

APPENDIX 3

The Marine Discharge of Treated Leachate [TOBIN, 2007]

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1. INTRODUCTION AND BACKGROUND

At present, as a condition of the landfill licence issued by the EPA for Derrinumera (Licence No. W0021-01), leachate is transported by tanker from Derrinumera Landfill to Castlebar WWTP for treatment in combination with the municipal wastewater received there. An Bord Pleanála, in certifying the EIS for expansion of the Castlebar WWTP, has made it a condition of such expansion that the importation of leachate there is discontinued when the new Castlebar WWTP is in place.

It will be prohibited to bring leachate to the expanded and upgraded WWTP, therefore, following best environmental practice, it has been considered that the treatment of leachate should be conducted at the source. For this reason Mayo County Council wish to include leachate treatment in the scope of the Derrinumera Waste Licence Review, in preparation for compliance with an An Bord Pleanála instruction to cease leachate imports to Castlebar WWTP. Part three of the Schedule attached to the An Bord Pleanála Certification of the expansion and upgrade of the Castlebar WWTP, issued on the 21st November 2001, stated:

"No sewage sludge or landfill leachate from outside the expanded Castlebar Waste Water Treatment Plant shall be transported onto the site for processing at this location having regard to the limited assimilative capacity of the Rivers system relative to the likely demands arising from within the Castlebar area."

Once the leachate is treated (in accordance with the discharge standards as will be specified by the Environmental Protection Agency) it will need to be discharged to the receiving environment. There are three theoretical options, 1) discharge to groundwater, 2) discharge to the Glaishty River, and 3) discharge to the nearest coastal waters (i.e. Newport). Option 1 is not considered appropriate due to the volumes being generated (maximum volume of leachate production expected to peak at 700 m³ per day, maximum discharge from LTF to be restricted to 500 m³ per day). Option 2 is not considered as appropriate due to the very low flow conditions in the Glaishty River. Option 3 is the best alternative solution and has been demonstrated in the Newport Sewerage Scheme Environmental Impact Statement to be an environmentally sustainable option. The preferred option therefore is to treat leachate on site, and to deliver the treated leachate to the proposed marine outfall discharge location for treated municipal wastewater at Newport via a pumped rising main on the selected route as shown on Drawing No. 1908-2200, Volume III.

An assessment of the issues arising from the above proposal has been undertaken by TOBIN Consulting Engineers, in order to establish the environmental sustainability of the proposal. Having regard to the proposed discharge of treated leachate from Derrinumera Landfill Site to the Newport Waste Water Treatment Plant proposed outfall, this report was drawn up to assess the characteristics of the untreated leachate at Derrinumera and also to assess any issues arising from the proposal.

This report examines the following:

- The Existing Leachate Management System;
- Typical Constituents of Leachate;
- Relevant Regulatory Standards and Recommendations, Required to Protect Migratory Fish and Mariculture at Clew Bay North;
- Derrinnumera Leachate Sampling Carried out to date;
- Proposal for Discharge Standards;
- Implications for Required Treatment of Leachate given Raw Leachate Sampling Results.

2. EXISTING LEACHATE MANAGEMENT SYSTEM AT DERRINUMERA

2.1. BACKGROUND

Derrinnumera Landfill has been receiving waste since 1974, and up until 1998 was best described as an un-engineered, dilute and attenuating landfill site. Due to the unlined nature of the waste, leachate could not be captured for treatment, however, the surrounding peat did offer a significant degree of attenuation to leachate migrating from the site.

Following licensing of Derrinnumera Landfill (Licence No. W0021-01, granted December 1999) by the Environmental Protection Agency as per the requirements of the Waste Management Act, 1996 and associated regulations, a bentonite cut-off wall was constructed at Derrinnumera in Summer 2001, with the main objective being to retain any leachate flowing from the permeable deposits in the enclosed area surrounding the wastebody, from escaping into the surrounding lands.

With the installation of the cut-off wall, leachate captured within the enclosed area was then diverted to a balancing lagoon, and pumped from there to three on-site storage tanks. As a condition of the Waste Licence issued by the EPA for Derrinnumera, leachate is transported by tanker from Derrinnumera to Castlebar WWTP for treatment.

After arriving at the treatment plant, leachate is currently discharged to the head of the works for co-treatment with Castlebar Town's incoming wastewater. The leachate and municipal wastewater is treated together prior to discharge to the Castlebar River system. The Castlebar River system flows into Lough Cullin and the Lough Conn System and from there eventually reaches the River Moy, south of Foxford. The River Moy ultimately discharges to the coastal waters of Killala Bay. It should be noted that the Moy Estuary/Killala Bay is a Candidate Special Area of Conservation (site reference 000458).

The Moy is a designated salmonid water in its entirety, therefore the preservation of high standards of water quality on the Castlebar River are essential to its salmonid spawning grounds. The Castlebar River is designated 'sensitive' under the Urban Waste Water

Treatment Regulations¹, partly due to the particularly low flows in dry weather and seasonally variable assimilative capacity to incoming treated effluent.

Treated effluent from Castlebar WWTP was, up until early June 2005, discharged to the Castlebar River at Knockthomas. On expansion of the plant, to provide a greater hydraulic capacity, a condition was applied by An Bord Pleanála to pipe the treated effluent to a new outfall location further downstream at the confluence of the Castlebar and Manulla Rivers. The new pipeline and outfall has consequently been constructed and was commissioned in early June 2005.

The EPA monitor effluent levels, river quality at various locations upstream and downstream of the Castlebar WWTP new and retired discharge locations, and regularly check the trophic status of Lough Conn and Lough Cullin. The overall biological rating of the stretch of river below the retired outfall has shown general improvement of water quality as the Q ratings improved since biological sampling by the EPA began in 1971. Since the outfall changeover occurred in June 2005, no EPA biological sampling results have become available. The receiving water Lough Cullin, along with Lough Conn has been classified as having a mesotrophic status². Since leachate importation at Castlebar WWTP commenced, no additional notable environmental effects have been observed or recorded in the receiving waters as a result.

In November 2001, Mayo County Council's application for the upgrade and expansion of the Castlebar WWTP was certified by An Bord Pleanála. An Bord Pleanála, in certifying the application, has made it a condition of such expansion that the importation of leachate there is discontinued when the new Castlebar WWTP is in place. The An Bord Pleanála condition implies that, once the upgrading and expansion of Castlebar WWTP occurs, alternative arrangements must immediately fall into place for the treatment of Derrinumera landfill leachate.

In this regard Mayo County Council must source an alternative means for the treatment and disposal of the leachate generated in Derrinumera Landfill. Following best environmental practice it has been considered that the treatment of leachate should be conducted at the source. The preferred option therefore is to treat leachate on site, and to deliver the treated leachate to the proposed marine outfall discharge location for treated municipal wastewater at Newport, via a pumped rising main on the selected route as shown on Drawing No. 1908-2200, Volume III.

¹ Urban Waste Water Treatment Regulations, 2001 (S.I. No. 254 of 2001).

² Source: EPA (2005), 'Water Quality in Ireland 2001-2003'

2.2. CURRENT LEACHATE VOLUMES AT DERRINUMERA

At present the leachate held within the cut-off wall is collected in a lagoon (with the leachate collected from the lined cells being pumped directly to holding tanks). From here it is pumped to, and stored in, 3 large identical precast concrete collection tanks on site. Each tank has a volume of 297m³ (i.e. 10.4m diameter with a working depth of the order of 4m).

The waste body at Derrinumerá has been surrounded by a 1.3km long 600mm wide bentonite cut-off wall, keyed 0.5m into bedrock since 2001. The purpose of the wall is to stop leachate migration from the waste body in the unlined historical deposit and it also diverts upland surface water around the unlined waste. Low permeability flows in the bedrock are not, of course, prevented by the cut-off wall. This leachate flows to a balancing lined lagoon at present, with a floor area of 860m² and a volume in the region of 3,600m³. This lagoon balances peaks in leachate production, which broadly mirrors rainfall, and provides a measure of settlement. Leachate is pumped from the lagoon to the three holding tanks from which the tankers are filled through a gantry loading system. The leachate is then taken off site to Castlebar WWTP for treatment.

The volumes to be handled and the strength of the constituents in the leachate, vary from winter to summer. Looking at the experience of 2001, 125m³/d approximately was transported in May and June and 130m³/d was tankered in September. Over the year an average daily leachate flow of 258m³/d was recorded, ranging from a minimum of 125m³/d to a maximum of 358m³/d. In 2002, which had been exceptionally wet, volumes as high as 650m³/d were removed in February and in November. In 2004 an average daily leachate flow of 269.7m³/d was recorded, and in 2005 the daily leachate flow averaged at 266.4m³/d. In the future, these volumes will change as cells are filled and capped off, with the maximum volume of leachate expected over the design life of the landfill peaking at 700m³/d, including a small allowance for supernatants generated from the small volume of liquid sludges and condensates. Once the LTF has been commissioned, the maximum allowable discharge of treated leachate from the plant will be restricted to 500 m³ per day and the existing on-site lagoon will be utilised as a balancing facility when the daily leachate production exceeds this volume. This figure has been used for design purposes.

3. TYPICAL CONSTITUENTS OF LEACHATE

Leachate will contain elements of all substances in the landfill that have not been broken down by microbiological activity within it and which are soluble in water. A landfill undergoes two distinct stages of biological waste decomposition during the cycle of breakdown of waste, namely the acetogenic and the methanogenic stages. Both of these stages can coexist in the one landfill, because the ages of the waste in the landfill can vary from place to place. The following describes these stages:

Acetogenic Stage

In the early stages following waste emplacement, acetogenic liquors containing high amounts of BOD and COD (consisting mainly of soluble organic compounds such as volatile fatty acids) together with high concentrations of ammoniacal nitrogen dominate the characteristics of the leachate.

Methanogenic Stage

In the later methanogenic stage of decomposition, although ammoniacal nitrogen levels remain, the soluble organic compounds are converted to landfill gas. In the methanogenic stage, leachate typically contains relatively low amounts of biodegradable organic matter.

Table 3.1 summarises the mean concentrations typically found in large landfills with a relatively dry high waste input rate for both stages of waste decomposition.

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Table 3.1: Summary of Mean Composition of Acetogenic and Methanogenic Leachates Sampled from Large Landfills with a Relatively Dry High Waste Input Rate

DETERMINANT	ACETOGENIC LEACHATES	METHANOGENIC LEACHATES
pH-Value	6.73	7.52
Conductivity (uS/cm)	16,921	11,502
Alkalinity (as CaCO ₃)	7,251	5,376
COD	36,817	2,307
BOD ₂₀	25,108	544
BOD ₅	18,632	374
TOC	12,217	733
Fatty acids (as C)	8,197	18
Ammoniacal-N	922	889
Nitrate-N	1.8	0.86
Nitrite-N	0.2	0.17
Sulphate (as SO ₄)	676	67
Phosphate (as P)	5.0	4.3
Chloride	1,805	2,074
Sodium	1,371	1,480
Magnesium	384	250
Potassium	1,143	854
Calcium	2,241	151
Chromium	0.13	0.09
Manganese	32.94	0.46
Iron	653.8	27.4
Nickel	0.42	0.17
Copper	0.13	0.13
Zinc	17.37	1.14
Arsenic	0.024	0.034
Cadmium	0.02	0.015
Mercury	0.0004	0.0002
Lead	0.28	0.20
Note: Results in mg/l except pH-value and conductivity (uS/cm).		

Source: EPA Landfill Manuals: 'Landfill Site Design Manual' (2000)

The concentration of various constituents of the leachate also varies greatly depending on whether it is sampled:

- (a) in the waste body itself, or;
- (b) in the holding tanks.

Leachate monitoring at Derrinnumera has shown that leachate sampled from the holding tanks tends not to have the same levels of BOD, COD, SS and ammonia as leachate sampled from the waste body itself. It is the leachate in the holding tanks that is relevant with respect to this report, as the leachate itself is to be treated after entering the holding tanks. Even without formal pre-treatment, it has been found that the concentration of the elements and compounds in the leachate declines from the wastebody to the holding tanks, though, of course, this requires full treatment before it can be discharged to a receiving water.

4. RELEVANT REGULATORY STANDARDS AND RECOMMENDATIONS

4.1. GENERAL

The environmental sustainability of the discharge of treated leachate at Newport WWTP marine outfall depends largely on a number of factors including: the characteristics of the raw leachate at Derrinnumera; the discharge standards required to protect aquatic life at Clew Bay; and current international best practice with secondary and tertiary treatment to treat this leachate to those required discharge standards.

