BEST AVAILABLE TECHNIQUES FOR LANDFILL LEACHATE EXTRACTION AND PUMPING?

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SUMMARY: Best practice in modern landfill management requires the efficient collection, extraction, pumping, and disposal of leachate. This paper discusses the options available for leachate extraction; from auger driven round cased boreholes to precast and in-situ concrete wells and upslope risers. The range of pumping systems available is also described, including recent developments in leachate pumping, and the relative merits of each are identified. The most appropriate techniques for leachate extraction are discussed for a range of typical landfill types, age, operational and environmental settings.

With the introduction of IPPC regulation to Landfills, all operators are required to adopt Best Available Techniques (BAT). Surprisingly, it is only necessary to apply good practice to leachate extraction and pumping systems as BAT is disapplied to landfill in the statutory instruments, and there is very little formal guidance currently available on best practice for leachate extraction and pumping. This paper describes the limited formal guidance currently available in the UK, and goes on to suggest the scope of issues, which the writers consider the industry needs to address in order to raise operator awareness of the techniques available, and to encourage UK landfill operators to adopt the best techniques available. The paper also discusses problems commonly confronted in obtaining consistent landfill dipped leachate level data, and suggests a new protocol for leachate level monitoring which may be applied to all actively pumped landfills where the problem is encountered.

1. INTRODUCTION

Best practice in modern landfill management requires the efficient collection, extraction, pumping, and disposal of leachate.

All landfills designed to current standards, and most landfills of an earlier design, should incorporate a containment lining system installed to a design based on a Hydrogeological Risk Assessment (HRA). The landfill must be maintained at or below the level adopted in the HRA in order that the theoretical rate of leachate emission through the liner does not exceed that considered acceptable in the HRA.

For the operators of many landfills the control of leachate levels has proven significantly more onerous than anticipated. This is particularly the case given that the permeability of waste under pressure is lower than might be expected intuitively, and has been measured at $1x10^{-6}$ m/s at depths of 30m in reported studies[1] and processed wastes exhibit even lower permeabilities.

To compound the problem, an almost universal rule has been adopted; that of the "maximum 1 metre leachate" depth rule. This rule has been applied equally to large shallow, wet and difficult to drain landfills where base drainage falls may be very slack, and to easily drained deep "dry and small" landfills. This one-depth-fits-all approach has possibly arisen due to the fact that when the HRA is carried out the hydrogeologist will seldom, if ever, have the benefit of knowledge of base falls, or of the practicable leachate collection chamber positions and spacings. These details will only later be derived during the detailed design stage, when the landfill engineer will no longer have the opportunity to improve drainability or vary the 1 metre depth requirement.

The ability to comply with the one metre depth rule was often made more difficult by the early practise of landfill designers whereby leachate collection wells were routinely built over the lining without lowering the lining locally. It has now been realised that it is necessary to form a "sump" into which the leachate drainage will gravitate, despite the increased construction complexity entailed by constructing a lower lining area beneath the chamber (or collection zone of an upslope riser).

The less than ideal drainage hydraulics of the majority of landfill sites, as described above, imparts a high level of dependency upon the quality of the extraction and pumping system. The extraction system starts at the point at the base of each well or manhole where the leachate enters the pump, or suction main.

Unless, the extraction and pumping system operates reliably and draws its flow from very close to the base of each sump or well, there will be a much-reduced ability to draw the leachate to the collection point from remote areas, and the likelihood arises that the 1 metre rule will not be achieved.

Therefore, it is important that best practise be applied to all these systems. For the many leachate treatment plants to which IPPC (PPC) permitting applies it will also be necessary to apply BAT, and BAT now has a very specific meaning and a scope of application which requires careful consideration.

2. BAT?

BAT originates from the IPPC Directive, 96/61 EC, and is implemented in the UK by the Pollution Prevention & Control Act 1999. It stands for Best Available Techniques, and supersedes BATNEEC (Best Available Technology Not Entailing Excessive Cost), under the Environmental Protection Act 1990, but embodies and extends the same principles. For all activities falling under the Directive, BAT must be applied, and the question therefore arises as to the extent that BAT must be applied to leachate extraction and pumping?

