REMEDIATION OF LEACHATE PROBLEMS AT ARPLEY LANDFILL SITE, WARRINGTON, CHESHIRE

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SUMMARY

When Waste Recycling Group (WRG) took over Arpley Landfill in Spring 1999, it inherited a site where leachate was up to 8 metres above consented levels. After tankering over 200,000m^3 of leachate for treatment off-site, investing nearly £3 million in leachate extraction infrastructure and a state-of-the-art on-site leachate treatment plant, the site is being transformed. The treatment plant was commissioned in October 2001, and by May 2003 had treated nearly 150,000 cubic metres of exceptionally strong leachate, to very high standards suitable for discharge into the river Mersey. Dramatic reductions in leachate levels have been achieved in all areas of the landfill site, with the great majority of locations either within, or close to, compliant levels. This paper describes how the project has been implemented, and presents detailed operational data for the leachate management and treatment system.

In terms of loads of contaminants being treated, the Arpley plant is almost certainly the largest leachate treatment plant in the UK, and represents a successful demonstration of use of Best Available Technology, to solve a serious leachate problem.

1. ARPLEY LANDFILL

Arpley Landfill Site is located on the south bank of the River Mersey, west of Warrington, on 130 hectares of land, originally used for disposal of dredgings from the Mersey and from the Manchester Ship Canal. Since it opened in October 1988, the site has received more than 10 million tonnes of domestic, commercial and industrial wastes, emplaced to depths of up to 30 metres, and continues to accept about 800,000 tonnes per year of primarily domestic wastes. Infilled areas are being progressively restored to a mixture of agriculture, woodland and public open space, being blended into the important 186 acre Moore Nature Reserve, which adjoins the site and is managed and funded by WRG (Warrington Worldwide, 2003). Wastes have been deposited within three phases, Birchwood, Lapwing and Walton, with increasing degrees of containment, in keeping with advances in legislative requirements. Plate 1 comprises an aerial view of the site, looking due west.

Plate 1: Arpley Landfill, looking due west towards the estuary of the River Mersey showing the leachate treatment plant in centre foreground

Tipping cells and phases have variable degrees of basal drainage in place. The original Birchwood Phase (18.5ha, 1988-1994) had no as-built construction drawings available, but it was reported that leachate drainage is by a herringbone of rubble drains. The subsequent Lapwing Phase (40.7ha, 1994-1997) comprises eight cells with a variety of drainage systems, each to a pumping chamber. The most recent Walton Phase (to be ultimately 45ha, 1997-), again has a variety of leachate drainage arrangements, albeit to higher standards than earlier areas.

When WRG acquired Arpley Landfill Site, from 3C Waste (Cheshire County Council) in Spring 1999, leachate management at the site was not under control, and there was complete lack of an effective infrastructure to enable adequate volumes of leachate to be extracted from the existing chambers. Substantial investigations and engineering works were necessary to sort out the problems which were faced.

2. INITIAL WORKS AT ARPLEY

Landfill gas control

Another aspect of the site which required high levels of attention and investment at Arpley, was control of landfill gases. Initial works concentrated on improved control of landfill gas emissions – the £8 million Arpley generation scheme is the largest landfill gas power station in the UK, and capable of generating 16MW of electricity for export into the National Grid, enough to supply the needs of 16,000 households. It was commissioned in October 2000. Gas is extracted from over 200 wells, which had to be drilled and installed, via more than 10km of pipelines. Also important in control of landfill gas, and of leachate generation, have been works to provide high specification capping to completed areas of filling. Reduction in levels of leachate across the site was also necessary, in order to allow extraction of maximum volumes of landfill gas.

Leachate collection and extraction

As described, a wide range of leachate drainage systems had historically been installed at Arpley, and these did not allow adequate quantities of leachate to be extracted. Extensive investigations by WRG revealed that specific leachate collection chambers were defective, due either to collapse or to silting, and remedial solutions were proposed and implemented. Because in the pumped removal of leachate from the collection chambers, it is the drainage of leachate from wastes into the chamber that controls rate of leachate extraction, **not** the finite capacity of the pump, then increasing the size of the pump would not have any effect. Instead, only by remediating leachate chambers, and by the phased installation of a leachate collection system designed to automatically manage leachate levels across the entire site, could overall yield of leachate be increased and maintained.

WRG invested approximately £1 million in the installation of a dedicated pneumatic leachate collection system, together with an interstage storage and transfer compound, all designed with extensive control and management facilities, so as to deliver leachate to a central location, from where it can be directed for disposal. This allowed over 120,000 cubic metres of leachate to be extracted and removed during the period Spring 2000 to August 2001, including 60,000m^3 during the first 8 months of 2001. Extended pumping trials during early 2001, demonstrated that extraction of over 300m^3/d was achievable from the combined phases of Lapwing and Birchwood, and that more than 150m^3/d could be pumped from the Walton Phase. Only as the leachate treatment plant has been able to discharge treated leachate off-site, have rates of tankering been reduced.

Leachate characterisation and treatability trials

Enviros Aspinwall (now Enviros) was appointed in June 1999, shortly after Arpley began to be operated by WRG, in order to undertake a review of possible leachate management options at the site. At that time, WRG was negotiating with North West Water plc (now United Utilities), for disposal of up to 300m^3/d of raw leachate, by pipeline into their nearby Great Sankey STW, across the River Mersey from Arpley. Every indication was being given by NWW and the Environment Agency that this was the favoured option for disposal of leachate, and on this basis WRG invested in a thrust-bored pipeline beneath the Mersey, from the landfill to the inlet of the STW. In fact, this pipeline has not yet been used, as repeated consent failures by the Great Sankey STW, made them unwilling to accept any leachate from Arpley at that time.