This area of Clew Bay, surrounding the proposed outfall hosts a significant shellfish industry having achieved the highest classification for shellfish quality under the Shellsan system. In addition, the area is also a designated area of Special Scientific Interest and is a candidate Special Area of Conservation, given the migratory salmonid pass into the Furnace Lough-Lough Feagh system and the presence of the Salmon Research Station at Furnace en route. The discharge standards required to maintain this very valuable ecosystem at its current condition, and to continually ensure the protection of its marine life, therefore require a great deal of examination.

4.2. MARINE DISCHARGE STANDARDS AND RECOMMENDATIONS

There are no specific guidelines dealing with the quality of landfill leachate prior to or after treatment. The most important EU legislation involving water quality and discharges of effluent to receiving waters with regard to assessing the standard and inorganic chemical concentrations within the leachate are summarised in the following sections:

4.2.1 *EU Directives on Water Quality*

4.2.1.1 *The Urban Waste Water Treatment Directive (Council Directive 91/271/EEC)*

The Urban Waste Water Treatment Regulations, 2001 (S.I. No. 254 of 2001) give effect to this Directive. These regulations specify limits on wastewater treatment discharge of BOD₅, COD and Total Suspended Solids. The Regulations also set discharge limits for Total Phosphorus and Total Nitrogen for discharges to sensitive waters as listed in the Third Schedule of the regulations. The Urban Waste Water Treatment Regulations set out deadlines for secondary treatment of wastewaters depending on the size of agglomerations.

4.2.1.2 *EU Council Directive (76/464/EEC) on Water Pollution by Discharge of Dangerous Substances*

EU Directive 76/464/EEC, dealing with water pollution by discharges of certain dangerous substances, was implemented by statute in Ireland, into the Local Government (Water Pollution) Act 1977. Various regulations gave effect to this Act, including:

- Water Quality (Dangerous Substances) Regulations, 2001 (S.I. 12/2001).

In the marine environment, these regulations cover the obligations under the Directive by setting limits on the concentration of various pesticides, solvents, metals, and some other substances in a water body. These limits themselves result from extensive testing of the toxicity of these compounds to marine life, not just at the adult stage, but at the juvenile or larval stage as well.

4.2.1.3 The Bathing Water Directive (Council Directive 2006/7/EC)

This Directive repeals Directive 76/160/EEC, which was one of the first pieces of European environmental legislation to be set. The Bathing Water Directive (76/160/EEC) set minimum mandatory standards for the quality of Bathing Water throughout the European Union. The aim of the Directive was to protect public health and the environment from faecal pollution at locations where people bathe. The Directive required Member States to identify popular bathing areas and monitor the bathing waters for indicators of microbiological pollution throughout the bathing season. The Directive allowed two years for each member state to set up the necessary legislation and ten years for compliance.

The main Irish legislation, which gave effect to Directive 76/160/EEC are as follows:

- Quality of Bathing Waters Regulations, 1992 (S.I. 155/1992), as amended by Statutory Instruments: S.I. 145 of 1994; S.I. 230 of 1996; and S.I. 177 of 1998.
- Quality of Bathing Waters (Amendment) Regulations, 2001 (S.I. 22/2001).

These regulations designate bathing areas and outline water quality parameters to be measured as well as specified testing frequencies and methods for analysis.

In December 2005 an agreement was reached between the Member States, the European Commission and European Parliament on a new Bathing Water Directive. This new Bathing Water Directive was adopted on February 15th, 2006 and revokes Council Directive 76/160/EEC.

Directive 2006/7/EC is aimed at tightening water quality standards and ensuring relevant information on bathing waters is available to the general public. This new Directive sets out provisions for the monitoring and classification of bathing water quality, the establishment of management systems for bathing water quality, and the provision of information on bathing waters to the public.

4.2.1.4 EU Shellfish Directive (Council Directive 79/923/EEC)

This Directive, (with amendments: Directive 91/692/EEC and Council Regulation 1882/2003/EC), seeks to protect or improve shellfish waters in order to support shellfish life

(bivalve and gastropod molluscs) and growth and thus to contribute to the high quality of shellfish products directly edible by man. The Directive sets physical, chemical and microbiological water quality requirements that designated shellfish waters must either comply with or endeavour to meet. The Directive is designed to protect the aquatic habitat of bivalve and gastropod molluscan species of shellfish. This includes oysters, mussels, cockles, scallops and clams. The Directive does not cover shellfish crustaceans like crabs, crayfish and lobsters.

The main Irish legislation, which gives effect to the Directive is as follows:

- Quality of Shellfish Waters Regulations, 2006 (S.I. 268/2006)

The Quality of Shellfish Waters Regulations, (S.I. 268/2006) revoke previous shellfish regulations (S.I. 200/1994 and S.I. 459/2001). The revoked regulations previously specified indirect standards for shellfish inhabited waters. The new Shellfish regulations (S.I. 268/2006) now prescribe actual quality standards for shellfish waters, designate the waters to which they apply, and require the preparation and implementation of action programmes in respect to all such waters *'to take reasonably practicable steps to reduce pollution in those waters with a view to meeting the standards specified in Schedule 4'*. The 2006 Shellfish regulations are not intended to overrule the operation of the Water Quality (Dangerous Substances) Regulations 2001 (S.I. 12/2001).

4.2.1.5 EU Water Framework Directive (Council Directive 2000/60/EC)

This Directive came into force on the 22nd of December 2000, and is generally known as the 'Water Framework Directive' or 'WFD'. The objective of the Directive is to rationalise and update existing water legislation by setting common EU wide objectives for water. The WFD has a broad scope relating to water quality in rivers, lakes, canals, groundwater, transitional (estuarine) waters and coastal waters out a distance of at least one nautical mile.

The fundamental objective of the WFD aims at maintaining "high status" in relation to all waters by 2015. Under this Directive Member States are obliged to ensure that a co-ordinated approach is adopted for the achievement of the WFD and for the implementation of programmes of measures for this purpose. The main activities for the implementation of the WFD will take place in the context of River Basin Management (RBD) Projects led by Local Authorities.

In accordance with the requirements put forward by the European Communities (Water Policy) Regulations, S.I. 722 of 2003 (which transposes the Water Framework Directive (2000/60/EC) into Irish law), work to date includes an initial characterisation and analysis of Ireland's river basin districts, which was conducted and submitted to the European Commission in the form of a National Summary Report in March 2005 by the Environmental Protection Agency. An *'Article 5 Characterisation : Summary Report'* was produced as part

of the Western River Basin District Management System, which encompasses the subject area of the proposed development.

4.2.2 Irish Water Quality Legislation

4.2.2.1 S.I. No. 268, *Quality of Shellfish Waters Regulations, 2006 (Revoking S.I. 459/2001 and S.I. 200/1994)*

These standards specify mandatory limits and guide values for shellfish inhabited waters, and also specify allowable concentrations of various parameters in shellfish flesh. The regulations are aimed at achieving the objectives of the Shellfish Directive (79/923/EEC) by setting limits on the concentrations of suspended solids, salinity, dissolved oxygen, petroleum hydrocarbons, organohalogenated substances, dissolved metals and faecal coliforms, etc. allowable in shellfish waters and allowable concentrations in shellfish flesh. Schedule 3 of the regulations outlines the designated areas of shellfish waters to which the regulations apply.

Under the obligations of S.I. 268/2006, a Regulation 6 Action Programme has been completed for Clew Bay, detailing two sampling locations, one of which is sited in Newport Bay, with the other sited in Westport Bay. In order to determine whether the shellfish waters are compliant with the Shellfish Regulations, sampling will be carried out by Bord Iascaigh Mhara (BIM) at these locations, as tasked by the Minister for Communications, Marine and Natural Resources. Any discharges to Clew Bay shellfish waters must not cause the receiving water to exceed the specified levels, i.e. these values need to be back calculated on the basis of dilution factors and tidal currents. A copy of S.I. 268/2006 is included in Annex G of this discussion paper.

4.2.2.2 S.I. No. 254, *Urban Wastewater Treatment Regulations, 2001*

The requirements for treated leachate from the Leachate Treatment Plant will fall in line with the Urban Waste Water Treatment Regulations (2001), which specify the following requirements:

- BOD 25 mg/l
- SS 35 mg/l
- COD 125 mg/l

Because of the salmonid status attached to the Newport River and Lough Furnace, both situated on the verge of Newport Bay, the following requirement has been included in accordance with the Quality of Salmonid Water Regulations, 1988 (S.I. No. 293 of 1988), in order to ensure the protection of migratory fish species:

- Amm N 5 mg/l

4.2.2.3 S.I. No. 12, *Water Quality (Dangerous Substances) Regulations, 2001*

EU Directive 76/464/EEC, dealing with water pollution by discharges of certain dangerous substances, was implemented by statute in Ireland, into the Local Government (Water Pollution) Act 1977. This Act gave effect to various regulations including the Water Quality

(Dangerous Substances) Regulations, SI 12 of 2001. In the marine environment, the Regulations cover the obligations under the Directive by setting limits on the concentration of various pesticides, solvents, metals and some other substances. These limits themselves result from extensive testing of the toxicity of these compounds to marine life, not just at the adult stage, but at the juvenile or larval stage as well. An extract from S.I. No. 12 of 2001, detailing limits of the relevant substances is included in Annex A of this discussion paper.

5. RESEARCH CARRIED OUT TO DATE

5.1. HYDRODYNAMIC MODELLING OF THE PROPOSED OUTFALL

An extensive body of marine research work has been done in support of the Newport Sewerage Scheme, including the calibration and verification of a Hydrodynamic Model of the Inner Newport Bay area. At the request of various stakeholders a second model, prepared by the Marine Institute for Clew Bay, was utilised to verify the findings of the initial model. This second model was upgraded through the inclusion of LIDAR bathymetric data, which provided much better resolution when it became available to Mayo County Council in 2004.

Preliminary Hydrodynamic Modelling

Based on the initial modeling, an outfall location (Outfall 4) was selected out of an initial total of 6 potential outfall locations (refer to Drawing No. 1908-2200, Volume III). The selection of this outfall was based on a number of factors, namely, water quality impact and initial dilution, navigation requirements (i.e. sufficient water depth above outfall risers) and a number of other engineering constraints (access and cost). The final location has an ordnance grid location of approximately E95670, N294210. The proposed site, at its centroid is located 50 metres north of Rosmore headland in waters having a depth of 3 metres at low water mean spring tide. The site is located slightly to the south of the deeper entrance to Burrishoole Bay so as to avoid the navigation channel and is also located approximately midway between the oyster bed areas to the east and west of the outfall.

The hydrodynamic modeling on Newport Sewerage Scheme has included the modeling of two types of plume. The modeling has predicted the effects of the discharge of two types of contaminants, that with a 'die-off factor', e.g. faecal coliforms and that with a 'conservative factor', e.g. heavy metals.

The faecal coliform simulations clearly showed that provision of disinfection and the location of the proposed outfall ensure that the proposed Newport treated sewage discharge would not impact on shellfish production in the Bay in respect of the extensive oyster bottom culture areas and licensed shellfish sites. Based on a discharge concentration of 2,000 faecal coliforms per 100 ml the model simulations give a maximum concentration at the outfall grid square (20 metres by 20 metres) of 19.43 per 100ml and mean concentration of 2.6 no. per

100 ml (Spring Tide). The treated leachate discharge standards proposals therefore include a faecal coliforms limit of 2,000 per 100ml.

To assess the potential impact on Lough Furnace from the build-up of the more persistent pollutants (for example non-biodegradable persistent compounds) which may be contained within the discharge, a tracer simulation was conducted utilising the hydrodynamic model. The model identified that the predicted mean concentration in Burrishoole Bay expressed as a percentage of effluent concentration was found to be 0.021% and 0.062% for spring and neap tides respectively. In terms of dilutions this represents 1 in 4,600 and 1 in 1,600 respectively. In conclusion, no significant build-up of tracer concentration was predicted in the Burrishoole Bay area.

The results from the modelling exercise were presented at a public meeting held in Aras an Chontae, Castlebar by Mayo County Council on 5th December 2002. Attendance at this public meeting included representatives from the Marine Institute, Clew Bay Oyster Cooperative Society, Newport fisheries, Bord Iascaigh Mhara (BIM), National Parks and Wildlife Service, Newport Development Association and Clew Bay Marine Forum. During this meeting a recommendation was tabled, that the Marine Institute had developed a Hydrodynamic Modelling computer program for Clew Bay at the request of the Co-ordinated Local Aquaculture Management Systems (CLAMS) and that the suitability of the preferred outfall location should be validated by utilising this model in addition to a further seaward outfall at Muckinish Island. Clew Bay Oyster Cooperative Society Limited also requested in correspondence that an outfall further seaward be considered on their model to prevent accumulation in the inner north eastern corner of Newport Bay.

