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ROBUST AND RELIABLE TREATMENT OF LEACHATE AT A CLOSED LANDFILL SITE IN SUSSEX, UK

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ABSTRACT

As fewer new landfill sites are opened and operated, increasingly the management of older sites containing large masses of domestic wastes is becoming increasingly important. Safe treatment and disposal of leachates is generally a key issue, and at many older unlined sites, the ingress of rainfall or groundwater is a significant issue needing consideration. Such leachate can typically be relatively weak, but is characterised by large seasonal variations in generation rate, in response to winter rainfall. Results have wide application at many closed landfill sites, which are often located far from access into the public sewer, where on-site supervisory staff are no longer available, and where wide seasonal variations in leachate generation rates pose a particular challenge. By a combination of the robustness of the SBR treatment process, and incorporation of automated SCADA controls, with remote access, such plants can operate reliably with minimal operator inputs.

1. INTRODUCTION

This paper will describe a case study at the closed Small Dole Landfill Site in Southern England, where leachate quality is strongly methanogenic, but year-round contains typically between 100 and 150 mg/l of ammoniacal-N. In spite of this, leachate flow rates have varied between 100 and 700 m^3/d since 2010, when a full-scale leachate treatment plant was designed and constructed, by substantial refurbishment and reconstruction of an existing treatment system.

The paper will describe the problems faced, the solutions adopted, and will present seven years of detailed operational data. Treatment involves twin Aeration Tanks, which operate within a modified Sequencing Batch Reactor (SBR) system, by means of an external and separate batch Settlement Tank. Because treated leachate must achieve very strict effluent discharge standards, in order to be disposed of into a small, slightly tidal watercourse, which flows around the perimeter of the landfill site, SBR effluent is passed first through Vertical Flow Reed Beds (VFRB), and then Horizontal Flow Reed Beds (HFRB), to provide polishing to high standards.

Final effluent is retained within a Treated Leachate Balance Tank, adjacent to the watercourse, and programming with tidal information allows for discharges of treated leachate to be made in accordance with tidal flows, although this is not a licence requirement.

Process design of the new leachate treatment plant included detailed laboratory treatability trials, and although (based on available leachate generation data) the plant was not originally designed for flows as high as 700 m^3/d, treatment has been so effective that the process was readily enhanced and extended to allow this to be carried out reliably.

1.1 Implementation of SBR treatment systems

Numerous recent papers, including Robinson T.H., 2013, 2015, and Robinson H.D et al., 2013, emphasise the advantages of the modified Sequencing Batch Reactor (SBR) system for treatment of landfill leachates, whereby regular volumes of leachates containing high concentrations of ammoniacal-N (toxic to bacteria that nitrify them to nitrate), can first be diluted within a large treatment reactor volume essentially containing treated leachate, such that bacteria are not inhibited (Ehrig and Robinson H.D., 2010). After a 20-hour extended aeration period, aeration of the reactor stops, suspended solids settle, and clarified treated leachate is decanted, before the cycle starts again. The modified SBR process forms the basis for hundreds of successful leachate treatment plants in the UK (e.g. Robinson H.D., et.al, 2005).

Robinson H.D. and Olufsen J., 2007, presented a similar case study to that of Small Dole LTP, where an SBR system at Efford Landfill treated leachates biologically, prior to passage through a horizontal flow reedbed for

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polishing, before effluents are discharged into a similarly sensitive watercourse, the Avon Water. As at Efford, this paper demonstrates that a well-designed, constructed and operated SBR, with a reedbed effluent polishing system, is able to operate consistently, reliably, and cost-effectively, to meet stringent surface water effluent discharge standards at all times.

1.2 The use of reedbeds

The benefits of reedbeds for incorporation into the treatment of landfill leachates have long been recognized by many authors. Most commonly, reed bed systems have been used successfully both for the complete treatment of relatively weak leachates from old, closed landfills (e.g. see Robinson H.D., 1999; Robinson H.D. et.al, 1999), and also for the polishing of leachates that have been treated biologically, in order to enable effluents to be discharged safely into surface watercourses (e.g. see Robinson H.D., 1993, 1999; Robinson H.D. et.al, 2003; 2008; Robinson H.D. and Olufsen, 2007; Strachan et.al, 2007; Novella et.al, 2004). In almost all circumstances, greatest success has been achieved where concentrations of ammoniacal-N in liquids entering the reed bed do not exceed 20 mg/l, whether beds are operated as vertical or horizontal flow systems.