The extensive work on leachate extraction at Arpley, was meanwhile allowing more representative leachate samples to be extracted and characterised, and better estimates to be made for volumes of leachate, in excess of the licensed maximum 1 metre head, across each phase of the site. Leachates from the different phases were found to vary considerably in quality – Table 1 summarises their strength in terms of concentrations of chloride, and of ammoniacal-N, one of the main contaminants requiring to be treated.

In terms of organic strength, stronger leachates at Arpley typically contained between 5,000 and 10,000mg/l of COD. BOD_5 values were relatively low – in practice subsequent work has however demonstrated that a significant proportion of the COD is degradable in a well-designed aerobic biological treatment system, with well-acclimatised micro-organisms, (described later).

Because leachates from the different phases vary considerably in their strengths, and because the acceptance criteria for available third party disposal outlets are also different, the leachate collection scheme was designed to separate stronger Walton leachates from the rest of the site.

Table 1: Summary of initial data for leachate strength in different phases at Arpley, in terms of chloride and ammoniacal-N (in mg/l)

Landfill Phase	chloride			ammoniacal-N		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Birchwood	38	641	2560	6	274	848

Lapwing	58	2816	12700	8	1048	3380
Walton	592	3522	5500	22	1695	3910

Starting in March 2000, Enviros conducted very detailed leachate treatability studies on leachates from Arpley, using a well-proven pilot-scale Sequencing Batch Reactor (SBR) system in their laboratory, which has been used as a basis for design of several dozen full-scale leachate treatment plants in the UK and overseas (e.g. Robinson and Luo, 1991; Robinson, 1999; Robinson and Strachan, 1999). Leachates from Lapwing/Birchwood, and from Walton Phase, were treated separately.

These trials had two main objectives:

(a). to determine whether there were any features of Arpley leachates that are likely to prejudice their successful treatment, either in a well-designed on-site plant, or in combination with domestic sewage at a sewage treatment works; and

(b). to obtain site-specific data that demonstrate the degree of treatment performance that can be anticipated from a full-scale treatment plant, by providing estimates of typical effluent quality, and to allow the treatment process to be optimised.

Results from the trials are summarised below in Table 2. Some Arpley leachates are relatively strong and undiluted. At 2000 to 2500mg/l, concentrations of ammoniacal nitrogen are at least twice those typically found at other sites. Values of COD, or organic matter resistant to biological degradation in treated effluent, were also relatively high, in the order of 2000mg/l.

The treatability trials showed that all of the ammoniacal nitrogen and BOD_5 could be successfully treated, without any signs of inhibition, although it was noted that chromium concentrations in Walton leachate were marginal and might subsequently require specific control and pre-treatment. Low levels of other heavy metals were found unlikely to provide any constraints.

At this stage, the presence of low concentrations of PCBs in some Arpley leachates, started to become an issue in negotiations regarding off-site disposals, although this had played no part in the selection of the leachates for the treatability trials. It was recognised that PCB concentrations in Birchwood and Lapwing leachates were very low indeed, not having been detected in the majority of all samples, since regular PCB monitoring commenced every 3 or 4 weeks during June 2000, at nearly 40 locations across the site.

Even in leachates where trace levels of PCBs were detected, typical levels were generally below one microgram per litre, and Enviros was able to demonstrate that the **total** amount of PCBs in leachate held within **all** Arpley phases was about 112 grams. To place this fact into a realistic perspective, it was calculated to be equivalent to the mean quantity of PCBs flowing past the Arpley landfill every 11 hours, in the River Mersey, during the previous four years (Environment Agency, 2002). In addition, wastewater treatment fate models such as the USEPA "Water 8" model, and results from the Enviros treatability trials, demonstrated that a very high percentage of PCB congeners are removed during biological treatment.

The only other significant trace organic compound detected in Arpley leachates was the herbicide mecoprop, ubiquitous in landfill leachates (Environment Agency, 2001), but readily and effectively degraded by biological treatment processes.

On this basis, given that the Great Sankey STW was no longer available as a disposal option for either raw leachates or even for biologically pre-treated leachates, and that the continued use of tankers to transport leachates long distances to other STWs was not a sustainable option, a decision was made by WRG to construct a large on-site, leachate treatment plant, capable of reliably meeting the tight discharge consents that would be applied for a discharge of effluent into the River Mersey.

Table 2: Results from pilot-scale treatability trials on Arpley leachates, 2000 – 2001.

Determinand	WALTON PHASE		LAPWING PHASE	
	Leachate	Effluent	Leachate	Effluent
COD	8260	3160	8510	2880
BOD_{20}	4990	38	1450	57
BOD_5	3020	22	495	14
TOC	3350	717	2500	835
fatty acids (as C)	639	<10	32	<10
pH-value	8.0	8.8	8.1	8.8
ammoniacal-N	2110	1.1	2050	0.8
nitrate-N	1.2	3130	0.5	3310
nitrite-N	<0.1	0.1	<0.1	0.1
alkalinity (as $CaCO_3$)	11500	1600	11500	2700
conductivity (µs/cm)	28500	30000	24400	24500
chloride	5200	5060	3150	3180
sulphate	<5	312	<5	15
phosphate	14.2	16.4	19.7	19.1
sodium	4030	6980	2480	5340
magnesium	95	75	76	56
potassium	1690	1720	1270	1430
calcium	123	54	67	43
chromium	2.17	1.96	1.0	0.82
manganese	0.55	0.5	0.32	0.39
iron	30.2	8.0	11.2	8.1
nickel	2.81	2.55	1.7	1.01
copper	0.04	0.05	<0.05	0.09
zinc	0.33	0.46	0.19	0.32
cadmium	<0.01	<0.01	<0.01	<0.01
lead	0.11	<0.04	0.19	<0.04
arsenic	0.004	0.018	0.011	0.044
mercury	<0.0001	<0.0001	<0.0001	<0.0001
Notes: Results in mg/l, except pH-value, and conductivity (µS/cm)				