Additional Validatory Hydrodynamic Modelling

The request to validate the selection of Outfall 4 from the preliminary hydrodynamic modelling and the request to consider a further seaward outfall resulted in the selection of two options (Option A [Outfall 4 from preliminary modelling exercise] and Option B [Outfall 6 from preliminary modeling exercise]). These options were then modelled utilising the Marine Institute model as developed for CLAMS. The inputs to the model were agreed in advance with representatives of the Marine Institute at Lough Furnace. Option A is located in the anchorage between Rosmore and Rossgibbileen Point (as referred to above). Outfall A has an ordnance grid location reference of approximately E95670, N294210. Option B is further seaward, located to the south-east of Muckinish Island and has an ordnance grid location reference of approximately E93503, N293116.

A copy of the report on the hydrodynamic modelling exercise utilising the Marine Institute hydrodynamic model, developed at the request of the Co-ordinated Local Aquaculture Management Systems (CLAMS), is included in the Newport Sewerage Scheme Environmental Impact Statement.

Based on a faecal coliform discharge of 2,000 no./100 ml, the highest concentration of faecal coliforms predicted by the model from Outfall A was 1.82 no./100 ml in the mixing zone. This value is an order of magnitude lower than the strictest requirements for faecal coliforms. The highest concentration for Outfall B was 1.09 no./100 ml in the mixing zone.

Based on a Copper discharge of 0.08 mg/l, the highest concentration of Copper predicted by the model from Outfall A was 0.0000875 mg/l (or 87.5 ng/l) in the mixing zone and Outfall B was 0.0000488 mg/l (or 48.8 ng/l) in the mixing zone. For a discharge of Cadmium of 0.001 mg/l, the predicted concentrations were 0.000001094 mg/l (or 1.094 ng/l) in the mixing zone at Outfall A and 0.00000061 mg/l (or 0.61 ng/l) at Outfall B in the mixing zone. As Copper and Cadmium are 'conservative' substances, meaning that they do not biodegrade, the results of this exercise are useful to apply to all other conservative substances as they present the available dilution factors. In the case of Outfall A this was calculated as being 913. In the case of Outfall B this was calculated as being 1,492.

At the request of the National Parks and Wildlife Service the discharge of Ammonia (as N) was modelled. Assuming a discharge concentration of 5 mg/l, the maximum level predicted was 0.0194 mg/l from Outfall A in the mixing zone and 0.0178 mg/l from Outfall B in the mixing zone. It should be noted that when Ammonia is dissolved in water, it is the unionised form of Ammonia which is potentially toxic to marine life unless its concentration is maintained within the limits established by research as being safe for adult, juvenile and larval stages of finfish and shellfish life. The formation of the toxic unionised form of Ammonia fraction of the Total Ammonia solution in water is influence by temperature, pH, salinity and other ions in a complex manner. Typically in salt water at temperatures of 10 to 18 degrees celsius at neutral pH, un-ionised Ammonia represents approximately 3-5% of the Total Ammonia value. Based on historical EPA analyses of waters in the Moy estuary and Inner Killala Bay in County Mayo a maximum fraction of 6.06% was detected. Applying this fraction to the results obtained yields a maximum un-ionised Ammonia result of 0.00117 mg/l at Outfall A in the mixing zone and 0.00101 mg/l at Outfall B in the mixing zone. These results are lower than the current environmental quality standard of 0.021 mg/l for marine life.

Summary Conclusion

Based on the results of the validity modelling exercise, discharging faecal coliforms at a concentration of 2,000 no./100 ml, Ammonia (as N) at a concentration of 5 mg/l, Copper at 0.08 mg/l and Cadmium at 0.001 mg/l from either Outfall A or B would not result in the exceedance of any relevant national standard for these analytes with regard to the protection of the aquatic environment.

From the preliminary hydrodynamic modelling the minimum dilution factors available under the worst case scenario (or minimum) dispersion conditions at Outfall A is approx 18.6. Based on the validity modelling exercise with the worst case wind conditions affecting Inner Newport Bay and Lough Furnace, the minimum dilution factors available at Outfall A is 913 and Outfall B is 1,492.

It is considered that based on the results of the preliminary and validatory hydrodynamic modelling, that Outfall A is a suitable location for the discharge of the treated sewage effluent and treated leachate. It is contended that the additional dilutions available from constructing the pipeline to Outfall B do not provide sufficient environmental benefit balanced against the additional cost, engineering constraints and environmental impact arising from the construction and operation of the extended pipeline.

Overall Conclusion for Conservative Substances

Having regard to the outcome of both modelling exercises it is considered that a very conservative approach to worst-case dilution factor for conservative substances would be 18.6. It should be considered that this is very much the worst-case scenario and would occur temporarily during worst tidal dispersion conditions.

5.2. ANALYSIS OF DERRJNUMERA LEACHATE

5.2.1 Toxicity Analysis

TES Consulting Engineers carried out toxicity testing as part of a 'Leachate Characterisation Study' conducted in August 2003. Toxicity testing was carried out by Microtox™ on both the raw and treated (Castlebar WWTP) samples by Shannon Toxicity Laboratory. This test is recommended for testing the inhibition of wastewater treatment plant microflora (i.e. inhibition of respiration and nitrification). The Sequence Batch Reactor (SBR) is a variant of an aerobic biological system. Unlike a conventional activated sludge plant with pre-settlement, an SBR system is worked entirely by bacteria and as such, the Microtox test is the toxicity test most suited to assess any toxic shock and subsequent negative performance effect, which the leachate could have on the system. A toxicity unit level of 2.2Tu³ is regarded as the background level for Microtox™. This represents a dilution of greater than 45% volume of leachate per volume of saline solution, which is the threshold or starting dilution used in this test. Results from both raw leachate samples and treated effluent samples proved that the requisite level of impact on the bacteria could not be produced, even by the least possible dilution of raw leachate that the test allows. For all samples tested, toxicity levels were found to be less than 2.2Tu. (The EPA guideline value for discharge of effluent to sewer by a licensed facility is 10Tu., which is significantly greater than the values

³ Toxicity/inhibition tests are carried out by exposing a group of test organisms in a series of dilutions of the test substance or mixture, under conditions, which are controlled. On the basis of the recorded effect frequencies in the various dilutions, the effect concentrations (Effective Concentration (EC) or Lethal Concentration (LC) are usually calculated for the 10, 50 and 90% mortality or effect level in the population. Example: If the results from a 24-hour EC₅₀ toxicity test is 20% v/v, this means that 200ml of wastewater made up to a litre with water had a specified effect on 50% of the test species, in 24 hours. To avoid confusion and to report increasing toxicity with a correspondingly increasing number (i.e. the more toxic the wastewater, the higher the numerical TU number assigned to it), the result is expressed as a function of the undiluted sample (100%). This form of expression is known as the Toxic Unit (Tu) and is defined as follows: $Tu = 100/EC_{50}$

obtained for the Derrinnumera leachate.) Annex D shows a table of results abstracted from the 2003 'Leachate Characterisation Study' for toxicity testing of leachate generated at Derrinnumera and wastewater samples taken at Castlebar WWTP. Table 6 of Annex D shows the results of the toxicity tests. (Refer also to Appendix 10 – 'Leachate Characterisation Report').

Mayo County Council conducted further toxicity tests in October of 2004. The Shannon Toxicity Laboratory again carried out analysis and results can be found in Annex E ('The Acute Toxicity of a Derrinnumera Landfill Leachate Sample to Aquatic Organisms, 2004 Results').

Aquatic toxicity is the science that deals with the effects of substances and physico-chemical conditions on aquatic flora and fauna. Used in conjunction with limits on chemical and physical constituents, toxicity limits afford a safeguard against the presence of unknown or unanticipated contaminants. Nevertheless, it is important to understand that toxicity tests can only measure the toxicological properties they are designed to detect. The 2004 tests, as with the majority of tests used in Ireland, were designed to detect acute (rapid), easily observed and unquestionably harmful properties such as lethality and immobilisation as opposed to looking specifically at fertility and growth effects.

Three different species were chosen for toxicity testing, i.e. Plants/Algae Group: Freshwater Algae *pseudokirchneriella subcapita*; Crustaceans Group: Freshwater Cladoceran *daphnia magna* or 'Water Flea'; and Fish Group: Juvenile Freshwater Salmonid *oncoryhnchus mykiss* or 'Rainbow Trout'. The toxicity results when testing these species against set concentrations of untreated leachate from Derrinnumera, yielded favourable results of 4.5Tu, 1.4Tu and 4.2Tu respectively, all being below the standard 10Tu set as a guideline value by the EPA.

5.2.2 Raw Leachate Chemical Analysis at Derrinnumera

In order to establish the site-specific characteristics of the Derrinnumera leachate an initial 'Leachate Characterisation Study' was conducted during August 2003. This particular time of year was chosen, as August is a month, which typically has lower rainfall levels leading to lower volume, higher strength leachate. The timing of the sampling was as such as to follow a period of dry weather. Samples were taken from the existing leachate holding tanks at Derrinnumera Landfill. In order to provide an indication of the efficiency of a conventional secondary treatment plant to co-treat this leachate with municipal wastewater, the treated effluent from the Castlebar WWTP was also sampled. A discussion of the results of treated effluent from the Castlebar Plant is dealt with in the 'Leachate Characterisation Study'. A copy of the 2003 results is included in Annex D of this report, and the 'Leachate Characterisation Study' (TES, 2003) is provided in Appendix 10, Volume IV.

On examination of the results, with regard to the majority of parameters analysed for, those substances were not detected above laboratory limits of detection. Hence a second round of

sampling for analysis of a selected set of determinands was carried out to a lower level of laboratory detection, in order to enable comparison of raw leachate concentrations with the relevant Irish Legislation. As technology enabling extremely low detection levels was not available in this Country, the analysis was carried out by the National Laboratory Service for the Environmental Agency in Wales during June 2005. The 2005 lab results are included in Annex F of this report.

The purpose of the examination of the untreated Derrinnumera leachate is purely to assess the relative levels of the contaminants and it must be emphasised that these are untreated values, before any process other than settlement in the leachate lagoon has been brought to bear on the constituents.

5.2.3 Discussion of Results

Overall, by comparing the raw leachate data for Derrinnumera with the respective Mean Composition of acetogenic and methanogenic leachates on Table 3.1, the results (i.e. heavy metals, electrical conductivity, major cations, BOD, COD, ammonia, phosphate, and chloride mean levels) detected at Derrinnumera are all significantly less than their respective means. This gives an indication that the raw leachate at Derrinnumera has a much lower concentration than average in Ireland, and lacks the more troublesome trace elements typical of leachates.

The mean BOD value for the 2003 leachate samples was approximately 179mg/l. It should be noted that again this value was less than the respective mean composition as quoted on Table 3.1. These values are typical of municipal leachate and are to be expected given that domestic waste is the principal waste type accepted at Derrinnumera Landfill. The strength of the raw leachate is not greatly in excess of domestic wastewater, and while the COD levels are higher than domestic wastewater, they are at maximum one quarter of the figure given for methanogenic leachate in Table 3.1. It is clear from the discussion up to this point, that the Derrinnumera leachate is quite significantly lower in strength by comparison with the generality of the municipal landfill leachates.

On analysis of the raw leachate, the majority of heavy metals were not detected above the laboratory detectable limit during 2003 tests. The 2005 analysis, carried out generally at lower lab detection limits, found some heavy metals at trace levels in the raw leachate. Results for arsenic, mercury and silver all suggested undetectable levels. For the remaining heavy metals, traces of these elements were detected by the 2005 testing laboratory, however all were again found to be of a lower concentration than those expected mean concentrations set out in Table 3.1. It is therefore envisaged that heavy metals concentrations will not be in excess of proposed standards set out in Section 6 once the leachate has undergone full and appropriate treatment.

Elevated levels of ammonia were observed in the 2003 leachate samples with a mean value of 100mg/l and a maximum of 137mg/l. It should be noted however, that this value was significantly less than its respective mean concentration. These values, in conjunction with

the results of the nitrate and nitrite analysis, are typical of landfill leachate and are consistent with the type of waste accepted and anaerobic conditions within the landfill.

The results of the total and faecal coliform analysis are consistent with the level of values typically found in a municipal landfill and are to be expected given that domestic waste is the principal waste type accepted at Derrinnumera Landfill.

All of the VOC and almost all of the SVOC parameters analysed during the 2003 Leachate Characterisation Study proved to be undetectable, however, low traces of pyrene, naphthalene, anthracene, phenanthrene, fluoranthene, benzo(a)anthracene and chrysene were detected in the raw leachate. When the untreated leachate was analysed for these parameters again in 2005, results were all below laboratory detection limits.