Robinson H.D. et al., 2015 and 2017 successfully demonstrated that reed beds have great potential to provide an environment in which biological oxidation and degradation of methane dissolved in leachates from closed landfill sites can readily, effectively, reliably and cheaply be reduced to concentrations acceptable for discharge into public sewers, but few other case studies have been reported. In addition to methane removal, those papers demonstrated that seasonal removal of low levels of ammoniacal-N (15 mg/l) was also taking place, however this had not been part of the original design purpose of the bed. It was also evident that removal of iron was taking place within that specific reed bed, where slow accumulation of iron within the bed over the longer term was taking place.

Wilson et al., 2015 proved that as well as providing successful biological treatment of leachates through the refurbished SBR process, the installation of vertical and horizontal flow reed beds at Small Dole leachate treatment plant provided effective tertiary treatment, which included the removal of small amounts of suspended solids in biological effluent to very low levels (<2 mg/l) prior to discharge. Wilson also determined that complete removal of ammoniacal-N was consistently achieved, to well within the consented discharge level of 6.0 mg/l, primarily by nitrification but also to a minor extent by uptake in the reed beds.

Robinson T.H., 2017 summarised the successful operation of three specific reedbed treatment systems, providing effective treatment of various determinands. At the first site, removal of suspended solids and iron was noticed, to very high standards, with significant levels of reduction in concentrations of ammoniacal-N; whilst the degradation of residual levels of BOD_5, COD and mecoprop was also evident. The second site (commissioned during 2013) has continued to remove all methane from leachate entering it, whilst the third provided very successful removal of any residual levels of ammoniacal-N and BOD_5. The reed bed situated there also assists in significantly reducing levels of phosphate in final effluent.

2. SMALL DOLE LANDFILL SITE AND LEACHATE TREATMENT PLANT

Small Dole Landfill and Leachate Treatment Plant (LTP) is owned and managed by CEMEX UK Operations Limited and is situated along the banks of the River Adur, West Sussex, UK, 10 km inland of the South Coast of England. Due to the location of Small Dole Landfill, and the tidal nature of the River Adur, the site is environmentally sensitive, and discharges of treated leachate must be monitored and regulated very carefully. When waste deposit ceased in 1995 and the site was closed, 30 Hectares of land was restored to grassland pastures.

2.1 Leachate Treatment Plant Update, 2010

Previously, discharges of leachate from the landfill site were controlled by pumping and spray irrigation onto the restored landfill surface, under a waste disposal license, achieving good evapotranspiration rates during warmer summer months in Southern England. Subsequently, during the 1990s, a leachate treatment plant was designed and constructed by the former owners of the site, upon closure of the landfill.

The original treatment system was inherited by CEMEX on the acquisition of the RMC Group. Following experience of the failure of the system to comply with Environmental Permit conditions that became significantly more restrictive, CEMEX invested in a major upgrade and the treatment plant was redesigned, constructed and commissioned by Phoenix Engineering during 2010. The LTP now operates as a modified SBR system, utilising previously installed underground aeration tanks, whilst incorporating a new raw leachate balancing tank and a settlement tank (Plate 1). Phoenix Engineering also installed a site-specific, bespoke SCADA system, which enables complete automation of the treatment system, and allows remote operation of the plant.

2.2 The Small Dole SBR Treatment Process

At Small Dole, a modified Sequencing Batch Reactor

PLATE 1: Aerial view of the updated Leachate Treatment Plant, following modifications made by Phoenix Engineering in 2010.

(SBR) process has been adopted in order to treat large volumes of leachate as efficiently as possible, using two pre-existing aeration tanks and a large settlement tank. This arrangement enables small volumes of leachate typically containing from 100 to 150 mg/l of ammoniacal-N, to be diluted within the continuously aerated treatment tanks, so that bacteria are not inhibited. In each 24-hour period, mixed liquor is transferred alternately from each of the 2 aeration tanks every 6 hours, to the settlement tank, before clarified effluent is decanted, and remaining mixed liquor returned to the aerated SBRs.

2.3 The Small Dole Reed Bed Polishing System

During the discharge of treated leachate from the Settlement Tank every 6 hours, biologically-treated effluent is fed through vertical and horizontal flow reedbeds in series (See Robinson, T.H., 2017) in a successful effluent polishing process. The reed beds were installed during the refurbishment to provide tertiary treatment and additional final treatment of the effluent. Effluent then drains into a treated leachate balance tank, which is designed to enable balancing of discharge flows into the Tidal River Adur, as and when required.