3. THE ARPLEY LEACHATE TREATMENT PLANT

Following protracted negotiations with local Environment Agency officers, for a discharge consent for treated leachate into the River Mersey, a Water Resources Act 1991 consent was finally forthcoming, and contained the following main numerical limits:

Maximum Daily Volume:	600m^3	pH-value:	6-9
BOD_5:	30mg/l	suspended solids:	45mg/l

ammoniacal-N:	15mg/l	polychlorinated biphenyls:	not detectable

Restrictions were also imposed on a range of heavy metals, and on various trace organic substances, but were not felt likely to threaten successful discharge of treated effluent. In addition, extended pilot-scale treatability trials had been undertaken on leachate from a single borehole, specifically selected as having the highest single PCB concentration anywhere on the Arpley site (up to a maximum of 12µg/l). These later trials had demonstrated complete removal to <0.1µg/l, (below the limit of detection), and on this basis, construction of the full-scale leachate treatment plant began in mid 2001.

The plant is shown in the context of the landfill site in Plate 2, towards the end of construction during October 2001 in Plate 3, and in an essentially completed state in Plate 4.

Results from the treatability trials allowed optimised process and detailed designs to be prepared for the full-scale plant by Enviros, working in partnership with civil engineers May Gurney, mechanical and electrical engineers Hytech Water, and staff of WRG.

The plant is designed to treat up to 300m^3/d of leachate containing 8000mg/l of COD and 2,500mg/l of ammoniacal-N, or correspondingly higher volumes of weaker leachates, at rates of up to 450m^3/d. Treatment comprises aerobic biological treatment in three very large roofed SBR reactors, with dosing of nutrients and automated control of pH-value in each tank, following the process designs now incorporated by Enviros into more than sixty full-scale plants worldwide. Effluent from each SBR discharges into an effluent balance tank, before passing through a Dissolved Air Flotation (DAF) system, which has proved extremely effective at removing residual solids, and also many colloidal materials (see Plate 5). Finally, effluent is polished by passage through nearly 3000 m^2 of reed beds, that provide final treatment to very high standards (as well as additional security for removal of solids), before discharge is made into the river Mersey, at rates consented up to 600 m^3/d.

Plate 2: Arpley Leachate Treatment Plant under construction in September 2001, looking north east and showing the landfill (left foreground), Great Sankey STW (left middle distance) and the River Mersey

Plate 3: Plant under construction, showing the twin raw leachate balancing tanks, three large SBR tanks, and effluent balance tank and reed beds top right

Although operation of all functions of the plant is completely automated, and used a programmable logic controller for maximum reliability, the plant operator interfaces with this by means of a bank of 4 PCs, one to interrogate and programme operation of each SBR reactor, and one to coordinate the operation of the overall treatment system (see Plate 8).

By December 2001 the treatment plant biological commissioning phase had been completed, each SBR tank having been originally “seeded” using a combination of biomass from existing full-scale leachate treatment plants, and local sewage treatment works.

The plant control system contains a great many safeguards and failsafe systems, to ensure that in the event of any malfunction or equipment failures, no adverse effects ensue. In such events, alarm functions take over, the operator is called, and the malfunctions can be identified, and a decision made remotely, using a simple telephone link. Operational data are stored by the system, and can be interrogated readily, for example to produce performance data.

Leachates being treated by the plant have been very similar to those anticipated, based on the extensive and detailed programme of sampling undertaken. In practice as large volumes of leachate have continued to be extracted from each phase, to be tankered away or treated, a blended leachate quality has stabilised, and concentrations of PCBs and chromium have reduced significantly. This has avoided any need for the construction of a chromium pre-treatment system for any leachates, although land had been set aside in case this was required.

Figures 1 and 2 compare COD values in incoming leachates with those in effluent discharged to the Mersey. Mean values have been about 10,000mg/l from the Walton Phase, and about half of this in leachate from the combined Lapwing/Birchwood Phase. COD values in treated effluent have fallen from initial values of up to 2000mg/l in early 2002, to very stable levels of about 1000mg/l since Summer 2002. This is probably the result of a number of factors, including continued acclimatisation of biological sludges which effect treatment, improved experience in selection of flocculants for the DAF plant, establishment of the reed beds and, not least, to increasing experience of the plant operator.

BOD_5 values in effluent are routinely less than 10mg/l, and monthly tests for effluent toxicity using the Microtox® procedure, have never found any detectable toxicity to the sensitive bacteria used in the test.

Figures 3 and 4 provide equivalent data for concentrations of ammoniacal-N in raw leachates and in treated effluent. Again, much higher values of up to 4000mg/l, typically about 3000mg/l, are measured in Walton leachate, whereas leachates from Lapwing/Birchwood have now stabilised at about 1200mg/l. The blend of leachates being treated typically contains between 1400 and 1800mg/l of ammoniacal-N, but effluent values rarely exceed 5mg/l (Figure 4). Removal is primarily by full nitrification – nitrite-N is rarely detected at significant levels in final effluent.