Landfill is controlled under the Landfill Directive, and this is implemented by the Landfill (England & Wales) Regulations 2002, which provides the general requirements for landfills and compliance with which can be assumed to include BAT compliance (Schedule 2). The requirements for leachate collection are nominal, and simply require (2.(c)) that the operator collects contaminated water and leachate, and treats it to the appropriate standard so that it can be discharged. Schedule 2, 3.(b) requires the operator to “ensure efficient collection of leachate”. This is the extent of the requirements, and Paragraph 3 of Reg. 5 of the Landfill Regulations effectively disapplies the detailed consideration of BAT for landfills, and thereby also for leachate extraction and pumping.

However, at those sites where an on site treatment plant is necessary, and that process has a throughput of more than 50 tonnes per day (non hazardous leachate), or 10 tonnes per day hazardous leachate, the treatment plant itself will fall under the IPPC Directive, and require BAT assessment, for the treatment plant itself. Despite the fact that the leachate extraction system forms a technically connected part of the treatment facility (i.e. the treatment plant could not function without its collection system), BAT will only apply to the treatment facility. However, for the plant to be the BAT solution at all, a reliable leachate collection extraction and pumping system will be essential (both for old unlicensed and current landfills).

3. LEACHATE EXTRACTION SYSTEMS

For the purposes of this paper we have assumed that leachate extraction (as opposed to the leachate collection network within the basal liner) embraces:

1. the wells and boreholes within the landfill into which the leachate collection network conveys the leachate;

2. the pump systems which extract the leachate from the wells and boreholes;

3. the systems which deliver the motive force to the pumps;

4. the pipes/pipelines which convey the leachate to the collection tank, or treatment plant location;

5. the monitoring and control systems.

Given the breadth of skills required to achieve the extraction of leachate it is not surprising that a number of specialist leachate extraction contracting organisations have emerged to fill the demand.

Existing technologies and products from closely allied fields have been refined, and new products have been developed. There are now recognised technologies and products, which are currently applied principally to leachate extraction from well and borehole designs, to pump systems.

3.1 Wells & Boreholes

The types of wells regularly utilised in leachate extraction are characterised as follows (listed in the approximate order of their first introduction):-

1. **massive engineering structures** in the form of rigid towers extending full height to the restored surface, and which were built during the late 1980 and early 1990’s to enable very deep vertical sided quarries in the UK to be infilled and continuously drained by pumping. A typical example is the Enderby Warren Quarry Landfill, Leicestershire, SITA UK;

2. the most commonly used wells have been **pre-cast concrete chamber rings**, in sizes between 600 mm and 1.8 m diameter, (sometimes larger) which were progressively raised with each lift of the waste, in which electric submersible pumps were most often used;

3. **percussion driven boreholes**, retrofitted into the waste, lined in drainage stone/filter textile and cased, before a pump is installed. Casings are normally steel initially but these can often be removed and replaced with plastics, and stone packing may be added to act as a drainage and filter medium;

4. **proprietary HDPE well systems** based upon designs developed initially in Germany have been used on a number of UK sites. These systems are raised progressively in much the same manner as pre-cast concrete wells. These are capable of withstanding greater settlement without damage, and are not prone to corrosion being made from plastic. The thickness of HDPE pipe walls used in these systems is substantially thicker than used in the water industry. Very thick sections are needed in order to withstand the large compression forces at the base of deep landfills.

5. **upslope risers** are wells laid against the battered internal slopes of landfills, which have become common to support the landfill lining materials. Upslope risers are laid against the sloping liner, and are assumed to suffer less from settlement damage than vertical wells, due to their proximity to the edge of the landfill. An advantage also arises, that a connection may be feasible into the leachate under-drains, enabling the possibility of cleaning (rodding or jetting) the leachate under-drainage system. However, designers of upslope risers must take care to select pipe wall strengths based upon actual stresses imparted by the overlying waste. The adoption of the pipe supplier's normal safe burial depth tables, which assume that pipes will be laid into trenches (and benefit from "arching" of the stone pipe surrounds which reduces crushing loads), has resulted in pump loss in oval, or crushed, upslope risers.

3.2 Leachate Pumping Systems

The following leachate pumping technologies are currently in use in landfills in the UK:

1. **Electric Pumps;** A wide variety of pump types are used, all must be suitably corrosion protected to a high standard, and non-leachate compatible materials avoided. The types of electrical pumps used include progressive cavity borehole pumps, multistage submersible pumps, high head dual impeller multistage pumps, explosion proof pumps (inherently safe in explosive landfill gas mixtures).