Plate 2 is an aerial photograph looking in a westerly direction, from above the location of the leachate treatment plant. The view shows the vertical flow reed bed (VFRB) to the right, and the two parallel horizontal flow reed beds (HFRB) to the left, with the River Adur visible in the distance. At the far western side of the site, the Treated Leachate Balance Tank (TLBT) controls the discharge of final effluent from the reedbeds, discharging consented volumes at time intervals determined by the tidal behaviour of the River Adur at this point. The daily consent for effluent discharge into the River Adur has been set at 600 m^3/d, however the site has occasionally been granted temporary higher discharge rates for fully treated leachate, when extreme weather conditions have been experienced (see later).

Many previous papers have highlighted the success of combining both biological treatment of leachates with effluent polishing provided by reedbed systems (e.g. Novella et al., 2004).

PLATE 2: Aerial view of the vertical flow reed bed, and the two parallel horizontal flow reed beds, following construction by Phoenix Engineering in 2010.

3. SMALL DOLE LEACHATE FLOW RATES AND QUALITY

Although the leachate within the south east of the Small Dole Landfill is relatively well contained within underlying gault clay horizons, the base of the western side of the landfill is made up of sandstone of the Folkstone beds, which are thought to be in direct hydraulic continuity with the surrounding groundwater. Because of the geological situation at Small Dole, and the proximity of the sensitive watercourse, a series of abstraction boreholes surround the perimeter of the Small Dole site, in which pneumatic pumps control the inflow of leachate from across the site, into a raw leachate balancing tank located at the leachate treatment plant.

3.1 Leachate Flow Rates

Since 2010, flows of leachate have varied significantly; from 80 m^3/day during summer months, to maximum recorded volumes of up to 700 m^3/day during early 2014. Typical mean daily leachate flows during the summer periods are below 100 m^3/day, whilst mean daily flows over winter are approximately 400 m^3/day (the winters of 2014 and 2016 were particularly wet). Figure 1 presents detailed daily flow data for the volumes of leachate being collected within the Raw Leachate Balance Tank (RLBT).

The River Adur flows from north to south past the western boundary of the landfill, and has a peak flow reported at around 115 cubic metres per second (CUMECs) and the West Adur at around 120 CUMECs (Environment Agency, 2008). Peak flow past the landfill has been predicted as being more than 235 m^3/sec.

3.2 Rates of Leachate Treatment

Originally the new treatment plant was only designed to treat previous measured peak flows of leachate from the landfill site, of up to 280 m^3/day. However, following a review of leachate generation rates experienced by the refurbished plant, it was concluded that the Small Dole treatment plant would in future be required to deal successfully with two challenges related to leachate generation:

1. High variations in flow rates; from typical summer leachate flows of 100 m^3 per day to rates as high as 700 m^3 per day during winter months.
2. Rapid responses to sudden rainfall events. For example, Winter 2013/14, when more than 77,300 m^3 of leachate needed treating during the six-month period (Nov-April), with a peak flow of 17,995 m^3 during March 2014 (average 622 m^3/d).

Records of the flows of leachate into the Small Dole LTP between 2011 and 2017 have enabled the following mean seasonal values for leachate generation to be calculated:

- Spring / Summer: (May to October) = 125 m^3/day
- Autumn / Winter: (November to April) = 280 m^3/day

Figure 2 shows that since the upgrade to the treatment plant during 2010, the system has consistently managed to treat the highly variable volumes of leachate with relative ease.

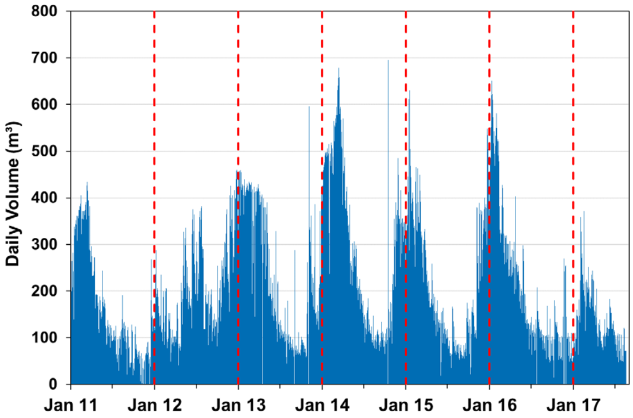

FIGURE 1: Daily Raw Leachate Flows at Small Dole from January 2011 to August 2017 (m^3).

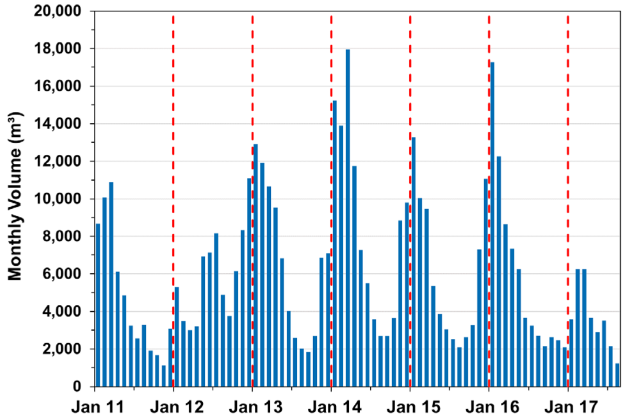

FIGURE 2: Monthly treated leachate volumes January 2011 to August 2017 (m^3).