Plate 4: The completed plant, spring 2002, showing the 3 roofed SBR tanks, the twin bunded leachate balance tanks, and the effluent balance tank and reed beds

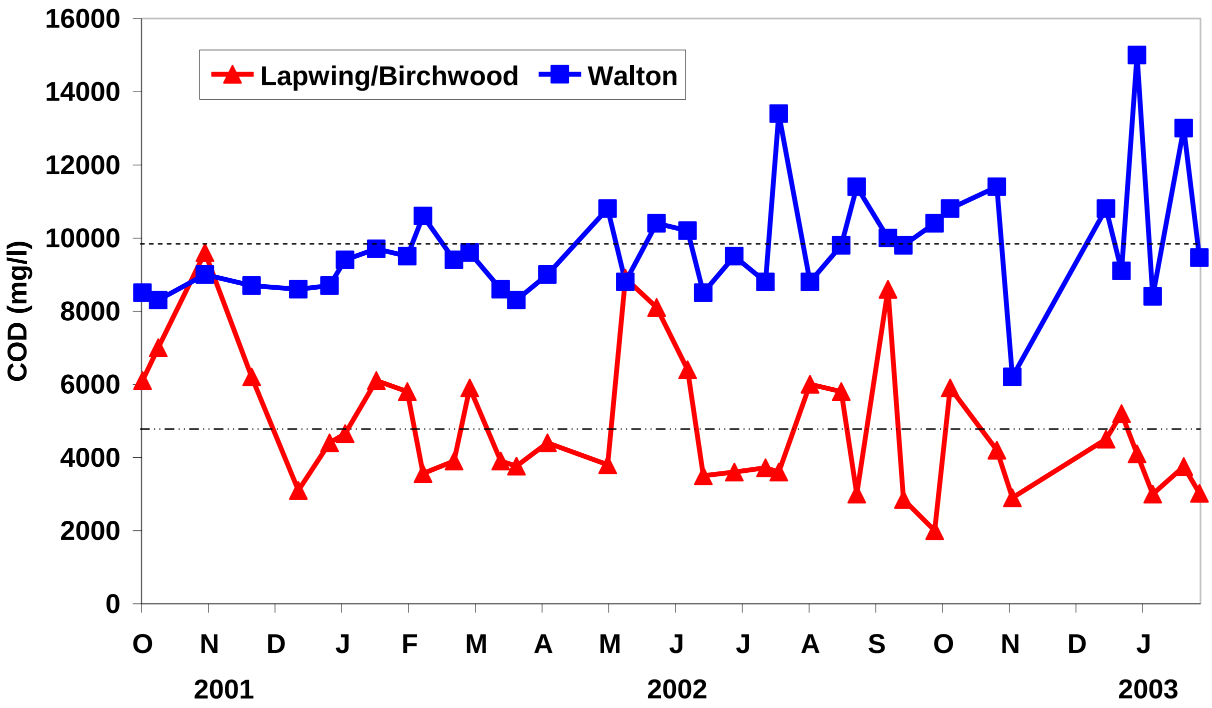

Figure 1: **COD values in raw leachates extracted from the Lapwing/Birchwood, and Walton Phases at Arpley, November 2001 to March 2003**

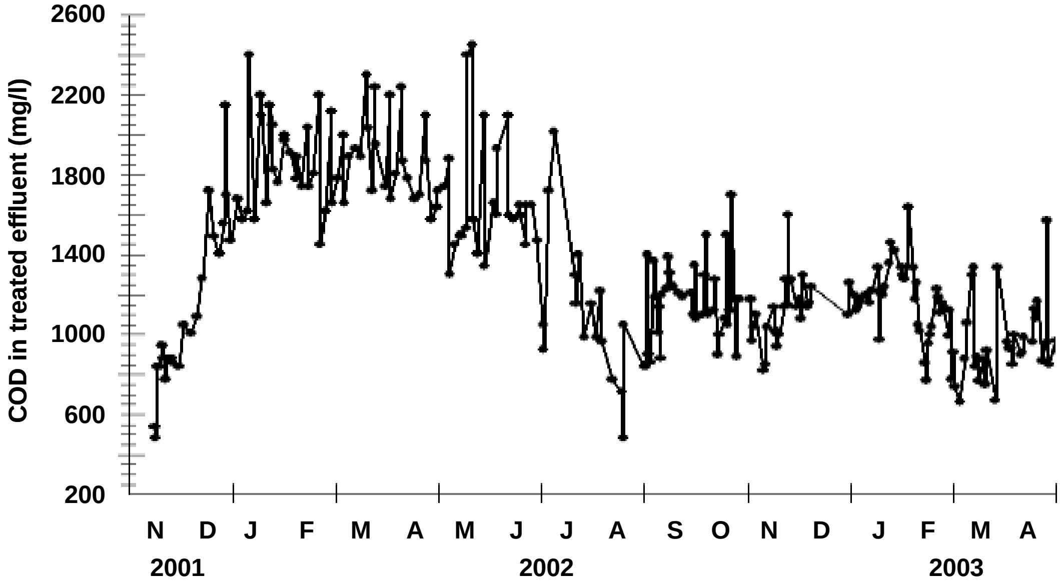

Figure 2: **COD values in effluent discharged to the River Mersey, November 2001 to May 2003**

