CREDENCE IN CLEAR LANDFILL WATERS:

State-of-the-Art Biological Treatment Systems for Landfill Leachates

By Lindsay Strachan* and Musa Mzizi**

* Director, GreenEng (Pty) Ltd, Tel: 031-266 8083, Mobile: 079 882 3940

** Superintendent, Department of Cleansing and Solid Waste (DSW), eThekwini Municipality

The leachate treatment team in Durban (from left to right): Mfundo Nhlengethwa (Engineer – DSW); Lindsay Strachan (Director – GreenEng); Charles Pass (Technician – GreenEng); Musa Mzizi (Superintendent – DSW)

SUMMARY

The protection of surface and ground water assets is crucially important to South Africa where there is wide consumption and daily use of such water by the population. In the eThekwini Municipality (which incorporates the City of Durban) landfills are located in the same catchment area where communities make frequent use of the surface and ground water reserves available to them for drinking, washing, cooking, etc. The treatment of landfill leachate and recycling and reuse of the treated effluent within the landfill 'footprint' is a management technique carried out by the DSW team of the eThekwini Municipality ensuring upon high quality effluent standards for such reuse. The emphasis is on **Treatment and Reuse** using effective natural systems (using biological systems and vegetation reedbeds) as opposed to other management methods which employ 'separation' principals such as storage and evaporation. After all, when one is to **reuse** the landfill leachate which emanates in significant biological loads from the landfill - one must place full credence in ensuring the waters are clear!

Clearer Waters: The Imhoff cone test on the left illustrates the difference between raw landfill leachate which is fed into the leachate treatment plants, and on the right a sample of the 'mixed liquor' from the sequencing batch reactor (SBR) where the top 'supernatant' is then sent to the reedbed for final 'polishing' treatment. The sludge in the bottom of the cone are the plant work-force – the activated sludge of bacteria that effects treatment!

BACKGROUND

The Department of Cleansing and Solid Waste (DSW) own and operate the Buffelsdraai and Mariannhill landfill sites with their own staff, resources and equipment. GreenEng (Pty) Ltd are the appointed specialist engineering Company who assist with the maintenance and operational management of the leachate treatment plants on each of these sites. The Mariannhill and Buffeldraai landfill sites have fully engineered and integrated leachate treatment plants, including engineered reedbeds, which treat up to 50 and 200 m^3/day of leachate respectively of varying biological strengths. These leachate treatment plants are currently maintained by a superintendent and plant technicians. Furthermore, at the behest of DSW, GreenEng is involved with the training of DSW's operational and engineering staff.

The Buffelsdraai landfill site is located some 35 km from the City of Durban in the north western reaches of the eThekwini Municipal area. The selection of the site was primarily because of the location of good geological conditions below the site comprising generally a sound intact tillite rock formation (Payne, 2005). The site is located within a sensitive water catchment area containing thousands of inhabitants of the local communities who use both surface and groundwater. The catchment ultimately drains into the Umhloti River which directly outlets into the Indian Ocean. The site opened in mid-May 2006 and initially receives the waste-stream that was originally accepted by the now closed La Mercy landfill site. The site will in the future, however, be the regional landfill for the City of Durban when the existing 20Mm^3 Bisasar Road landfill site is closed in some 6~8 years time. Hence, should there be limited affects by proposed waste minimisation strategies in Durban, the Buffelsdraai waste disposal rate will ramp up to some 6,000 tons per day. The area

of the Buffelsdraai *waste foot-print* is some 90 hectares and the waste volume some 45~55 Mm^3. Buffelsdraai landfill is a permitted GLB+ (**G**eneral, **L**arge, positive water **B**alance ie. leachate producing) landfill by the National regulatory authority of the Department of Environmental Affairs and Tourism (DEAT) in accordance with the National Minimum Requirements for Waste Disposal by Landfill (DEAT & DWAF, 1994, rev. 1998, rev. 2005).

Since the Buffelsdraai catchment is subjected to high intensity tropical rainfall events, the operation the landfill can be enormously challenging. First, there must be continuous access for disposal fleet vehicles and second, the simultaneous containment, treatment and release of clean water and treated leachate must be effective. The site is located at a far distance (some 10 km) from any appropriate available sewer line and coupled with the fact that the site is located upstream of various rural communities, the implementation of a leachate treatment and management system that offers a high quality of water discharge from the site was essential. This Buffelsdraai leachate treatment plant piggy-backs on the success of the existing Mariannhill Leachate treatment plant – a smaller plant of some $50m^3$ per day shown in Figure 1. Leachate management measures have been taken at Buffelsdraai to limit leachate flows during tropical rainfall events and a leachate treatment plant that adopts natural treatment systems has been engineered comprising a biological treatment step through a Sequencing Batch Reactor (SBR) process, followed by final effluent polishing through engineered reed beds.

Figure 1. The Mariannhill Leachate Treatment Plant, a $50m^3$/day 'prototype' for the new $200m^3$/day Buffelsdraai leachate treatment plant.