3. LEACHATE QUALITY

Because of the seasonal variation in leachate generation rates, the strength of incoming leachates from the Small Dole Landfill Site depends heavily on the time of year. Table 1 highlights the differences in mean leachate strength between summer and winter periods.

Because of increased dilution during winter months, leachates generated during summer months are shown to contain more than double the levels of COD and BOD (increases of 252% and 244% respectively), when compared to winter. Similarly, leachates produced during the summer contain 51% more ammoniacal-N than those generated during the winter periods.

Table 1 demonstrates that regardless of the time of year, or the resultant leachate strengths or volumes; leachates are consistently treated by the LTP process. COD, BOD_5, and ammoniacal-N are all treated to very low levels during both summer and winter periods.

The fact that there is little change in chloride concentrations between effluents and raw leachates during treatment in both summer and winter periods, is to demonstrate that dilution effects during the treatment process are not significant, in terms of changes in quality through the treatment system.

4. LEACHATE STRENGTHS AND SEASONAL LOADING

As discussed previously, the generation of leachates at Small Dole varies drastically, depending on seasonal variations in rainfall. Six-month periods during Autumn/Winter (November to April) and Spring/Summer (May to October) show an obvious change in leachate generation rates, where winter mean flow (280 m^3/day) is more than double that of summer months (125 m^3/day).

Although resultant strengths of leachate are much lower during winter months, it has been observed that the overall loading of contaminant concentrations on the treatment plant are significantly higher during these periods. Despite the lower concentrations of contaminants within the leachate being generated, the sheer volume of leachate containing these contaminants, means a higher load is put through the LTP during winter months.

Using chloride as an indicator for the level of dilution within the leachate being collected; Figure 3 demonstrates that although chloride concentrations are generally lower than 350 mg/l during winter months and greater than 600 mg/l during summer months, the mean daily load for chloride during winter is consistently higher than 125 kg/day, compared to mean daily loads of below 50 kg/day during the summer. The same is true for all other significant parameters, so in terms of contaminant load, the plant must provide greatest treatment during colder winter months.

Figure 4 therefore presents data for ammoniacal-N concentrations and loading results, showing a very similar trend to chloride. Although concentrations of up to 150 mg/l are reached during summer months, mean daily loads are much higher during winter periods, exceeding 20 kg/day of ammoniacal-N during every winter period; and reaching 40 kg/day during the winter of 2013/14.

5. RESULTS AND DISCUSSION

Although dilution of the leachate being generated within the landfill site is occurring seasonally, dilution plays no role in the treatment process itself (as highlighted by chloride concentrations in Table 1). Therefore, although concentrations of contaminants such as ammoniacal-N vary drastically on a seasonal basis, the treatment plant must treat the variable strengths of inflowing leachate feeds.

TABLE 1: Variations in strength of Leachate produced at Small Dole.

Season	Summer Period		Winter Period	
Months	May - October		November - April	
Samples (no.)	160		168	
Sample	Leachate	Effluent	Leachate	Effluent
COD	1,377	99.0	548	77.9
BOD	50.4	1.30	20.9	0.84
ammoniacal-N	104	0.22	69.0	0.24
nitrate-N	1.17	101	0.50	71.9
chloride	606	655	460	391

Figure 5 presents results for the concentrations of ammoniacal-N within the leachate at Small Dole, compared to the concentrations of nitrate-N in the final effluent, prior to discharge to the River Adur.

Because the points for ammoniacal-N coming in to the plant, and nitrate-N exiting the system match so well, this shows that all ammoniacal nitrogen is being effectively fully nitrified and converted into nitrate nitrogen. This, combined with the trace levels of ammoniacal-N in final effluent (presented in Table 1), demonstrates the success of the system at achieving complete nitrification treatment, as required by the discharge consent.

6. CONCLUSIONS

On behalf of CEMEX UK Operations Limited, during 2010 Phoenix Engineering designed, constructed and commissioned a refurbished leachate treatment system at Small Dole Landfill Site in Sussex, UK, which both automated the operation and substantially improved its performance; resulting in increased robustness, reliability, and enhanced treatment capability. Following this refurbishment, the Small Dole treatment plant has consistently been able to treat all leachates generated by the landfill, in spite of large seasonal variations in leachate volumes and leachate strengths.