The 2003 results for the polychlorinated biphenyl (PCBs), chlorinated pesticides and diesel range organic analysis indicate that no PCB congeners or chlorinated pesticides were detected above laboratory limits in the leachate samples. It should be noted that the limits of detection for the PCB congeners or chlorinated pesticides were 0.01 parts per billion (ppb). However, low concentrations of diesel range organics were detected in the first leachate sample taken. The laboratory interpretation of the chromatogram indicated that highly biodegraded diesel was the source.

A total of 11 standard PCB congeners were analysed for during the 2005 sampling round, all of which were not detected above laboratory limits of detection. Of the chlorinated pesticides, which were chosen for analysis during 2005 (see Annex F), none were detected above laboratory limits of detection.

The 2003 results for acid, triazine and nitrile herbicides, organophosphorous pesticides and organotin analyses indicated that no acid, triazine, nitrile herbicides or organophosphorous pesticides were detected in the raw leachate samples with the exception of low concentrations of triphenyltin, which was detected in the fourth leachate sample taken, whilst none was detected above limits of detection in all of the other 2003 samples.

5.2.4 Summary of Results

Considering the raw leachate data initially, it is clear that when the raw leachate for Derrinnumera is compared with the respective Mean Composition of acetogenic and methanogenic leachates on Table 3.1, the results (i.e. heavy metals, electrical conductivity, major cations, BOD, COD, ammonia, phosphate, and chloride mean levels) detected at Derrinnumera are all significantly less than their respective means. This raw leachate is less concentrated than average in Ireland, and lacks the more troublesome trace elements typical of leachates from more industrialised areas.

Polyaromatic hydrocarbons (PAHs), which are commonly found in landfill leachate, were detected in the raw leachate at trace levels. These are a group of lipophilic substances that

are ubiquitous in the environment. They are almost insoluble in water and are commonly sorbed on to airborne particles. They enter the environment from the following systems: wood fires, exhaust from petrol and diesel engines and the runoff from bitumen road surfaces. The most common points of entry of PAHs into the landfill would be through fire ash and cinders.

With regard to the traces of diesel range organics detected in the raw leachate sample, it is possible that diesel contaminated soil or another diesel contaminated waste source may have been accepted in the landfill unknowingly and caused these levels.

Triphenyltin was detected in the raw leachate sample. This substance was used as a constituent in marine anti-fouling paint. However, its use has discontinued as a result of an international ban. It is possible that old paint cans containing anti-fouling paint may have been accepted into the landfill unknowingly and caused the trace levels detected.

In summary, the Derrinnumera Leachate, even when sampled in June and August at its most concentrated likely condition, is of weaker strength than average landfill leachates in Ireland. Aerobic biological secondary treatment processes are unlikely to be inhibited by any toxicity effects, as the toxicity tests show, and so the full range of treatment systems outlined in Section 7 are expected to be suitable for consideration by Contractors tendering for leachate treatment as part of a DBO process.

6. PROPOSED DISCHARGE STANDARDS

As there are no specific guidelines dealing with the quality of landfill leachate prior to or after treatment, it is proposed to treat the leachate to those standards proposed for the Newport Waste Water Treatment Plant discharge, given the fact that treated leachate will be co-discharged with Newport WWTP final effluent. The standards proposed are as follows:

- BOD₅ 25 mg/l
- Suspended Solids 35 mg/l
- COD 125 mg/l
- Ammonia (N) 5 mg/l
- Faecal Coliforms 2000 No./100ml

In addition to the above standards, it has been anticipated that additional requirements are appropriate to be specified for the treated leachate to ensure the protection of the sensitive receiving environment of Newport Bay, associated water bodies, protected species and habitats. There are no specific guidelines recommending the quality of landfill leachate prior to or after treatment. The establishment of discharge standards as required for the treated leachate in accordance with the Waste Licence Review is a function of the Environmental Protection Agency under the Protection of the Environment Act, 2003, Waste Management Act, 1996, Environmental Protection Agency Act, 1992 and associated regulations. This Waste Licence is currently being reviewed by the Environmental Protection Agency.

In obtaining a complete reference list of standards appropriate to substances which could potentially be contained within the treated leachate and which present a potential risk, a number of publications and guidances were referenced in addition to consultations with the Environmental Protection Agency and Bord Iascaigh Mhara, including;

- Environmental Protection Agency Act, 1992 (Urban Waste Water Treatment) Regulations, 2001 (S.I. No. 254 of 2001);
- Quality of Salmonid Water Regulations, 1988 (S.I. No. 293 of 1988);
- United States Food and Drug Administration, *National Shellfish Sanitation Program Standards* (USFDA, 1995),
- Water Framework Directive 2000/60/EEC;
- European Communities Directive concerning the quality of bathing waters (76/160/EEC and 2006/7/EC) and related statutory instruments;
- European Communities Directive concerning the health conditions for the production and placing on the market of live bivalve molluscs (91/492/EEC);
- Dangerous Substances Regulations, 2001 (S.I. No. 12 of 2001);
- Environmental Protection Agency *Towards Setting Guidelines Values for the Protection of Groundwater in Ireland, Interim Report* (EPA, 2003); and,
- European Communities (Quality of Shellfish Waters) Regulations, 2006 (S.I. No. 268 of 2006).

The European Communities (Quality of Shellfish Waters) Regulations, S.I. No. 268 of 2006 specifies limits for eleven categories of parameters however it could be considered that the limit values specified in the regulations may not cater for every possible substance present in the treated leachate. Whilst the project team engaged in consultation with the Environmental Protection Agency and Bord Iascaigh Mhara during the environmental impact assessment process regarding additional environmental quality standards for treated leachate in the context of the proposed receiving waters, there was no information available with regard to what these environmental quality standards would be set at. In the absence of this information, the only approach available to the project team in selecting appropriate discharge standards for treated leachate was on the basis of a literature review of existing environmental quality standards as enshrined in national legislation. In many cases recommended environmental quality criteria in international publications were less than existing background levels in the Irish environment or there was an insufficient dataset for assessment of background levels on a national basis. When assessing the appropriateness of these discharge standards, it should be noted that ultimately the Environmental Protection Agency will be required to establish the discharge standards for the treated leachate being discharged from Derrinnumera landfill as part of the Waste Licence Review process which is currently on-going.

From the preliminary hydrodynamic modelling the minimum dilution factors available under the worst case scenario (or minimum) dispersion conditions at the preferred outfall location is 18.6 (Refer to Section 5.1). Based on the validity modelling exercise with the worst case wind

conditions affecting Inner Newport Bay and Lough Furnace, the minimum dilution factors available at this outfall A is 913. To this extent, in assessing appropriate discharge values for specific 'risk' determinands, it was considered that the most conservative approach would be to apply a factor of 18.6 to the target environmental quality standard. It is stressed that this was the minimum dilution factors available for a limited time (i.e. 30 minutes during the tidal cycle) after which available dilutions significantly increase. To this extent the calculated discharge limits for the treated leachate are included below in *Table 6.1 Proposed Discharge Standards for Treated Leachate*. This table presents the discharge concentration to be attained in the treated leachate (subject to Environmental Protection Agency licensing), the predicted concentration at the edge of the initial mixing zone and the appropriate relevant Irish statutory limit.

When referencing the table below, please note the following;

1,000 microgrammes = 1 milligramme

1,000 milligrammes = 1 gramme

1,000 grammes = 1 kilogramme.

Additional Screening Values for Receiving Environment

Given the extremely low levels of contaminants predicted to be discharged in the treated leachate, there is no short-term negative impact predicted in the environment. Pre- and post-discharge monitoring will be implemented such that all specified standards are met in order to safeguard the quality of water in the bay. In addition to the monitoring requirements for treated leachate as specified by the Environmental Protection Agency in the Waste Licence for Derrinumera Landfill, biannual monitoring of the receiving waters, sediment, fish and shellfish tissue at sites adjacent to the proposed discharge and moving away from the discharge will be implemented to safeguard the ecological integrity and in particular the favourable conservation status of the receiving environment in the short, medium and long-term. The development and implementation of this monitoring programme will be conducted in consultation with the relevant state and semi-state bodies (i.e. Environmental Protection Agency, Mayo County Council, Department of Environment, Heritage and Local Government and the Department of Communications, Marine and Natural Resources [including the Marine Institute]) with input from local stakeholders. When considering the above, consultation will be engaged in with the EPA as the establishment of discharge standards for the treated leachate is a function of the Environmental Protection Agency under the Protection of the Environment Act, 2003, Waste Management Acts, 1996-2003, Environmental Protection Agency Act, 1992 and associated regulations through the Waste Licensing Review process. This process is currently on-going.

When assessing the results of the biannual monitoring programme referred to above, the 'early warning limits' as specified hereunder in *Table 6.2 Proposed Screening Criteria for Receiving Environment* will be referenced, in addition to any limits specified through the Waste Licensing process for Derrinumera landfill by the Environmental Protection Agency.

It should be noted that the development of appropriate standards for the receiving environment are subject to change (influencing factors include new legislation and the outcome of new scientific research) and as such the relevant standards will be reassessed on an annual basis. It should also be noted that in the event of elevated results being detected in the receiving environment, that the source of such elevated results may not necessarily arise from the discharge of treated leachate – the purpose of the biannual monitoring programme will be to confirm the capability of the receiving environment to continue to accept discharges of treated leachate.

It should be noted that the results of this Biannual Monitoring Programme will be forwarded to the Environmental Protection Agency for consideration as part of their Waste Licence enforcement activity at Derrinnumera Landfill. Should the results of the Monitoring Programme indicate that alternative limits or controls are required at the Leachate Treatment Facility or the landfill in general, Mayo County Council will implement same in agreement with the Environmental Protection Agency.

As outlined previously in Section 5, from the preliminary hydrodynamic modelling the minimum dilution factor available under the worst-case scenario (or minimum) dispersion conditions at Outfall A is approx 18.6. Based on the validity modelling exercise with the worst case wind conditions affecting Inner Newport Bay and Lough Furnace, the minimum dilution factors available at Outfall A is 913 and Outfall B is 1,492. To this extent, in assessing appropriate discharge values for specific 'risk' determinands, it was considered that the most conservative approach would be to apply a factor of 18.6 to the target environmental quality.

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Table 6.1 Proposed Discharge Standards for Treated Leachate

Determinand	Concentration in Discharge of Treated Leachate	Concentration in Receiving Waters Post Initial Mixing Zone (20 M x 20 M grid) Min. Dilutions 18.6*	Irish Regulatory Standard	Reference	Name of Standard
GENERAL					
PH	7-9 pH units	-	7-9 pH units	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
BOD	25 mg/l	-	25 mg/l	S.I. No. 254 of 2001	Urban Waste Water Treatment Regulations, 2001
COD	125 mg/l	-	125 mg/l	S.I. No. 254 of 2001	Urban Waste Water Treatment Regulations, 2001
Ammonia (as N)	5 mg/l	-	-	-	-
Suspended Solids	35 mg/l	-	35 mg/l	S.I. No. 254 of 2001	Urban Waste Water Treatment Regulations, 2001
Faecal Coliforms	2,000 per 100 ml	-	-	-	-
Phenol	0.5 ug/l	-	-	-	-
Colour	Deviation of <10 from background	Deviation of <10 from background	Deviation of <10 from background	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
Salinity	<40 PSU	2.15 PSU	<40 PSU and less than 10% Increase in background	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
Dissolved Oxygen	Average Equal or Greater than 70% Min. 60%	-	Average Equal or Greater than 70% Min. 60%	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
Total Petroleum Hydrocarbons	No visible film No harmful effects on shellfish	-	No visible film No harmful effects on shellfish	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
Polychlorinated Biphenyls (sum ICES 7 CBs: PCBs 28, 52, 101, 118, 138, 153 and 180)	0.30 microgrammes per litre	0.016 microgrammes per litre	0.30 microgrammes per litre	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
DISSOLVED METALS					
Arsenic	40 (max.) microgrammes per litre	2.15 microgrammes per litre	40 (max.) microgrammes per litre	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
	20 (avg.) microgrammes per litre		20 (avg.) microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations 2001
Cadmium	5 microgrammes per litre	0.27 microgrammes per litre	5 microgrammes per litre	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006

* This is indicative of conditions at low water spring tide. Dilutions at all other phases of the tide are greater than this.