2. **Eductive Pumping;** Utilises the "venturi effect" in a liquid as the pumping mechanism. A small volume of liquid at high pressure provides the motive force at the eductor located at the base of the leachate borehole or well, where the venturi is located. The eductor is based on the principle of using a small volume of liquid at a high pressure which inducts a larger flow at the venturi nozzle, and both the initial flow and the inducted flow is then delivered back to the starting point using the remaining liquid pressure (head). At the original pump location, a simple header tank is provided which allows the excess flow generated to discharge over a weir, and the remaining portion is recirculated through the pumps where it is pressurised and recirculated to the venturi to again educt and draw in more leachate.

3. **Pneumatic (air driven) Reciprocating Pumps:** Introduced from the US in the mid-1990s, these pumps use air as the motive force at the pump head, and are currently very popular in the UK. Pneumatic pumps can be selected for their self-regulating capability, and normally

do not require any external form of level sensing to initiate pumping. The design uses a lightweight (often plastic) pump float that rises with the incoming liquid as the pump cylinder fills. Once the pump bore fills to a sufficient depth the rising float activates a small lever which triggers an air valve which starts a one stroke air-cycle which forces the float

Table 1: Leachate Pump Types, with Advantages and Disadvantages

Pump Type	Installation/ Capital Cost	Operational Considerations (MF = maintenance frequency, LC = level control, EE = energy efficiency)	Approx. Max. lift/flow	Health & Safety
Electric Pumps				
centrifugal (sewage type)	average inc. precast chamber	MF – average LC – external EE - average	30m/ 3 to 30 l/sec	Explosion rating applies, but risk exists from the 3-Phase power distribution cables needed around site
progressive cavity	above average inc. chamber	MF - low LC – external EE - good	>30m/ 3 to 5 l/sec	As above
borehole	below average no chamber cost - just b/h packing & lining	MF – average LC – external EE - good	30m/ multistage 3 to 30 l/sec	Good - b/hs usually too small for man entry
Hydraulic Pumps				
eductor	average (if compact site) otherwise pipe costs high with in and out (twin) pipes always required.	MF - low* LC – external EE - poor	20m - 30m/ 3 to 30 l/sec	Good - avoids electricity distribution risks as all equipment can be locked away in pump room
Pneumatic Pumps (positive displacement & centrifugal) ***(NB: Air drying / filters required)***				
floating piston	above average	MF - high LC – self governing EE - best	10m/ 1 to 3 m^3/hr	As above
mechanically coupled push rod**	below average	MF - No information available LC - Submerged pressure transducer EE - good	60 m approx. / 3 to 5 l/sec	As above
Hydraulic-ally driven submersible	average	average	up to 30m/ 3 to 30 l/sec	Average to good/Explosion proof

* - unless calcification occurs (often at pressure drop at eductor nozzle).
** - there is only one supplier to the UK of this recently introduced pump type, as far as we are aware.

back down, and with it the liquid which has filled the cylinder. As the piston drops the inlet valve opens and the cylinder begins to fill again for the next cycle. If insufficient depth of liquid remains in the borehole, the float will not rise, and the pump will cease to operate. All the pneumatic equipment (e.g. compressors, actuators, and controls) above the pump itself are available off-the-shelf, as these components are routinely used in factory applications (e.g. production line and machine tool equipment).

4. **Hydraulically Driven Submersible Centrifugal Pumps:** "Hydrainer" pumps are a well-known example of a pump type that couples a hydraulically driven motor to a pump impeller. These are most commonly used in temporary applications on construction sites, but may also be permanently installed in landfills with the advantage of being intrinsically safe against explosion.

The selection of leachate pumping systems is a complex matter and the best system will vary from site to site with site conditions. Most operators carry out their own trials and make their own pump systems' selection at site level, and the selection of the "Best Practise" solution, and BAT, will vary similarly to suit the site conditions.

Table 1, describes the relative merits of the leachate pumping systems available.

3.3 Factors Affecting Choice of Leachate Extraction System

The most appropriate techniques for leachate extraction will vary with the landfill type, age, operational and environmental setting.