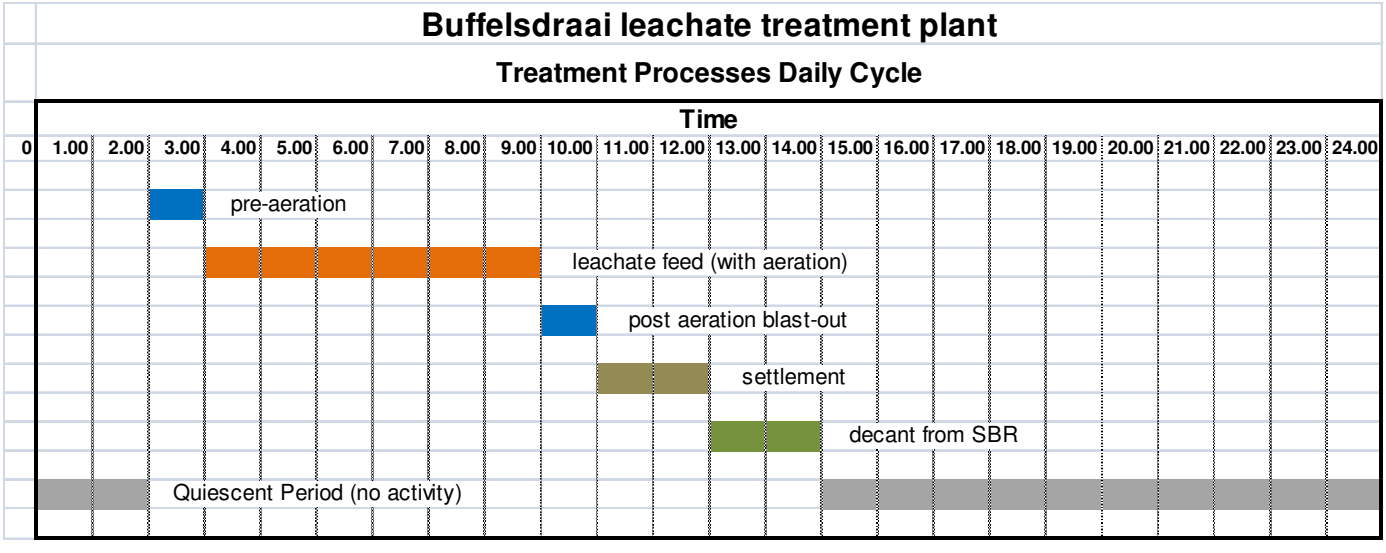
BUFFELSDRAAI AND MARIANNHILL LEACHATE QUALITY

The Buffelsdraai landfill site currently only comprises cell 1 for the disposal of MSW, with cell 2 commissioning imminent. In any event, the current rate of disposal of solid waste is low and accordingly so is the comparative daily flow-rate of landfill leachate which is up to some $10m^3$/day. The quality of landfill leachate is somewhat 'medium strength' with low levels of ammoniacal-nitrogen albeit elevated levels of Chemical Oxygen Demand (COD). Comparatively, the Mariannhill leachate is 'strong leachate' with elevated levels of ammoniacal-nitrogen and COD. A 'full suite' of leachate quality parameters is shown in table 1 below.

LEACHATE TREATMENT PLANT PROCESSES

The feed rate to the Buffelsdraai SBR is some $10m^3$ per day (10,000 litres/day). As shown in the diagram below, the daily treatment cycle comprises 8 hours aeration time within which time leachate feed takes place over 6 hours. There are 3 No. 15kW ABS type venturi aerators. Hence, the aeration cycle delivers some **360kW of power utilised**. For the 20m3/day feed rate, this translates to some **18kW per m^3 of treated leachate**.

The feed rate to the Mariannhill SBR is some 30 to $50m^3$ per day (30,000 to 50,000litres/day). As shown in the diagram below, the daily treatment cycle comprises 20 hours aeration time within which time leachate feed takes place over 18 hours. There are 2 No. 9kW ABS type venturi aerators utilised in the plant. Hence, the aeration cycle delivers some **180kW of power utilised**. For the 30m3/day feed rate, this translates to some **6kW per m^3 of treated leachate**.