Table 6.1 Proposed Discharge Standards for Treated Leachate (continued)

Determinand	Concentration in Discharge of Treated Leachate	Concentration in Receiving Waters Post Initial Mixing Zone (20 M x 20 M grid) Min. Dilutions 18.5*	Irish Regulatory Standard	Reference	Name of Standard
DISSOLVED METALS (continued)					
Chromium	30 (max.) microgrammes per litre 15 (avg.) microgrammes per litre	1.61 microgrammes per litre	30 microgrammes per litre 15 microgrammes per litre	S.I. No. 268 of 2006 S.I. No. 12 of 2001	EC (Quality of Shellfish Waters) Regulations, 2006 Water Quality (Dangerous Substances) Regulations 2001
Copper	10 (max.) microgrammes per litre 5 (avg.) microgrammes per litre	0.54 microgrammes per litre	10 microgrammes per litre 5 microgrammes per litre	S.I. No. 268 of 2006 S.I. No. 12 of 2001	EC (Quality of Shellfish Waters) Regulations, 2006 Water Quality (Dangerous Substances) Regulations 2001
Lead	20 (max.) microgrammes per litre 5 (avg.) microgrammes per litre	1.08 microgrammes per litre	20 microgrammes per litre 5 microgrammes per litre	S.I. No. 268 of 2006 S.I. No. 12 of 2001	EC (Quality of Shellfish Waters) Regulations, 2006 Water Quality (Dangerous Substances) Regulations 2001
Mercury	0.40 microgrammes per litre	0.02 microgrammes per litre	0.40 microgrammes per litre	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
Nickel	50 (max.) microgrammes per litre 25 (avg.) microgrammes per litre	2.69 microgrammes per litre	50 microgrammes per litre 25 microgrammes per litre	S.I. No. 268 of 2006 S.I. No. 12 of 2001	EC (Quality of Shellfish Waters) Regulations, 2006 Water Quality (Dangerous Substances) Regulations 2001
Silver	10 microgrammes per litre	0.54 microgrammes per litre	10 microgrammes per litre	S.I. No. 268 of 2006	EC (Quality of Shellfish Waters) Regulations, 2006
Zinc	200 (max.) microgrammes per litre 40 (avg.) microgrammes per litre	10.75 microgrammes per litre	200 microgrammes per litre 40 microgrammes per litre	S.I. No. 268 of 2006 S.I. No. 12 of 2001	EC (Quality of Shellfish Waters) Regulations, 2006 Water Quality (Dangerous Substances) Regulations 2001
STANDARD IONS					
Cyanide	10 microgrammes per litre	0.54 microgrammes per litre	10 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001
Fluoride	1500 microgrammes per litre	80.65 microgrammes per litre	1500 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001
VOLATILE ORGANIC COMPOUNDS					
Dichloromethane	10 microgrammes per litre	0.54 microgrammes per litre	10 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001
Toluene (Methylbenzene)	10 microgrammes per litre	0.54 microgrammes per litre	10 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001
Xylene (Dimethylbenzene)	10 microgrammes per litre	0.54 microgrammes per litre	10 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001
TRIAZINE HERBICIDES					
Atrazine	1 microgramme per litre	0.054 microgrammes per litre	1 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001

Substance	1 microgramme per litre	0.054 microgrammes per litre	1 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001
ORGANOTIN COMPOUNDS					
Tributyltin	0.001 microgrammes per litre	0.00005 microgrammes per litre	0.001 microgrammes per litre	S.I. No. 12 of 2001	Water Quality (Dangerous Substances) Regulations, 2001

* This is indicative of conditions at low water spring tide. Dilutions at all other phases of the tide are greater than this.

In the table above, where two standards are specified, e.g. the dissolved metal Arsenic, the requirement is that the limit value specified in European Communities (Quality of Shellfish Waters) Regulations, 2006 should be considered the maximum value and the limit value specified in the Water Quality (Dangerous Substances) Regulation, 2001 should be considered as the average value.

Compliance with discharge standards will be as per the detail of interpretation specified in the revised Waste Licence granted to Derrinmera Landfill by the Environmental Protection Agency.

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Table 6.2 Proposed Screening Criteria for Receiving Environment

Determinand	Screening Criteria for Receiving Waters	Source	Screening Criteria for Shellfish Tissue (mg/kg)	Source
pH	7 – 9 pH units	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Temperature	Differential from background levels less than 2 degrees celsius	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Colouration (after filtration)	Differential from background levels of less than 10 milligrammes per litre	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Suspended Solids	Differential from background levels of less than 30%	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Salinity	Mandatory Less than 40 practical salinity units and differential from background levels less than 10%	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Dissolved Oxygen	Guide 12-38 practical salinity units 80% (average value)	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Total Petroleum Hydrocarbons	No visible film or deposit on shellfish or waters nor harmful effects on shellfish	S.I. No. 268 of 2006	Not Applicable	Not Applicable
Faecal Coliforms	100 faecal coliforms per 100 millilitres	S.I. No. 268 of 2006	Equal to or less than 300 in the shellfish flesh and intertubular fluid	S.I. No. 268 of 2006
Organohalogenated Substances	0.30 microgrammes per litre Polychlorinated Bi-phenyls	S.I. No. 268 of 2006	Mandatory 300 microgrammes per kilogramme wet weight @ 1 percent lipid	S.I. No. 268 of 2006
Tributyltin	0.001 microgrammes per litre	S.I. No. 12 of 2001	Guide 400 microgrammes per kilogramme wet weight @ 1 percent lipid	Not Applicable
Atrazine	1 microgramme per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Simazine	1 microgramme per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Standard Ions				
Cyanide	10 microgrammes per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Fluoride	1500 microgrammes per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Volatile Organic Compounds				
Dichloromethane	10 microgrammes per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Toluene	10 microgrammes per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Xylene	10 microgrammes per litre	S.I. No. 12 of 2001	Not Applicable	Not Applicable
Dissolved Metals				
Arsenic	40 microgrammes per litre	S.I. No. 268 of 2006	30 mg per kg dry weight	S.I. No. 268 of 2006
Cadmium	5 microgrammes per litre	S.I. No. 268 of 2006	5 mg per kg dry weight	S.I. No. 268 of 2006

Chromium	30 microgrammes per litre	S.I. No. 268 of 2006	6 mg per kg dry weight	S.I. No. 268 of 2006
Copper	10 microgrammes per litre	S.I. No. 268 of 2006	400 mg per kg dry weight	S.I. No. 268 of 2006
Mercury	0.4 microgrammes per litre	S.I. No. 268 of 2006	1 mg per kg dry weight	S.I. No. 268 of 2006
Nickel	50 microgrammes per litre	S.I. No. 268 of 2006	5 mg per kg dry weight	S.I. No. 268 of 2006
Lead	20 microgrammes per litre	S.I. No. 268 of 2006	7.5 mg per kg dry weight	S.I. No. 268 of 2006
Zinc	200 microgrammes per litre	S.I. No. 268 of 2006	4,000 mg per kg dry weight	S.I. No. 268 of 2006
Silver	10 microgrammes per litre	S.I. No. 268 of 2006	15 mg per kg dry weight	S.I. No. 268 of 2006
Organoleptic Parameters				
Taste	No impairment of taste in shellfish flesh			

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7. SUGGESTED TREATMENT METHODOLOGY FOR DERRINUMERA

This section deals with the type of leachate treatment that would be considered to be the most suitable form of treatment for Derrinumbera Landfill. As this is a Design Build and Operate (DBO) project, the exact nature of leachate treatment processes or technologies will emerge from the procurement process and thus have yet to be agreed, however, the following lends insight into the most likely treatment outcome.

The design of the LTF and ancillary works, including any such elements of the existing leachate handling works as are retained, shall be in accordance with Best Available Techniques (BAT) and shall be such as to facilitate the operation, monitoring, sampling and maintenance of all processes and equipment. The process and equipment chosen shall have been used successfully in similar sized plants treating similar type leachates.

The following process options will be considered for effective treatment of the leachate.

- Air stripping/aeration in lagoons or SBR processes;
- Reed beds;
- Rotating biological contactors;
- Membrane Filtration;
- Chemical Precipitation;
- Electrolytic Oxidation;
- Reverse osmosis;
- Other proven systems.

The tendering contractor will offer the system that he considers to be the most economically advantageous, and which consistently achieves the required treated leachate standards.

The choice of treatment process should be a function of the nature of the leachate to be treated, which in itself is dependant on the composition and volume of the leachate and the selected discharge medium and its location. Looking at the constituents of the leachate, it is clear that BOD, COD, Ammonia and Suspended Solids have to be removed as main targets. Because of the anaerobic character of leachate, aeration is also necessary to significantly increase the oxygen levels of the treated leachate.

It is clear from these considerations that aerobic treatment is the most suitable form of treatment. It is the most frequently applied technology in the world with respect to leachate treatment, and it is a proven technology. This form of leachate treatment is basically aimed at the decrease of the oxygen demand of the leachate, the removal of suspended solids and the increase of oxygen levels in the treated effluent. As a side

consequence, heavy metals and micro-pollutants will also be removed, to a greater or lesser extent as discussed below. The Sequencing Batch Reactor technology (SBR) is just one form of aerobic treatment, it is a robust and simple aeration system with good process flexibility. Indeed, when the existing holding tanks were constructed at Derrinnumera, their size and dimensions were selected so that if the need ever arose, they could be converted to an SBR system.

For this type of leachate treatment, the oxidation of nitrogen from Ammonia to the oxidised forms of Nitrogen is the most critical biochemical process. The design of an SBR system therefore is based on nitrogen loading as the limiting factor. At the Derrinnumera Landfill Site, two tanks were originally constructed, each of effective volume 297 m³ volume (595 m³ total), which can easily be converted into SBR tanks. Since then, a third tank has been added.

The effluent quality will be improved by leachate treatment in an SBR system of this larger volume (750 – 1,000 m³), optimised for the specific leachate characteristics of Derrinnumera. This would be achievable by converting the third Holding Tank to an SBR unit as well, in which case the expected, and most likely best achievable effluent quality by secondary treatment is as listed in Table No. 7.1.

Parameter	Unit	Value
COD	mg/l	400
BOD	mg/l	< 20
N-Kj	mg/l	20
NO ₃ -N	mg/l	10
N-total	mg/l	30
P-ortho	mg/l	< 2
SS	mg/l	< 250

Table No. 7.1 - Expected achievable effluent quality from an SBR process

These levels of reduction of COD, Ammonia and Suspended Solids would not meet the Urban Wastewater Treatment Regulations standards, and the projected reductions of some metals would also be small. Improved Suspended Solids reduction can be brought about by Filtration of the effluent, but metals reduction will also be required with a further tertiary treatment step involving precipitation using a chemical coagulant, with filtration following that step, or a membrane filtration stage following secondary treatment.

Such a filtration step might itself tend to reduce the COD. By Raising the temperature of the leachate, even by 1-2 deg C, a significant improvement in the efficiency of the nitrification process will be seen, and waste low grade heat available from the Sludge Drier, and the landfill gas currently being flared can be used with heat exchangers to assist this process. We have been deliberately conservative in predicting the likely

efficiencies of removal of the various parameters; in the UK case studies examined in Annex C, considerably better removal rates for COD, SS and Ammonia were recorded in actual working situations.

Given the presence of polyaromatic hydrocarbons (PAHs) and Triphenyl Tin in the raw leachate sampled at Derrinumera, but at levels only marginally above those permissible in a treated leachate, an activated carbon filtration system may be required to 'polish' the post-SBR treated leachate with respect to these two elements. Again activated carbon treatment is a proven technology in the removal of hydrophobic trace organics, and can be provided for provisionally in design, and added at a later stage if the actual full-scale performance of an SBR system needs this polishing stage.

In summary, while secondary treatment of leachate at Derrinumera can meet treated effluent standards for many parameters, a further polishing stage such as precipitation and filtration will be necessary to meet all of the standards, and steps to use waste heat to enhance the removal of ammonia may also be necessary.

The treatment of leachate being discharged into Clew Bay will be to an appropriate standard based on limits specified in Irish legislation. The design philosophy has been to comply with the Urban Waste Water Treatment Regulations, 2001 and to otherwise treat the leachate such that the environmental quality standards specified in the Water Quality (Dangerous Substances) Regulations, 2001 and European Communities (Quality of Shellfish Waters) Regulations, 2006 are already attained in the pipeline prior to discharge to the receiving environment. The Environmental Protection Agency have a key role in establishing discharge standards for the treated leachate at Derrinumera landfill as part of the Waste Licence review which is currently being conducted. Discharge concentrations in the treated leachate and wastewater will be monitored to ensure that the specified discharge standards are complied with in accordance with the requirements of the revised Waste Licence.

Initial Dilutions, even under worst-case conditions will further improve the quality of the discharge in the mixing zone directly over the outfall (as shown in Table 6.1), and far field dilutions will take many of the elements to below the measurability level.