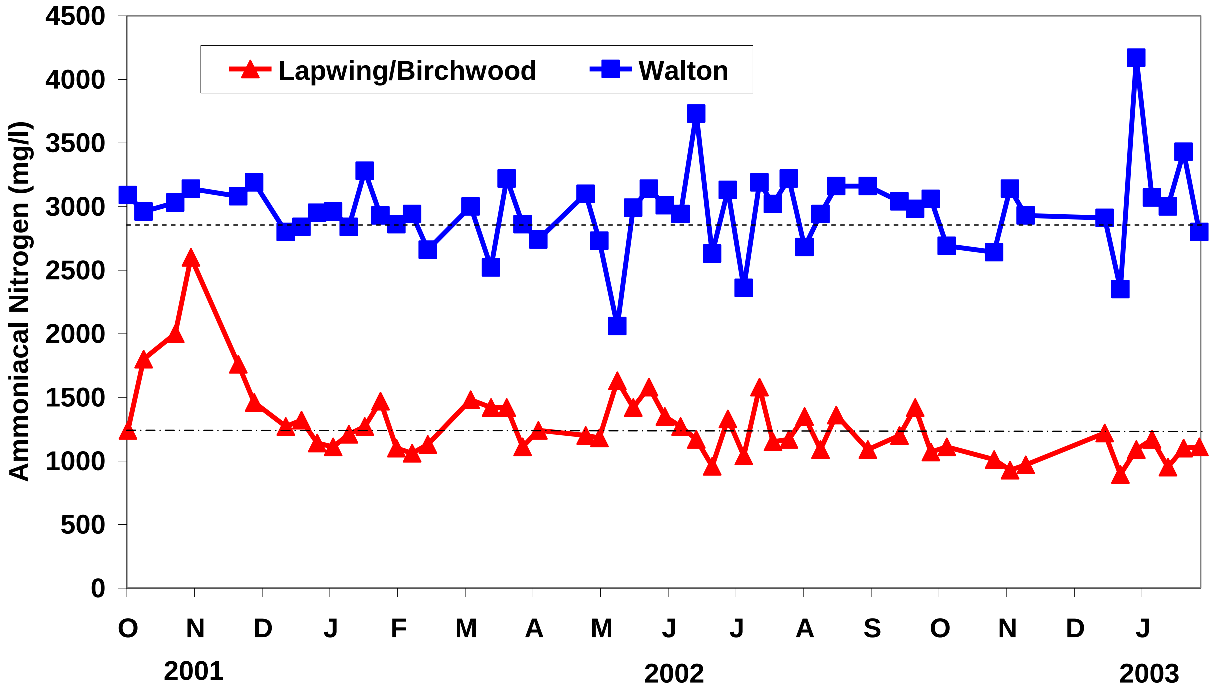

Figure 3: Concentrations of ammoniacal-N in raw leachates extracted from the Lapwing/Birchwood, and Walton Phases at Arpley, November 2001 to March 2003

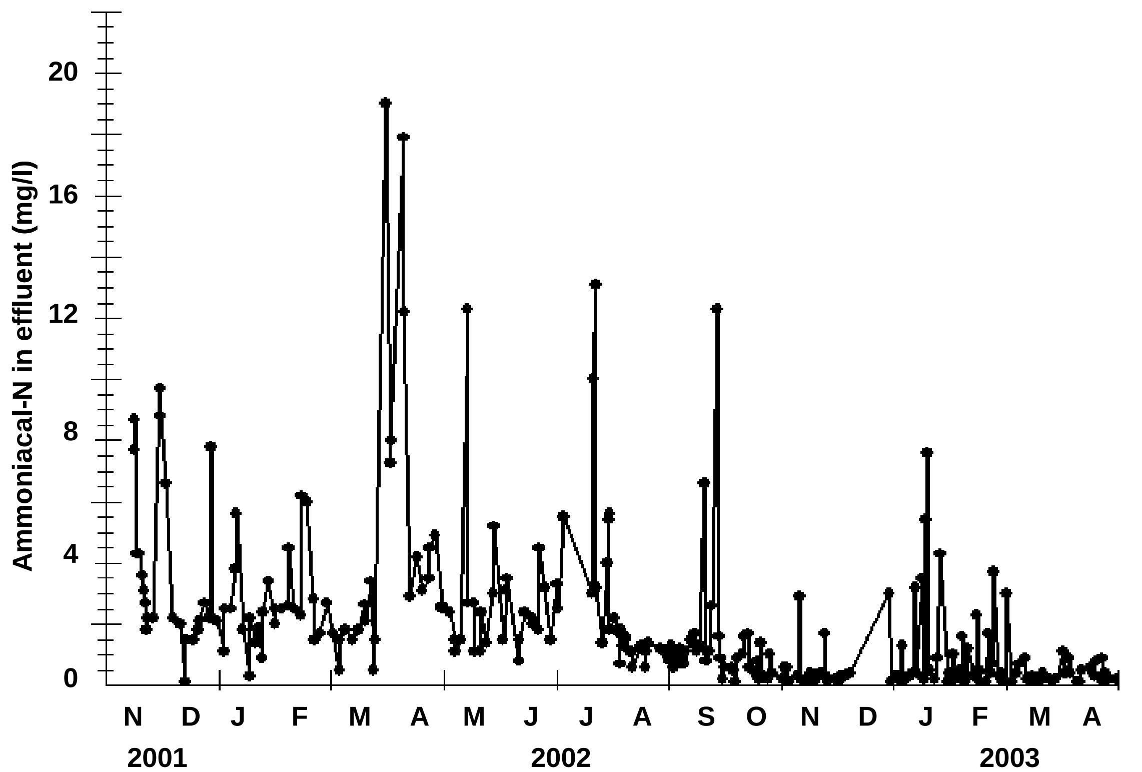

Figure 4: Concentrations of ammoniacal-N in effluent discharged to the River Mersey, November 2001 to May 2003

Table 3 presents a typical detailed picture of treatment of leachates by the full-scale plant, providing detailed analyses of the raw leachates, the final effluent, and the intermediate treatment stages. Increases in sodium values during treatment result from the use of NaOH, to provide alkalinity needed to maintain pH-values in the optimum range, programmed in the automatic control system. Concentrations of this, and of other salts such as chloride which are essentially untreated by the plant, are not of concern in effluent, because of the tidal nature of the Mersey as it passes the site.

