Council Directive on the Disposal of Animal Waste**	90/425/EEC
1990	**Council Directive on the Disposal of Animal Waste** Amending Directive	90/667/EEC
1991	**Council Directive Concerning Urban Waste Water Treatment**	91/271/EEC
1991	**Council Directive on Hazardous Waste**	91/689/EEC
1991	**Council Directive on Batteries containing Dangerous Substances**	91/157/EEC

Compiled by Kevin Cullen, Consulting Hydrogeologist.

FUTURE GROUNDWATER DEVELOPMENT: THE NEED FOR PROPER PUMPING TESTS

In recent years, the development of groundwater resources in Ireland has expanded. The standards of drilling and assessments of groundwater resources have improved considerably. For instance, geophysical surveys are now a common exploration tool in locating optimum sites; exploration drilling and testing is usual before local authorities decide whether to use surface water or groundwater; well designed boreholes often involving the installation of screens is now the norm; and source protection schemes are increasingly being prepared. However there is one vital aspect that needs improving in my view. At present the standard of pumping tests on most wells is poor. Seldom are sufficient data collected to enable the aquifer coefficients - transmissivity (T) and specific yield (S) - to be calculated. Step tests are rarely carried out. The drilling and use of observation wells is not common. Consequently we have few values on the transmissivities and specific yields of our major aquifers.

Properly conducted pumping tests which involve the calculation of T and S enable:

(i) Scientific predictions on well efficiency, optimum pumping rates, drawdowns at different pumping rates, the long term viability of the source, and effects on nearby wells and springs;

(ii) A more scientific and quantitive approach to delineation of source (well or spring) protection zones.

Groundwater protection policies are becoming an essential part of decision making on the location of potentially polluting developments and in the prevention of pollution. Designation of source protection zones using arbitrary fixed radii eg. 300m and 1000m, is a good first step but does not include hydrogeological or contaminant transport considerations. In the next few years a more scientific approach using vulnerability mapping, analytical equations and even numerical modelling will become necessary. These are not possible without the parameters - T and S - provided by properly conducted pumping tests. Further information on these tests can be obtained by contacting the GSI.

Donal Daly, Geological Survey of Ireland.

REVIEW

Paper: **The use of sodium bentonite in landfill liners**
Author: Robert Trauger
Publication: Water Technology International 1992. Century Press London

Composite liners, composed of both natural bentonite and synthetic barrier liners, are likely to be the preferred future landfill liner systems. The geomembrane has an extremely low permeability, but is subject to leakage due to punctures or seaming flaws. Conversely, a bentonite liner is far less likely to incur puncture damage because of either its thickness or its swelling/sealing capability. However bentonite liners are subject to leakage due to flow through preferential flow paths. The natural and synthetic components of the liner can work synergistically to decrease the overall liner leakage by a factor greater than if considered separately.

This paper provides a good summary of the origin of bentonite, its desirable engineering properties, and the use of bentonite geocomposite liners. If you want a copy contact me at the GSI.

Donal Daly, Geological Survey of Ireland.

LECTURE

"The Protection and Management of Groundwater in Wisconsin"
by Dr. Alexander Zaporozec, Wisconsin Geological Survey, at GSI, 10th March, 1992.

Wisconsin is often called the Dairy State of America due to its intensive agricultural activities. It also has a strong tourism tradition as there are 15,000 lakes in the state and many forests, especially towards the north. The State consists of 72 counties. It's mean annual temperature is 6°C and there is about 700mm precipitation each year mainly from snow. The bedrock geology of the state consists of four main lithologies: Pre Cambrian rocks; Cambrian sandstones, shale and dolomites; Ordovician dolomites; and Silurian shales.

A layer of unconsolidated material up to 92m thick covers most of the State and provides good protection to its groundwater except in the centre where the overburden cover is thin. Three main aquifers underlie the State - unconsolidated sands and gravels, dolomites and sandstones

Groundwater supplies about 50% of the public water requirements. 70% of the private supplies are from groundwater with 98% of rural and 68% of urban private supplies obtained from groundwater.

In 1934 Wisconsin became one of the first States in America to monitor groundwater levels. There are 195 observation wells at present and they are mostly monitored weekly. They have 41-50 years of data.