Sampling of the treated wastewater from the Castlebar WWTP, when treating this leachate from Derrinumera, has shown that the secondary treatment process of a WWTP of the scale of Castlebar and Westport is capable of handling such leachate. Consequently the tankering of that leachate on an interim basis to Westport, where there is spare capacity to accept it, during any interruptions in normal treatment and pumping to the Newport WWTP Outfall, is sustainable.

ANNEX A - Extract from S.I. No. 12 of 2001 – Water Quality (Dangerous Substances) Regulations, 2001

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STANDARDS

The annual mean concentration in a water body of a substance specified in a Table hereunder shall not exceed the standard specified in the Table in relation to that substance. The standards are expressed in units of ug/l, i.e. micrograms per litre, and incorporate the notes to the Tables.

TABLE 1
 PESTICIDES AND SOLVENTS

Substance	Standard (ug/l)
Atrazine	1.0
Dichloromethane	10.0
Simazine	1.0
Toluene	10.0
Tributyltin	0.001
Xylenes	10.0

The standard for Tributyltin shall apply in relation to tidal waters only and shall be deemed to be met if the results of monitoring for biological effects indicate no reproductive impairment in gastropods.

TABLE 2
 METALS AND OTHER SUBSTANCES

Substance	Standard (ug/l) for fresh Waters		Standard (ug/l) for tidal waters
	Hardness of water measured in mg/l CaCO ₃		
	≤100	>100	
Arsenic	25	25	20
Chromium	5	30	15
Copper	5	30	5
Cyanide	10	10	10
Fluoride	500	500	1,500
Lead	5	10	5
Nickel	8	50	25
Zinc	(see notes)	100	40

Values for metals are for total metal concentration (dissolved and colloidal/s.s.).

The term ≤100 means less than or equal to 100.

The term >100 means greater than 100.

In the case of Zinc, the standard shall be—

8 ug/l for water hardness less than or equal to 10 mg/l CaCO₃

50 ug/l for water hardness greater than 10 mg/l CaCO₃ and less than or equal to 100 mg/l CaCO₃.

**ANNEX B - Final Report – Pollution Inventory Discharges to Sewer or Surface
Waters from Landfill Leachates**

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FINAL REPORT

Pollution Inventory discharges to sewer or surface waters from landfill leachates

Ref: REGCON 70

May 2001

Report prepared for the Environment Agency by:



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Attached CD-ROM

1. Unprocessed data set.xls
2. Raw calculations on effects of leachate treatment.xls

Both files are in Word 97.

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1. INTRODUCTION

The Pollution Inventory (PI) for England and Wales provides details of emissions to air, land and water from processes regulated under Integrated Pollution Control. Under Article 19 of EU Directive 96/61/EC, the UK is required to submit emissions data by 2003 on all IPPC activities to the European Pollution Emissions Register (EPER). Reporting for (non-inert) landfill sites will be achieved by including them in the PI, beginning on a limited basis in 2001, for emissions to sewer and surface waters. The Pollution Inventory lists 57 organic substances and 8 metals, reported as an annual mass for each substance if a stipulated reporting threshold is exceeded. This is a much larger list than the 26 substances currently required for EPER. The list of 65 substances and their reporting thresholds are shown in Appendix 1. The reporting thresholds have been set at lower levels than for EPER, with the intention of capturing data for at least 95 percent of all releases from activities that are regulated by the Environment Agency for England and Wales (the Agency).

To assist the Agency in preparing a reporting protocol for landfill operators, a study has been undertaken into the occurrence of the relevant substances in raw and treated leachates from UK landfills. This report presents the results of that study.

2. OBJECTIVES AND SCOPE OF STUDY

The objectives of the study were to determine the extent to which the listed substances are likely to be present above their reporting thresholds in raw and treated leachates, and to generate a database suitable for the derivation of default values that operators could use, as an alternative to carrying out frequent extensive additional chemical analyses.

Data were obtained by carrying out one-off analysis of 63 raw leachates, from 58 landfill sites, and 24 samples of treated effluents from on-site leachate treatment facilities, during late 1999/early 2000. Figure 1 below comprises a map that shows the locations of landfills sampled, and where those sites had full-scale leachate treatment plants, that enabled samples of treated effluent to be taken.

Subsequently, during December 2000, supplementary samples were taken from 9 additional sites, where treatment by reed bed or methane stripping was being carried out prior to discharge. These samples were taken in order to try and fill in gaps within the database, and to extend results for removal of specific contaminants by particular treatment types.

3. METHODOLOGY

3.1 Sampling and analysis

Samples of leachates and of treated effluents, from full-scale, on-site, leachate treatment facilities were obtained during late 1999/early 2000, from landfill sites in England, Ireland, Scotland and Wales. In all instances, samples were either obtained from frequently-pumped wells, boreholes or sumps, or specific provision was made to pump leachate or effluent for an extended period before samples were taken. The intention was to avoid the taking of stagnant samples, which may have undergone changes in composition while within sampling infrastructure.

No samples were filtered or specifically settled in any way before being taken – the intention being to represent, as fairly as possible, the quality of leachate or effluent that might realistically be discharged.

At each site, various samples were taken. A range of sanitary parameters and metals was determined by Severn Trent Laboratories (STL) in Coventry, on samples taken into two one-litre PET bottles. These samples were refrigerated to 4°C as soon as possible, and in most cases could be delivered to the laboratory within 24 hours of sampling. For less than 20 percent of samples, generally those from remote parts of Scotland, Ireland and South-West England, this period extended up to a maximum of 48 hours.

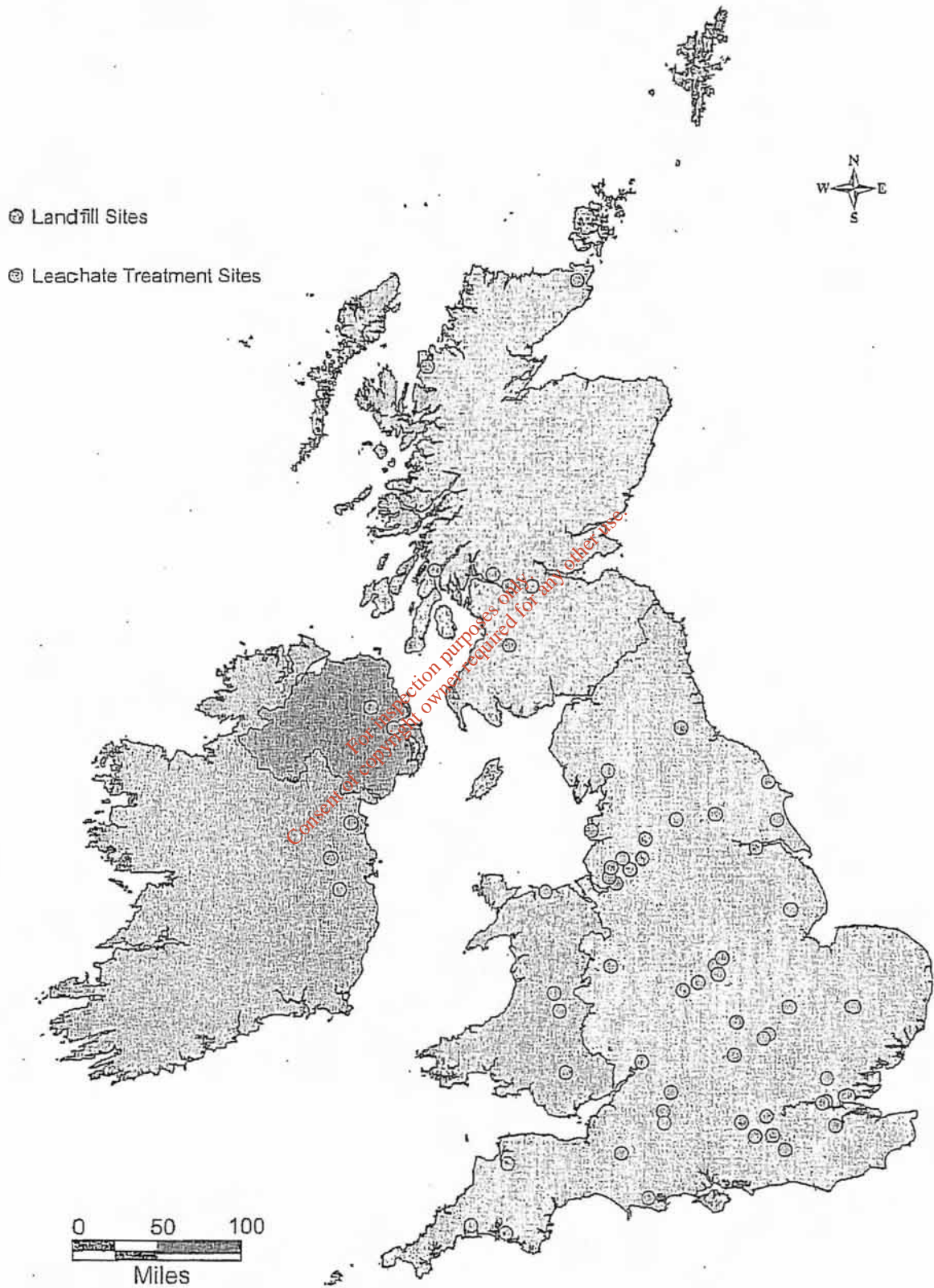
Samples for determination of compounds and elements on the Pollution Inventory list were taken into prepared sample bottles, and submitted to the laboratories of SAC Scientific in Biggleswade, Bedfordshire, as soon as possible. SAC Scientific (SAC) had previously been used to undertake determination of Red List Substances, as part of a large sampling and review exercise into leachate quality at UK landfill sites, undertaken during the period 1990 – 95 (Robinson, 1996), on behalf of the UKDoE/EA.

For some determinations, notably metals, results were obtained from both SAC and STL, although samples submitted to SAC were taken into bottles containing nitric acid or hydrochloric acid as appropriate, and those sent to STL were not. Comparison between the two sets of results was of interest, and is discussed in Section 4.1 below.

All samples and site locations remain anonymous, in order to respect confidentiality agreements made with site operators.

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Figure 1. Map of landfills and leachate treatment plants sampled



3.2 Independent Analysis

Six samples of leachate or treated leachate were taken in duplicate, and one set of samples was submitted to Mr Chris Pickford at the laboratories of AEA Technology (AEA) at Harwell. AEA has been involved in a long-running programme on behalf of the Agency, to develop standard methodologies for the determination of Red List substances in landfill leachates, and undertake inter-laboratory comparison studies of this.

AEA was able to offer an independent check on some of the results being provided by SAC, for those Red List substances included within the Pollution Inventory list. AEA is far from being a "routine commercial laboratory", with costs per sample for just Red List analyses being in excess of £1000 + VAT, but is able to offer sophisticated techniques such as use of radioactive isotopes of compounds, to provide more accurate data on extraction efficiencies for specific compounds from landfill leachate matrices.

Results for the comparison between AEA and SAC results for Red List compounds, on the six duplicate samples, are presented in full in Appendix 2, where detailed analytical notes are included within tables of results. The specialised techniques used by the AEA laboratory generally provided improved limits of detection, although no recovery of dichlorvos was achieved, and AEA reported detection of the herbicide atrazine at concentrations of up to 3 times greater than the SAC detection limit, although SAC reported no atrazine in any of the six samples.

Results from AEA nevertheless provided confirmation that SAC represents a good commercial laboratory for determination of trace organic substances in landfill leachates, recognising that analysis involves very low levels of contaminants, within relatively dirty samples.

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4. RESULTS

The full raw data set is included with this report on a CD-ROM. It is presented as a single Excel worksheet. No site names are given in the data set, but the site identifiers show which treated leachates are derived from which raw leachates. For each site, the worksheet includes descriptors of the waste input types, the relative wetness or dryness of the site and the biochemical status of its leachate. For the treated leachates, descriptors placing the treatment process into one of four categories of treatment are included.

Results from the supplementary samples taken in December 2000 are included as a separate block of data in the worksheet. They have not been included in the main data analysis presented here for raw leachates, but have been used when calculating the percentage removals during various leachate treatment processes.

4.1 Completeness and quality of data

Complete data sets were obtained for most determinands. However, laboratory delays occurred before analysis for nonyl phenol in a large group of samples. This is thought to have resulted in significant loss of compound, as result of which, too few reliable results for nonyl phenol were obtained for data analysis. No results were obtained for octyl phenol.

Metal results compared well between the two laboratories, except for some metals at the lower concentrations, where samples that had been acidified on site gave higher concentrations. The comparison between the two laboratories is shown graphically for all metals, in Appendix 2. An example is shown in Figure 2, which compares the results for zinc between the two procedures. For the data analysis, the results from the samples acidified on-site were used.