Other contaminants, such as mecoprop, are completely degraded during biological treatment, although present at up to 50 µg/l in raw leachates. PCB congeners have never been detected in effluent (detection limit of <0.1 µg/l), although samples are routinely and frequently tested.

Table 3: Results for treatment of leachate in the full-scale plant at Arpley Landfill, March 2003. (leachate treatment rate at 360m^3/d)

Determinand	Walton leachate	Lapwing leachate	SBR effluent	DAF effluent	Final effluent
COD	5990	4730	1470	1060	1010
BOD_{20}	1720	1130	67	6	16
BOD_5	688	537	20	<1	<1
TOC	1240	1260	356	281	286
fatty acids (as C)	26	31	<5	<5	<5
pH-value	8.3	8.2	8.2	7.6	8.1
ammoniacal-N	1460	1240	3.7	3.2	1.5
nitrate-N	1.9	1.3	1490	1238	1238
nitrite-N	<0.1	<0.1	0.6	0.1	<0.1
alkalinity (as $CaCO_3$)	9110	7490	1430	1010	880
conductivity (µS/cm)	19700	16700	16300	16800	17500
chloride	2710	2430	2300	2650	2670
sulphate	-	113	240	205	197
phosphate	13.9	9.0	5.8	0.2	0.5
sodium	2560	2140	3490	3770	3840
magnesium	93	107	87	89	80
potassium	1100	886	902	955	991
calcium	134	173	119	108	100
chromium	0.67	0.46	0.37	0.27	0.29
manganese	0.68	0.86	0.18	0.056	0.26
iron	13.0	12.1	5.51	0.72	0.67
nickel	0.74	0.61	0.45	0.44	0.46
copper	0.08	0.029	0.025	0.026	0.038
zinc	0.29	0.15	0.19	0.19	0.20
cadmium	0.0020	0.0020	0.0020	0.0010	0.0010
lead	0.11	0.050	0.028	<0.005	0.009
arsenic	<0.010	<0.005	0.020	<0.010	<0.010
mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Notes:
- Results in mg/l, except pH-value, and conductivity (µS/cm)
- Samples taken on 11 March 2003

Plate 5: The main DAF tank

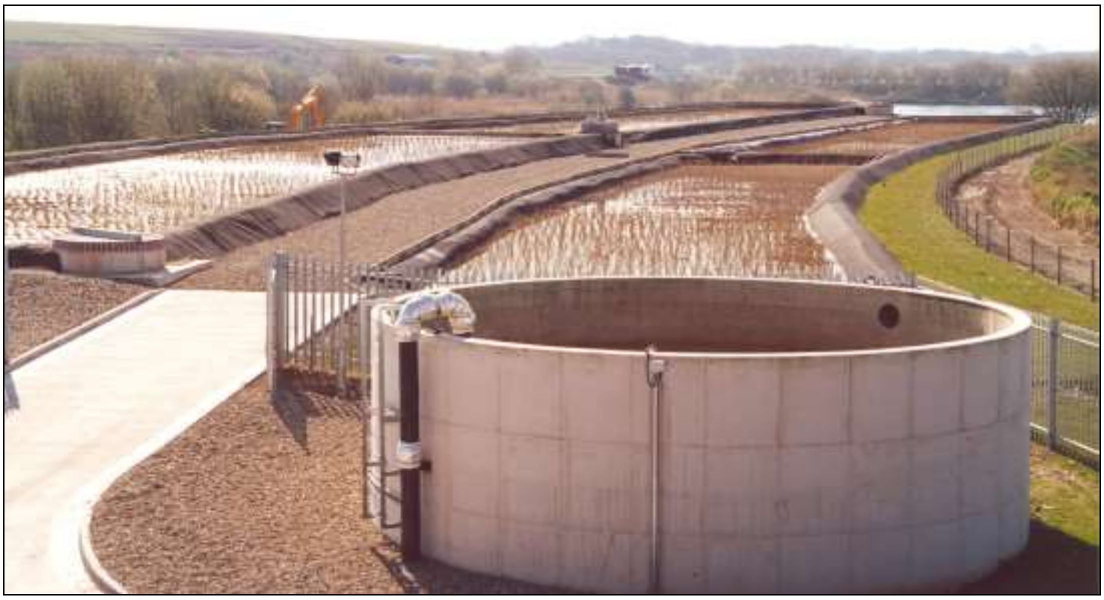

Plate 6: Effluent balance tank, and recently planted reed beds (October 2001)

Effluent from the DAF plant is polished by passage through a series of terraced reed beds (Plate 6) – a wholly natural process in which the reed plant rhizomes provide additional treatment to high standards, as part of Best Available Technology – before final effluent is discharged into the Mersey at typical rates of between 10 – 20 cubic metres per hour.

Delivery of leachate into the SBR tanks involves two large and bunded feed storage tanks (Plate 7), allowing additional blending of leachates from the various parts of the site, for optimum treatment.