It is still common practise to install leachate collection wells progressively as the landfill rises cell by cell. These wells provide a very good extraction capacity, and will be essential in all wet and/or low waste input rate sites where leachate would otherwise collect and need to be extracted before the landfill surface reaches the final restoration level.

However, these wells are usually of a large enough diameter that they comprise a space large enough for man entry, so the construction of these generates "confined spaces" within the (normally methanogenic – landfill gas producing) landfilled waste.

Under the Construction Design and Management Regulations it could be argued that this method should not be adopted for landfills in dry areas, which will not be expected to generate leachate until some time after they reach final levels. Such landfills can be retrofitted with gas & leachate collection boreholes, which will be of smaller bore. The bore will be too small to permit man entry, and hence the presence of "confined spaces" and the inherent risks involved to personnel are removed. However, the smaller bore can cause operational difficulties with pumps either becoming trapped down boreholes or difficulties arise when reinstalling pumps at the base of the borehole following maintenance.

In Table 2, we have summarised some of the factors as they relate to typical landfill types.

Table 2: Factors Influencing Leachate Extraction System Design

Landfill Type	Well system	Extraction system	Comments
Shallow	Progressive concrete rings or HDPE risers, retrofit boreholes, upslope risers	Any	Suction risers allow safe external installation with pumps on the top, & only a suction pipe within the confined chamber space, but are limited to no more than 4m suction depth.
Sloping walls			
Deep with; **Vertical walls or Sloping walls**	Progressive concrete rings or HDPE risers, retrofit boreholes. Upslope risers	Any	Deep and very deep vertical wall sites show high well failure rates, due to high pressures and large settlements.
Very deep vertical walls	Progressive concrete rings or HDPE risers, retrofit boreholes.	Limited by lift height, see Table 1.	
Land raise	Perimeter gravity drains may be possible	Any. However, in practise a high volume pump may be used at a central collection chamber.	~

4. EXISTING GUIDANCE AVAILABLE AND BEST PRACTICE/TECHNIQUES

Although nearly 10 years old, Waste Management Paper 26b[2] (WMP26b, 1995 – paragraph 6.52) remains the most definitive UK guide to landfill design practise. It provides some very general guidance on gravity drainage systems within the landfill to avoid the "unacceptable build up of leachate on the site lining system". Drainage paths must be provided to conduct the leachate by gravity to the sumps, and a risk assessment must be carried out by the designer to determine the nature of the of any leachate drainage system (i.e. all-over blanket layer of stone, or "herringbone" drainage). WMP26b also quotes previous NRA internal guidance on base falls, plus drainage blanket stone specifications, but merely refers to the possible use of geotextiles without providing any further guidance on suitable geotextiles.

Waste Management Paper 26b also categorises the types of "collection sumps" (6.58 & 6.59), but as this publication pre-dates the adoption of pneumatic pump systems, provides no guidance at all on these systems.

We are told in WMP26b that "the removal system shall be accessible for CCTV and jetting", but no guidance is given on how this can be achieved in deep landfills.

The Irish EPA "Landfill Manuals, Landfill Site Design" [3], gives a similar level of information, but similarly provides no guidance on pneumatic pumps systems. Interestingly, all pumps "must be intrinsically safe" (Paragraph 5.4) in the EPA's sister publication "Landfill Operational

Practices"[4]. Nevertheless, this requirement is seldom applied in the UK and no safety problems appear to have been reported. This is presumably due to even non-intrinsically safe pumps (eg centrifugal types) in landfills being in the presence of methane concentrations in excess of the Upper Explosive Limit, and the pump casings themselves being sealed in such a manner that the propagation of a spark outside the casing is prevented.

4.1 Raising Operator Awareness of Leachate Extraction System Best Practice

This paper outlines a number of leachate extraction and pumping technologies, each of which involve differing Health & Safety issues and require specialist skills to operate.

Good practice in the installation, operation, and maintenance of leachate collection systems by suitably trained and experienced staff is essential to enable leachate collection to maintain leachate levels within consented limits.

Leachate level non-compliances are a major source of breaches of Waste Management Licence Conditions. Permanent damage may be sustained to linings once limits are breached and an excessive emission of leachate may occur. This may jeopardise the future integrity of the landfill containment system, and the water quality underlying the site may take many years to recover.