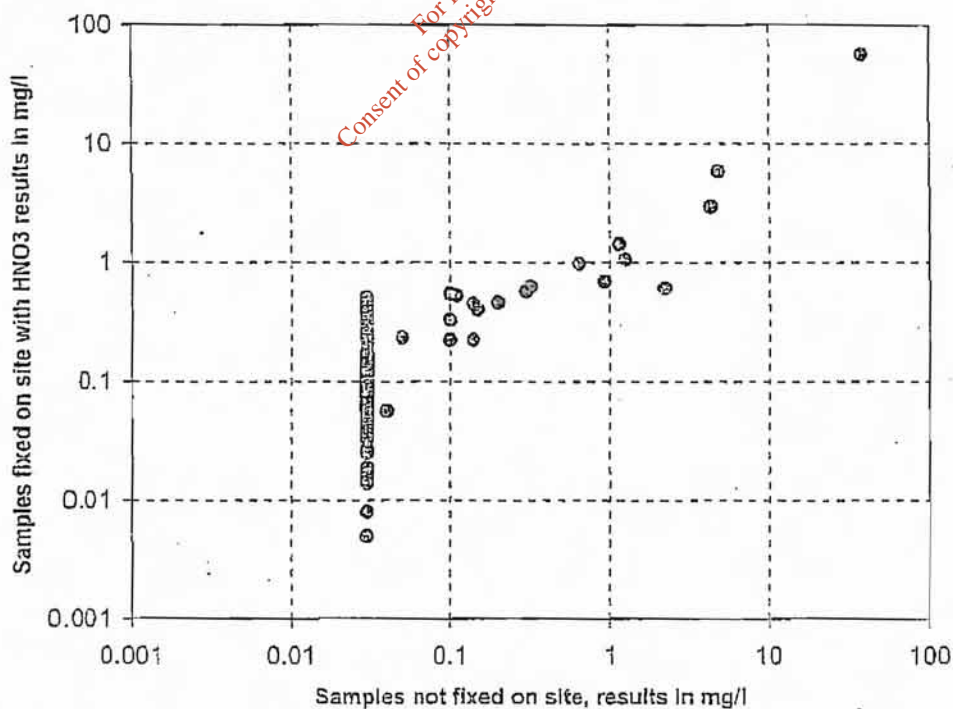


Figure 2. Comparison of zinc in raw and treated leachates, from two different procedures.

4.2 Representativeness of the leachates sampled

The distribution of chloride and concentrations of ammoniacal-N in the 63 raw leachates is shown in Figures 3 and 4 and their summary statistics are compared below with those in an earlier study:

	This study		Robinson (1995)	
	mean	median	mean	median
chloride	1555	1290	1256	1140
NH ₃ -N	611	405	491	453

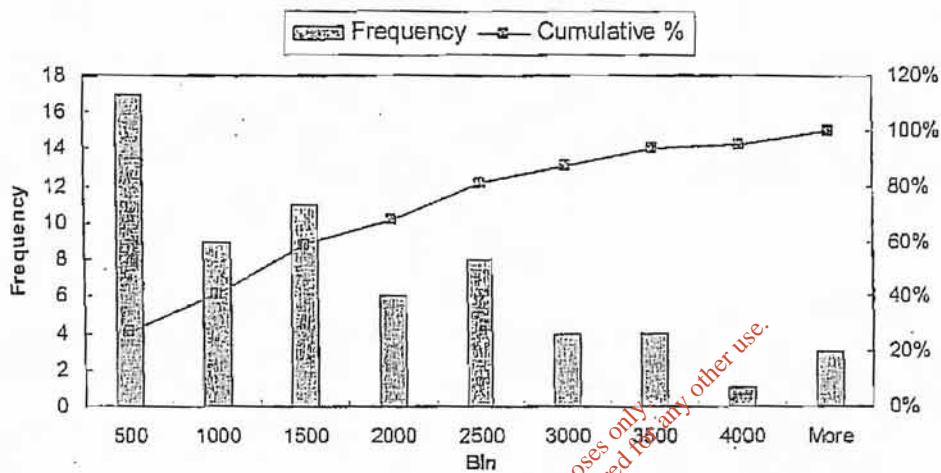


Figure 3. Histogram of chloride concentrations in raw leachates in this study (concentrations in mg/l)

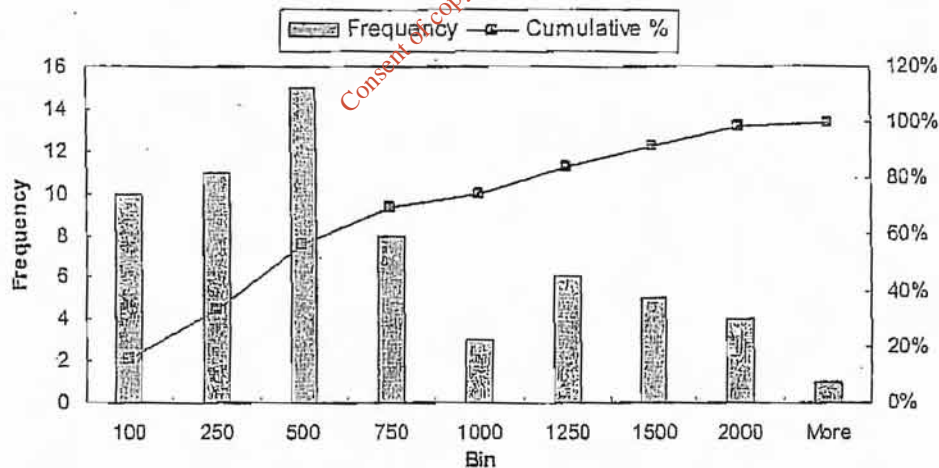


Figure 4. Histogram of concentrations of ammoniacal-N in raw leachates in this study (concentrations in mg/l)

The distribution and statistics for these two key indicator parameters, and their similarity to the values in earlier studies, suggest that the leachates sampled in this study spanned the typical range of UK leachates and are as representative as could reasonably be achieved.

4.3 Threshold reporting limits

The reporting thresholds in the Pollution Inventory are stated as a *mass* per year. In Table 1 these have been converted to threshold *concentrations* for a range of leachate discharge flow rates. The flow rates encompass the majority of discharges from UK landfills. Also shown in Table 1 are the detection limits achieved in this study for each substance. Although lower detection limits can sometimes be obtained in cleaner waters for some of the listed substances, those in Table 1 represent what is reliably achievable in leachate samples on a routine basis at commercial laboratories. For many of the substances, at typical leachate discharge flows, the reporting thresholds are several tens or hundreds of $\mu\text{g/l}$. For some, at the higher flow rates, the threshold concentrations are in the ng/l range and are below the detection limits normally achievable in leachate. Shaded values indicate reporting threshold concentrations that are below the detection limit. For these substances, at the discharge flows concerned, there would be difficulty in estimating the annual mass emission and determining whether it was below the reporting threshold. At flow rates of $100\text{m}^3/\text{d}$ or greater, 15 substances could be problematic, rising to 35 substances at flow rates of more than $1000\text{m}^3/\text{d}$.

Table 1. Descriptors used for raw and treated leachate samples

RAW LEACHATE		
<i>waste input type</i> [based on knowledge of the site]	W1	Municipal
	W2	Municipal + non-hazardous industrial wastes
	W3	Co-disposal of Special/hazardous wastes
<i>moisture regime</i> [based on knowledge of the site, plus analysis data for Cl, $\text{NH}_3\text{-N}$, etc.]	D1	Dry
	D2	Medium
	D3	Wet
<i>leachate biochemical status</i> [based on examination of conventional analyses]	A	Acetogenic
	AT	Transitional
	M	Methanogenic
TREATED LEACHATE		
	T1	Methane stripping
	T2	Wetland
	T3	Biological
	T4	Biological + polishing (various systems)

substance	Reporting threshold		Equivalent concentration threshold at daily leachate flow (in m ³) of:						Detection Limit
	annual mass:		10	50	100	200	500	1000	
	units	value	(all concentrations in ug/l)						
aldrin	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
atrazine	g	60	16.4	3.3	1.6	0.8	0.3	0.2	0.1
azlnphos-methyl	g	4	1.1	0.2	0.1	0.05	0.022	0.01	0.2
azlnphos-ethyl	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
benzene	kg	1	274	55	27	14	5	3	10
bentazone	kg	1	274	55	27	14	5	3	0.1
biphenyl	kg	1	274	55	27	14	5	3	0.1
carbon tetrachloride	g	250	68	13.7	6.8	3.4	1.4	0.7	1
chloroform	kg	4	1096	219	110	55	22	11	1
chloronitro toluenes	kg	1	274	55	27	14	5	3	0.1
4-chloro-3-methylphenol	kg	1	274	55	27	14	5	3	0.2
2-chlorophenol	kg	1	274	55	27	14	5	3	0.2
chlorfenvirphos	g	10	2.7	0.5	0.3	0.14	0.05	0.03	0.1
2,4 D non-ester	kg	1	274	55	27	14	5	3	
2,4 D ester	g	400	110	22	11.0	5.5	2.2	1.1	0.1
DDT all isomers	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
dameton	g	200	55	11.0	5.5	2.7	1.1	0.5	
diazinon	g	10	2.7	0.5	0.3	0.14	0.05	0.02	0.1
1,2-dichloroethane	kg	2	548	110	55	27	11	5	1
2,4-dichlorophenol	kg	1	274	55	27	14	5	3	0.2
dichlorvos	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
dieldrin	g	2.5	1	0.14	0.07	0.03	0.014	0.007	0.1
dimethoate	g	400	110	22	11.0	5.5	2.2	1.1	0.1
endosulfan	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
endrin	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
fenitrothion	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
fenthion	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
hexachlorobenzene	g	20	5.5	1.1	0.5	0.3	0.11	0.05	0.1
hexachlorocyclohexanes	g	20	5.5	1.1	0.5	0.3	0.11	0.05	0.1
hexachlorobutadiene	g	4	1.1	0.2	0.1	0.05	0.022	0.01	0.1
isodrin	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
linuron	g	800	219	44	21.9	11.0	4.4	2.2	0.1
malathion	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
mecoprop	kg	1	274	55	27	14	5	3	0.1
mevinphos	g	8	2.2	0.4	0.2	0.11	0.04	0.02	0.1
naphthalene	kg	1	274	55	27	14	5	3	0.1
nonylphenol ethoxylate	kg	1	274	55	27	14	5	3	
nonylphenols	kg	1	274	55	27	14	5	3	0.2
octylphenols	kg	1	274	55	27	14	5	3	
omethoate	g	4	1.1	0.2	0.1	0.05	0.022	0.011	
parathion	g	0.5	0.14	0.03	0.014	0.007	0.003	0.001	0.1
parathion methyl	g	1.5	0.41	0.08	0.04	0.02	0.008	0.004	0.1
pentachlorophenol & its compounds	g	50	13.7	2.7	1.4	0.68	0.27	0.14	0.1
permethrin	g	10	2.7	0.5	0.3	0.14	0.05	0.03	0.1
polychlorinated biphenyls	g	2	0.55	0.11	0.055	0.027	0.011	0.005	0.05
simazine	g	80	22	4.4	2.2	1.10	0.44	0.22	0.1
triazophos	g	2	0.55	0.11	0.055	0.027	0.011	0.005	0.1
tributyltin compounds	g	5	1.37	0.27	0.137	0.068	0.027	0.014	0.1
trifluralin	g	4	1.10	0.22	0.110	0.055	0.022	0.011	0.1
triohenyllin compounds	g	5	1.37	0.27	0.137	0.068	0.027	0.014	0.1
tetrachloroethylene	kg	9	2466	493	247	123	49	25	1
toluene	kg	1	274	55	27	14	5	3	10
trichlorobenzene all isomers	g	40	11.0	2.2	1.1	0.55	0.22	0.11	0.3
1,1,1-trichloroethane	g	200	55	11.0	5.5	2.7	1.1	0.5	1
1,1,2-trichloroethane	g	200	55	11.0	5.5	2.7	1.1	0.5	1
trichloroethylene	kg	11	3014	603	301	151	60	30	1
xylanes	kg	1	274	55	27	14	5	3	10
arsenic	kg	6	1644	329	164	82	33	16	1
cadmium	kg	1	274	55	27	14	5	3	6
chromium	kg	20	5479	1096	548	274	110	55	20
copper	kg	20	5479	1096	548	274	110	55	5
lead	kg	20	5479	1096	548	274	110	55	20
mercury	g	130	35.6	7.1	3.6	1.8	0.7	0.4	0.5
nickel	kg	20	5479	1096	548	274	110	55	10
zinc	kg	20	5479	1096	548	274	110	55	5

Table 2. Comparison of threshold reporting levels with detection limits achieved in this study

4.4 Data analysis

For the raw leachates, each site was given a qualitative descriptor for each of three factors, namely: waste input type; moisture regime; leachate status (methanogenic/acetogenic). These were considered the factors most likely to affect the presence and concentration of the listed substances. For the treated leachates, the treatment process was allocated one of four descriptors, representing the generic level or type of treatment process. Data were examined for correlation between concentrations of listed substances and these descriptors as well as other conventional leachate parameters, such as chloride and TOC. The descriptors used for this analysis are shown in Table 2.