During summer months, when generation rates are lower and leachate strength is stronger (ammoniacal-N greater than 100 mg/l), the treatment plant has been successful in continuously removing all contaminants down to below the required discharge consent. Although the treatment plant must deal with stronger leachates during summer periods, far greater flows of leachate generated during winter months mean that within these periods the overall mass loading of contaminants is significantly greater.

The addition of a dedicated external settlement tank to the two, parallel, pre-existing buried aeration tanks, has been successful in not only improving the overall performance of the plant but also in greatly increasing its flexibility in treatment capacity. This has enabled more than twice the originally-predicted volumes of leachate to be treated (more than 700 m^3), than were first envisaged (280 m^3/day).

As part of the refurbishment, vertical flow and horizontal flow reed beds were installed to provide successful tertiary treatment, including the removal of small amounts of suspended solids and any residual ammoniacal-N, prior to discharge into the River Adur.

The refurbished plant has performed extremely well, always achieving discharges that are compliant with the sites Environmental Permit. This provides a good example of a modified SBR leachate treatment plant, that is likely to have widespread applications at similar closed landfill sites around the world.

Results obtained at the Small Dole leachate treatment plant demonstrate how effectively SBR and reedbed treatment options can be combined, to treat large volumes of leachates and achieve stringent discharge consents; allowing final effluents to be discharged to sensitive watercourses. Using results obtained at Small Dole, future treatment plants can be designed confidently, on a similar basis, where treatment of leachates with similar loading rates, at similar volumes, is required.

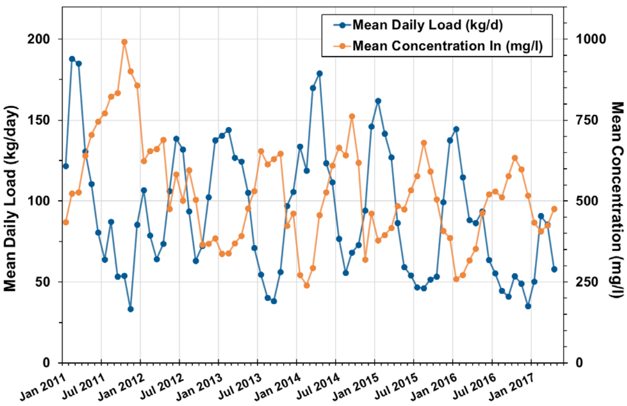

FIGURE 3: Chloride mean concentration (mg/l) and mean daily load (kg/day).

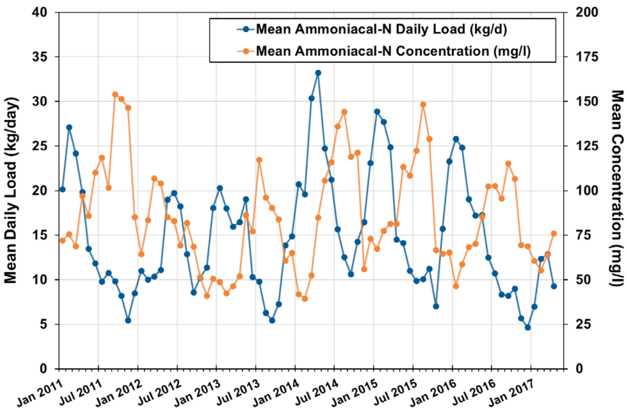

FIGURE 4: Ammoniacal-N mean concentration (mg/l) and mean daily load (kg/day).

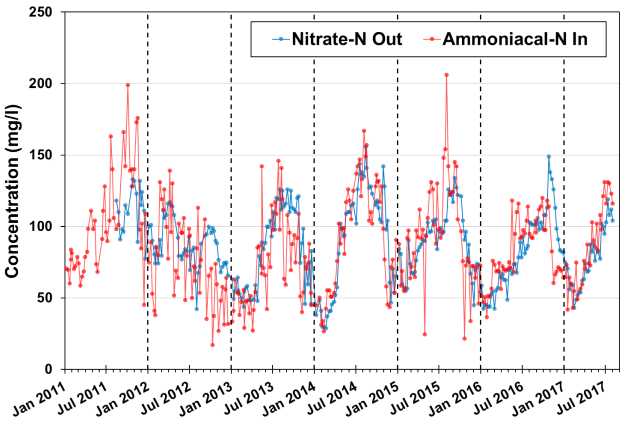

FIGURE 5: Concentrations of ammoniacal-N within raw leachate and Nitrate-N within final effluent at Small Dole, January 2011 to August 2017 (mg/l).

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