Plate 7: Bunded leachate feed tanks, with one SBR treatment reactor in the background

Plate 8: The bank of four PCs, which interface with the PLC systems that run the plant automatically, and are connected to the telemetry systems

4. IMPACTS ON THE LANDFILL SITE

Monthly totals for leachate volumes extracted from within Arpley Landfill, and removed either by tanker to appropriate off-site treatment, or treated by the on-site plant and discharged to the river Mersey, are presented in Figure 5.

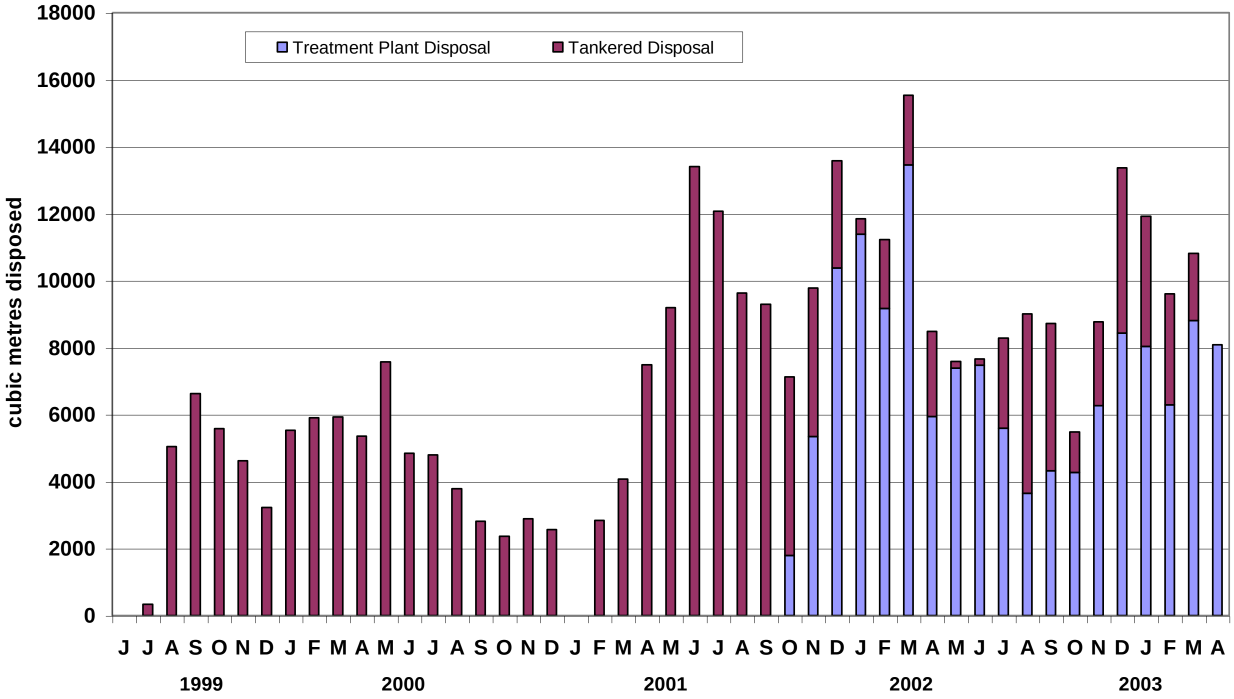

Figure 5: Monthly volumes of leachate removed from Arpley Landfill, for either off-site treatment via tanker, or for on-site treatment and disposal to the River Mersey

This demonstrates the extensive tankering undertaken from mid-1999, soon after WRG took control of the site, until the treatment plant began to be commissioned in Autumn 2001. It also shows the benefit of installing coherently-designed and managed, pumped leachate collection systems, which resulted in greatly increased capacity to pump leachate during 2001 and subsequently.

Figure 6 summarises cumulative removal of leachates from Arpley during the period from early 2001 to May 2003, (63,000m^3 of leachate having been tankered off-site prior to this period). This shows how on-site treatment of leachate has now effectively taken over from tankering, and during this 27-month period, a total of more than one quarter of a million cubic metres of leachate has been removed steadily and consistently, at an average rate close to 10,000m^3 per month.

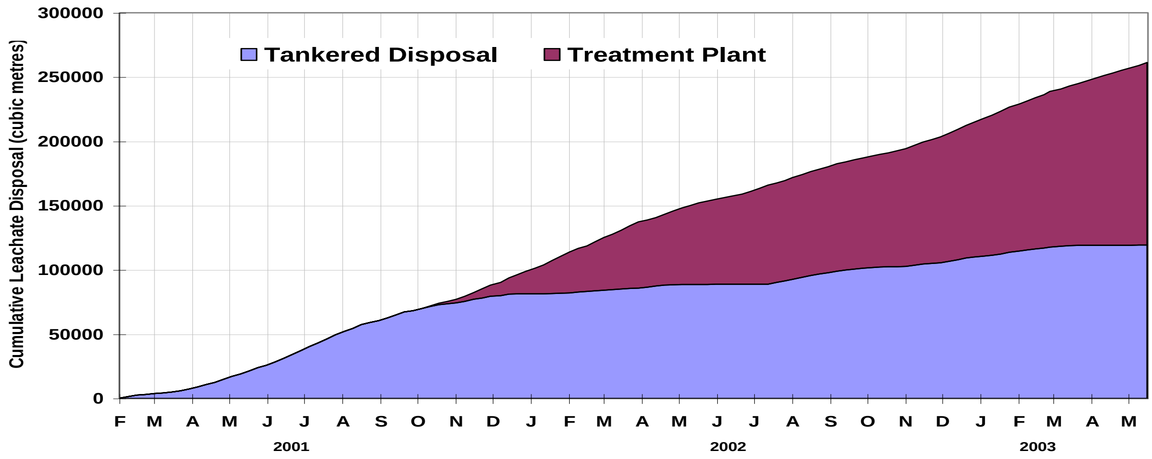

Figure 6: Cumulative removal of leachates from Arpley, over 27 months from 2001 – 2003, for off-site treatment via tanker, or on-site treatment and disposal into the River Mersey (nb; 63,000m^3 of leachate also tankered off-site prior to 2001)

The impact on leachate levels within the landfill site has been considerable. Figure 7 summarises changes in mean leachate head in each phase of Arpley – each level representing an average measured depth of leachate, from a large number of monitoring points within that phase.