The leachate biochemical status was determined as follows:

acetogenic: if any of the following applies: BOD/COD > 0.4
 COD > 5 000 mg/l
 pH < 6.5

methanogenic: if none of the above applies

4.5 Overview of raw leachate data set

Table 3 shows the frequency of occurrence of each substance in the original 57 raw leachates. Out of the whole list, only 12 substances were present in more than 5% of samples, and only 8 of these were present in more than 50% of samples. Six of the 12 substances were metals and 4 were aromatic hydrocarbons. Summary statistics for all 12 substances are shown in Table 4.

Table 4. Summary statistics for substances found in more than 5 % of raw leachate samples in this study (concentrations are given in µg/l)

Substance	Frequency % samples	mean	median	min	max	5%ile	95%ile
zinc	100	1,246	135	8	56,000	18	1,376
mecoprop	98	21.8	11	<0.1	140	0.253	67
arsenic	94	16	8	<1	160	<1	39
nickel	86	159	60	<10	1,530	<10	635
naphthalene	70	3.04	0.46	<0.1	42	<0.1	11
copper	60	26	11	<5	354	5	82
toluene	54	87	21	<10	1,287	<10	347
biphenyl	51	0.46	0.1	<0.1	8.6	<0.1	1.26
xylenes	35	59	35	<30	208	<30	147
chromium	33	92	50	<50	1,240	<50	218
lead	8	60	<50	<50	410	<50	59
PCP	8	0.32	<0.1	<0.1	1	<0.1	1.0

All 12 substances showed a marked positive skew, with the mean being significantly greater than the median.

4.6 Raw leachate correlation with descriptors

For each substance in Table 4, the raw leachate data have been graphed as bar charts against the descriptors for waste input type, moisture regime and leachate biochemical status. These

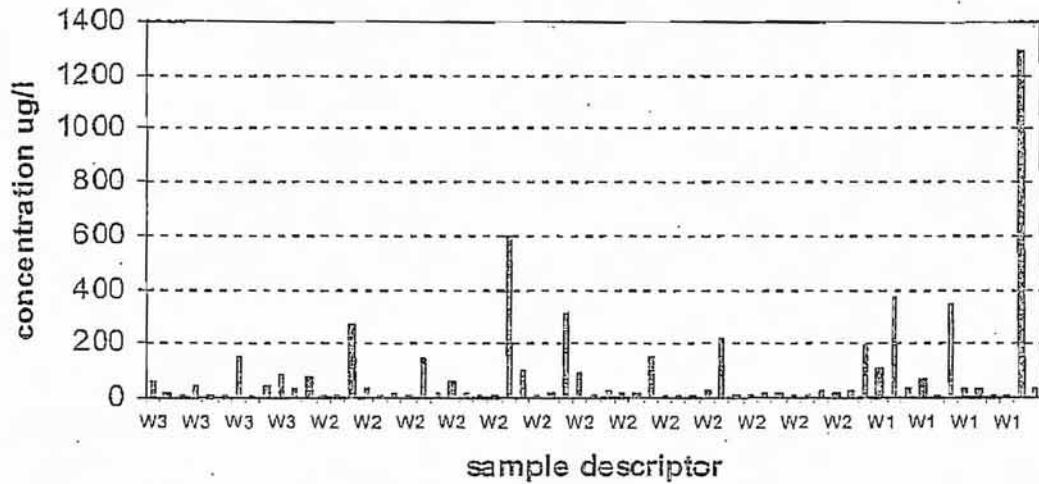


Figure 5. Correlation of toluene in raw leachate with waste input descriptor, this study

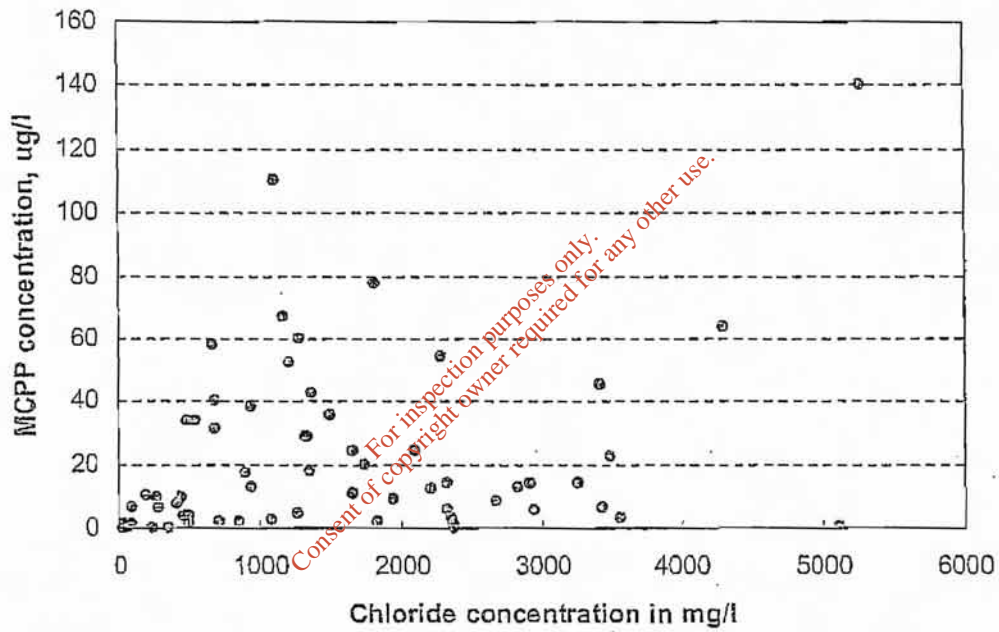


Figure 6. Correlation of mecoprop in raw leachates against chloride concentration, this study

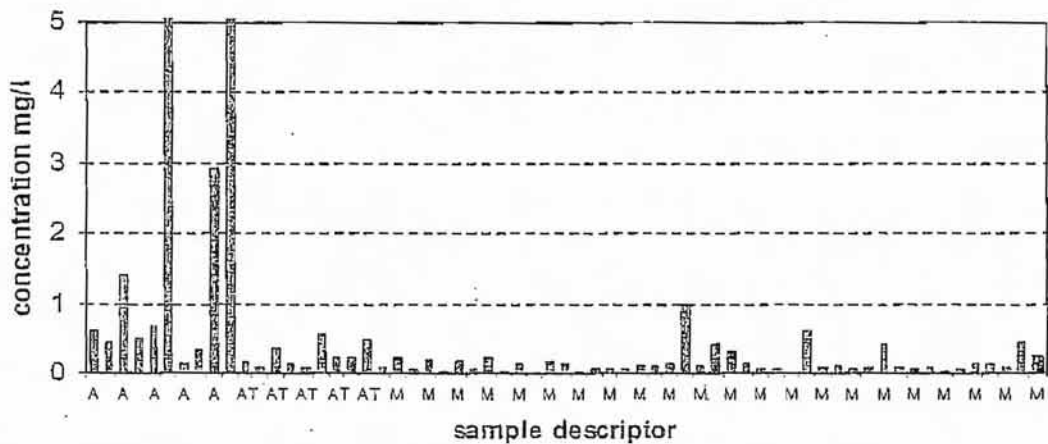


Figure 7. Correlation of zinc concentrations with leachate status, this study.

The median percentage removal was calculated for the 12 substances listed in Table 4, for each of the four treatment classes. In some cases, even with the supplementary samples from December 2000, there were insufficient data to do this rigorously, as many of the raw leachates at sites with treatment plants did not contain the listed contaminants. In some cases, percentage removals were therefore estimated, e.g. treatment T4 (biological plus polishing) was assumed to be at least as efficient as T3 (biological only). The calculated and estimated removal percentages are shown in Table 5, which is based on the combined data from the original and supplementary samples.

Table 5. Median percent removal of substances during leachate treatment by different processes.

	T1	T2	T3	T4
zinc	0	90	70	70
mecoprop	0	50	99	99.5
arsenic	20	50	70	70
nickel	0	0	20	20
naphthalene	40	0 ⁽¹⁾	95	95
copper	10	20	50	50
toluene	25	0 ⁽¹⁾	80	80
biphenyl	0	0 ⁽¹⁾	60	95
xylenes	40	0 ⁽¹⁾	60	75
chromium	0	0 ⁽¹⁾	30	30
lead	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾	0 ⁽¹⁾
PCP	0 ⁽¹⁾	0 ⁽¹⁾	50	60

notes: (1) little or no data obtained from this study, so default value set at zero, but in practice some removal may occur, and may be revealed in future studies.

A high percentage removal was found for mecoprop, and to a lesser extent for the other organic determinands listed in Table 4, during most forms of treatment. Metals were removed to varying degrees. Of the metals, zinc and arsenic were removed to the greatest extent, typically 70-90%, while nickel and chromium were least affected, typically being reduced by only 20-30%.

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Appendix 1. UK Pollution Inventory list for discharges to sewer and surface water

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Appendix 1. UK Pollution Inventory list for discharges to sewer and surface water

substance	Reporting threshold	
	units	annual mass value
aldrin	g	0.5
atrazine	g	60
azinphos-methyl	g	4
azinphos-ethyl	g	0.5
benzene	kg	1
benzazone	kg	1
biphenyl	kg	1
carbon tetrachloride	g	250
chloroform	kg	4
chloronitro toluenes	kg	1
4-chloro-3-methylphenol	kg	1
2-chlorophenol	kg	1
chlorfenvinphos	g	10
2,4 D non-ester	kg	1
2,4 D ester	g	400
DDT all isomers	g	0.5
demeton	g	200
diazinon	g	10
1,2-dichloroethane	kg	2
2,4-dichlorophenol	kg	1
dichlorvos	g	0.5
dieldrin	g	2.5
dimehoate	g	400
endosulfan	g	0.5
endrin	g	0.5
fenitrothion	g	0.5
fenthion	g	0.5
hexachlorobenzene	g	20
hexachlorocyclohexanes	g	20
hexachlorobutadiene	g	4
isodrin	g	0.5
linuron	g	800
malathion	g	0.5
mecoprop	g	1
mevinphos	g	8
naphthalene	kg	1
nonylphenol ethoxylate	kg	1
nonylphenols	kg	1
octylphenols	kg	1
ornothoate	g	4
parathion	g	0.5
parathion methyl	g	1.5
pentachlorophenol & its compounds	g	50
permethrin	g	10
polychlorinated biphenyls	g	2
simazine	g	80
triazophos	g	2
tributyltin compounds	g	5
trifluralin	g	4
triphenyltin compounds	g	5
tetrachloroethylene	kg	9
toluene	kg	1
trichlorobenzene all isomers	g	40
1,1,1-trichloroethane	g	200
1,1,2-trichloroethane	g	200
trichloroethylene	kg	11
xylenes	kg	1
arsenic	kg	6
cadmium	kg	1
chromium	kg	20
copper	kg	20
lead	kg	20
mercury	g	130
nickel	kg	20
zinc	kg	20

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Appendix 2. Comparison of results from analysis of six selected duplicate samples of leachate and treated leachate, by laboratories at SAC Scientific, Biggleswade and AEA Technology, Harwell

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Notes for tables:

- (1) All results in nanogrammes per litre.
- (2) Analyses "S" (unshaded) by SAC Scientific.
- (3) Analyses "A1" and "A2" where duplicate result obtained, (shaded), by AEA Technology
- (4) NR = no result (extraction failed)
- (5) Limits of detection (LOD) as shown. Values by AEA within a factor of 10 x LOD are given in parentheses and have very high uncertainty. Values with raised LODs reflect interferences; i.e. a positive value was obtained, but the mass spectrum indicated that the detected compound was not the target compound.
- (6) Red List organophosphorus compounds: 200ml spiked with internal isotope standards, extracted with dichloromethane (3x), and derivatisation as appropriate.
- (7) Red List organochlorine compounds and VOCs: 400ml extracted in duplicate. Poor recovery for both duplicates of sample 81.

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Appendix 3. Graphical comparison of metals results from two laboratories, using two different methods of sample storage and pretreatment

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