In 1981 the monitoring network was reviewed and examined under six criteria: density; hydrogeology; characters of fluctuation (e.g. weather) length and continuity of record; frequency of measurement; and well construction and documentation.

Key monitoring stations were developed for each main aquifer for continous measurements.

There are three common problems associated with the quality of Wisconsin's groundwater.

- Hardness - quite high in most areas ($>100mg/lCaCO_3$)
- Iron and manganese; and
- Nitrates and pollution due to the use of pesticides and herbicides in agriculture.

The first pesticides were detected in Wisconsin's groundwater about 10 years ago and recently up to 21 different types of pesticides have been detected in water samples. There is also some concern about water from deeper wells in the southeast of the State as there is natural radioactivity in the rock.

The main nitrate sources are septic tank and farmyard effluent. There are also a large number of landfills in the State.

Also, the construction of the well itself can lead to groundwater contamination mainly through an inadequate seal at the top of the borehole.

In 1994 it will become mandatory to have petrol stations investigated and leak detection systems must be installed with all the petrol tanks.

Several laws govern the state as regards groundwater, one of the most important being the 1971 updated "Well Construction Code" which states that to bore a well, a licence must be obtained through registration with the Department of Natural Resources. This licence must be renewed on a regular basis.

A groundwater co-ordinating council, which consists of representatives from six agencies, comes together for regular meetings and also to raise funds for groundwater research projects carried out in the Universities.

Interesting points were raised during the talk such as the fact that permits are needed for the installation of septic tanks and the county sanitarian is present at each installation to make sure procedures are correctly followed.

Sara Duffy, Department of Engineering Hydrology, U.C.G.

NEW PUBLICATIONS

"Irish Farming, Weather and Environment".
Edited by Tom Keane. Produced by AGMET Group and published by Teagasc, 19 Sandymount Avenue, Dublin 4.

Farming will always be a core activity of the Irish economy as well as being an important component of the social fabric of the country. Our interest in weather reflects the central importance the Irish Climate plays in this regard. Because weather is an integral component of farming we need to be able to manage it better.

A new book entitled "Irish Farming, Weather and Environment" sets out to provide the general reader and student alike with an easy to read book on weather and the Irish Climate and its role in agriculture. The layout and structure of this book ensures that readers are attracted to the topic. In the process they acquire a greater knowledge of the subject and learn how cognisance is taken of both weather and climate in everyday farming.

The book can be divided into two sections. The first seven chapters prepare the ground work and describe the various climatologies of the major weather elements as they affect Ireland such as precipitation, temperature, sunshine and radiation, wind and evaporation. Comparisons are made with the climate of EC Europe. Weather forecasting and the interpretation of forecasts are also treated.

The second part of the book is devoted to the application of the new found knowledge to a range of farming systems. Soil-weather interactions important to farming are the subject of a central chapter in the book. Crops (roots, cereals, horticulture, forestry) and their diseases, animals and their diseases, are governed by a number of environmental factors. The timing of farming activities such as tilling, sowing, spreading fertilizers, herbicides and pesticides, harvesting and many other farming activities are regulated by the weather and climate.

Each enterprise is given an expert and practical treatment in the book. Liberal use is made of coloured highlighting, diagrams and maps.

This book of 16 chapters (216 + xii pages) has been written by a wide range of experts from Teagasc and educational colleges as well as the Meteorological Service. Preceding each chapter there is a synopsis of the content covered in the chapter as an aid to the general reader. At the end of each chapter is a series of multiple choice questions, which should stimulate the study of the subject. The book is ideally suited to both the practising farmer and related disciplines. It is also intended for those pursuing courses in agriculture, hydrology, biology, geography, environmental studies, etc.

Price IR£10 plus IR£2 packing and postage payable to Teagasc.

"Weather, Soils and Pollution". Compiled by Marie Sherwood. This is another excellent publication by the AGMET Group. The booklet summarizes a good deal of information useful to those involved in agriculture, water pollution control and planning amongst others. The map provided in the booklet entitled "Runoff risk Categories for Soils", will have many applications.

Price £2.50 postage 50p. It is available from the AGMET Group, c/o The Meteorological Service, Glasnevin Hill, Dublin 9.