The Arpley Landfill Licence specifies that leachate levels in each phase of the site shall not exceed 1 metre above the base of individual cells, and it is clear from Figure 8 that the massive efforts made by WRG since they acquired the site, have resulted in considerable progress towards this objective.

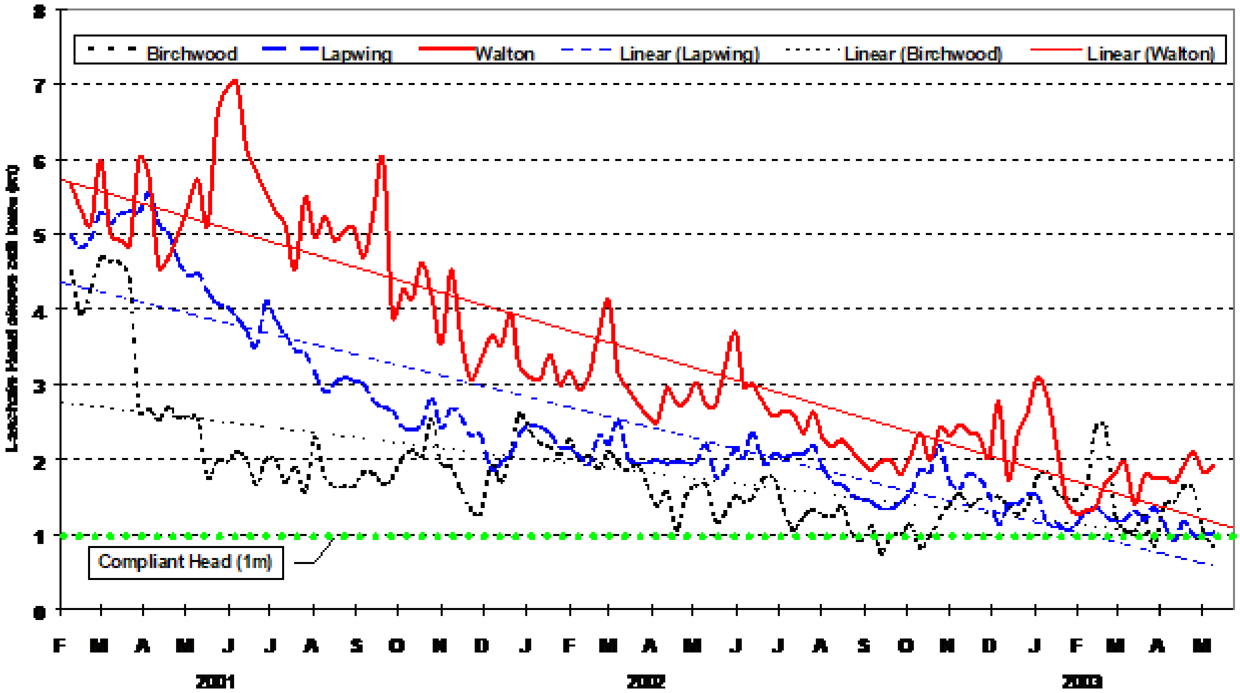

Figure 7: Changes in mean leachate head within each phase of Arpley Landfill Site, February 2002 to May 2003 (metres above cell bases)

In each phase of the site, levels of leachate are now either compliant, or close to being compliant – a significant achievement. Continued pumping and treatment of leachates during coming months is likely to achieve full compliance during 2003.

5. CONCLUSIONS

The remediation of serious leachate problems at Arpley, over a four year period since the site was acquired by Waste Recycling Group in Spring 1999, represents one of the largest such projects ever undertaken at a UK landfill site. Leachates across the various phases of the site have been characterised in detail, and with mean COD values in the range 5,000mg/l to 10,000mg/l, and concentrations of ammoniacal-N from 1,000 mg/l to 4,000 mg/l, they represent some of the strongest leachates to be reported at a UK landfill.

Extensive engineering works have been undertaken, to enable leachate to be extracted at adequate rates from the three phases of the site. The completed pumping scheme has allowed leachate to be extracted reliably and consistently over a 3-year period, at rates of up to 16,000 cubic metres per month, and at a long-term average rate of about 10,000 cubic metres per month.

One of the largest on-site leachate treatment plants in Europe has been designed, constructed, and commissioned at the Arpley site, following extensive treatability studies, and since October 2002 has treated a total of nearly 150,000 cubic metres of leachate, consistently and reliably, at rates of up to 13,500m^3/month, to enable safe discharge of treated effluent into the River Mersey.

From a situation where leachate levels were up to 8m out of compliance when the site was acquired by WRG, levels are now either compliant, or close to compliance, in all phases of the landfill. Levels are still falling, as leachate continues to be extracted and treated at average rates of about 10,000m^3/month, and it is anticipated that levels will be brought into compliance across all areas during 2003.

The scheme certainly represents Best Available Technology, and a state-of-the-art solution.

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