With the implementation of BAT, and the advent of mono-disposal cells for hazardous wastes, these systems will become more complex, and remain just as vital.

The provision of suitable guidance and training is important to ensure the reduction in emissions, which IPPC is intended to produce, but very little official guidance is available, and this is particularly the case for pneumatic pumping systems.

Additional guidance in the following areas may be beneficial to the operation of leachate abstraction and pumping systems:-

1. Selection of materials suitable for use in contact with leachate: to avoid corrosion, excessive wear, and short pump hydraulic seal lifetimes.

2. A method for the selection of concrete in contact with leachate to suit the contaminants present. (Current practise which results in the adoption of Sulphate Resistant mixes, may no longer be sufficient for certain mono-disposal cell leachates.)

3. Minimum pipe bores for the maintenance of reasonable intervals between rodding or jetting of pipelines. This would also include guidance for pneumatic systems designers to provide an adequate pipe bore to avoid excessive pipe losses.

4. Minimum air pressure reserves at compressors for pneumatic systems to ensure adequate allowance for distribution losses.

5. Minimum falls in pipelines for the avoidance of air-locks, and air valve requirements in leachate pipework.

6. Filters and dryers for the avoidance of the build-up of moisture in pneumatic systems.

7. The choice of level detection control systems in wells, as the industry begins to introduce continuous leachate level monitoring, and automated pump controls into all well types.

8. The implementation of the ATEX Directive 94/9/EC for the use of abstraction pumping equipment in potentially explosive atmospheres (explain)

4.2 Leachate Level Monitoring

The normally accepted method for leachate level monitoring is by dipping boreholes maintained for this purpose.

We have found that at many sites, especially where there is no base leachate blanket, or where leachate base drainage has become clogged, there are persistent and large discrepancies in levels between monitoring well locations, and that such borehole monitoring results may also suggest incorrectly that a landfill is saturated with leachate. It is also a common experience that monitored borehole leachate levels may remain high despite pumped wells remaining drawn down and empty.

It is our view that the levels monitored can often in fact broadly reflect no more than the level of perched water tables in many sites, especially where clay temporary cover materials are used. Where these perched water tables are intercepted by a monitoring well which is un-drained at the base, the well or borehole simply fills to the perched water table depth due to the down flow of leachate.

Under such circumstances, it is preferable to rely on recording the recovery levels of leachate in the leachate extraction pumping wells, after a short period without pumping. These leachate recovery levels have been shown to provide much more consistent level data. In the view of the authors, this method should be considered at all landfill sites when big variations are seen in leachate levels dipped at dedicated wells or boreholes.

A paper presented by Howard Robinson at the CIWM's Annual Waste Management Exhibition and Conference, 2003[5] describes how, by using the technique described above, Arpley Landfill Site has been transformed in terms of leachate extraction and leachate level control to be a fully leachate management compliant site.

5. SUMMARY & RECOMMENDATIONS

The authors have explained the limited relevance of the principles of BAT when applied to landfill leachate extraction. They have summarised the currently available techniques, and commented on the selection of each in tables and in text.

A brief review of current official UK guidance shows that little is available, and most has not been updated for more than 5 years. The need for updated guidance that would for example include for the first time the popular technique of pneumatic pumping, is acute. All systems of this type have been introduced since the available guidance was written.

The authors have identified subject areas which new guidance might cover. They have also introduced a new method for the assessment of leachate levels, by utilising pumped wells and allowing leachate levels to recover over a period of time, which has been shown at the Arpley Landfill Site to provide a more accurate view of the actual leachate levels than traditional static monitoring at dedicated wells.

6. ACKNOWLEDGEMENTS

The authors would like to thank Viridian Systems Limited, Stuart Well Services Limited, B&M Pipelines Limited, and Hydrainer Pumps Limited for their assistance with this paper.

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Key Words:

Leachate collection, leachate pumping, leachate monitoring, borehole, well, extraction, upslope riser, BAT, Best Available Techniques, pneumatic pumping, hydraulic pumping, air pumping, electrical pumping, centrifugal pumps, positive displacement pumps, progressive cavity pumps, eductor, float, waste management paper, friction loss, rodding, jetting.