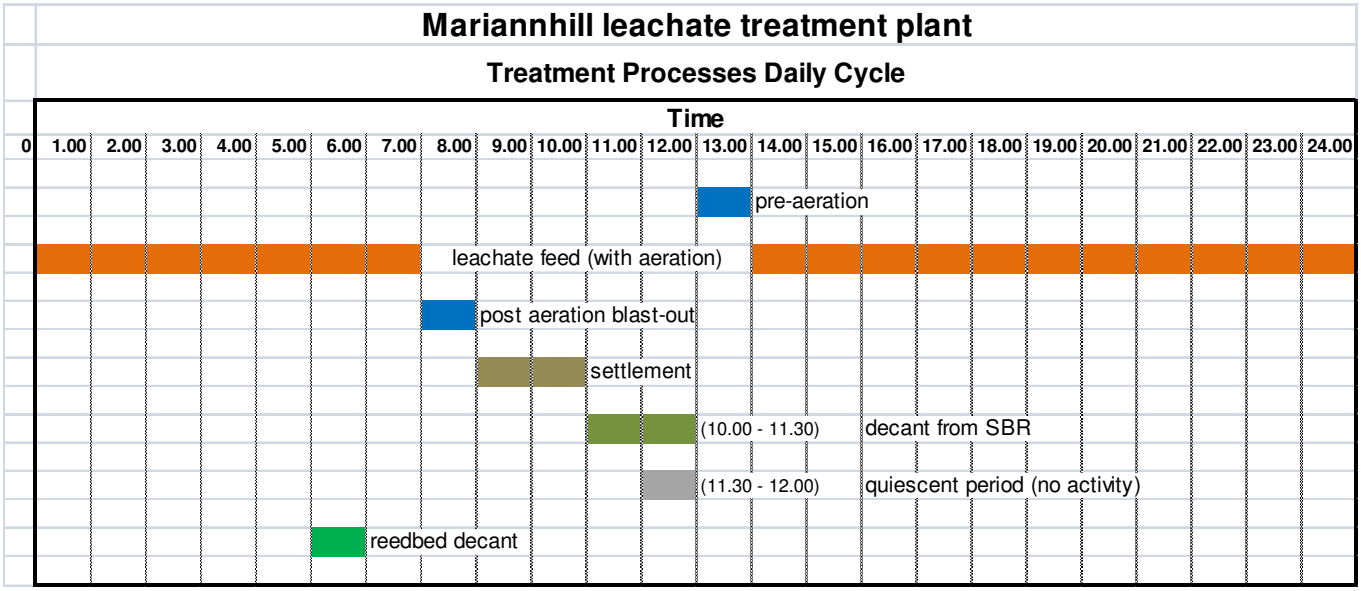


Table 1: Leachate and treated effluent quality from the Buffelsdraai and Mariannhill leachate treatment plants.

Parameter	Buffelsdraai "Raw leachate"	Buffelsdraai "SBR Mixed Liquor"	Buffelsdraai "Treated Effluent"	Mariannhill "Raw leachate"	Mariannhill "SBR Mixed Liquor"	Mariannhill "Treated Effluent"
pH-value	8.4	8.2	8.3	8.1	7.6	7.8
Alkalinity ($CaCO_3$)	2880		456	6260		680
Conductivity	1209		622	1846		1566
COD	2204		485	3816		1405
BOD_5	645		116	725		128
BOD_5/COD	0.29		na	0.19		na
NH_4-N	227		<0.1	1232		0.4
NO_3-N	<0.10		48	<0.1		102
NO_2-N	0.03		<0.01	0.03		<0.01
PO_4-P	1.80		9.3	3.90		2.9
SO_4	150		132	150		188
Na	350		338	350		354
Mn	1.40		0.25	0.78		0.71
Fe	1.30		2.4	0.53		2.50
Ni	0.49		0.19	0.82		0.68
Zn	0.08		0.03	0.23		0.76
Cd	0.01		<0.01	0.01		0.01
Pb	0.10		0.03	0.12		0.12
Volatile Sus. Solids		49			68	
Total Sus. Solids		1835			6795	
Sludge Vol. Index		<10			133	

Notes:

(a) All results are in mg/l except for pH-value (dimensionless) and electrical conductivity (mS/m). (b) nl - indicates either not legislated or that no record of legislation limitation could be found.

LEACHATE 'POLISHING' TREATMENT IN REEDBEDS

Treated leachate is discharged from the treated effluent balance tanks of both plants to engineered reed beds. Some 300m^2 and 800m^2 of reed bed area is provided for the Mariannhill and Buffelsdraai plants respectively, and in the Buffelsdraai case effluent is split into two similarly sized reed beds. The reed beds are planted with *Phragmites Australis* and indigenous *Typher Carpenthis* specie. The entire landfill property for both sites is declared conservancy areas for the promulgation of indigenous plant species; hence the outflow ends of reed bed provide a *catch-net* against the potentially invasive reeds of the top bed. Effluent waters then outlet from the reed beds through a sampling chamber into a storage tank. This treated effluent is then either decanted into the site water tanker to be utilised for dust suppressant water on the site haul roads or for irrigation of the vegetation areas within the landfill conservancy areas.

A recent unexpected finding at the landfill sites during the drier winter months is the **'Battle of the Reedbed Species'**. The water depth within the soil medium is crucial to the vegetation types. The lower water table is seemingly conducive to the growth of the bulrushes (Typha Capensis) with new shoots appearing to be migrating upstream of the reedbed invading the Phragmites Australis section at Buffelsdraai. However, at Mariannhill with the water level only just below the soil depth, the Phragmites are on the march invading the bulrushes! In fact, there is a significant dying off of the Phragmites reeds at Buffesdraai throughout the reedbeds whilst at Mariannhill the dying off of the bulrushes owed to the 'invasion' is significant: 'looks like a herd of elephants ran through the reedbed' (student's remark upon visiting the plant). Figure 2 below illustrates the Phragmites invasion at the Mariannhill reedbed.

Figure 2: The Mariannhill reedbed system. The plant operator Mlu Ngubo demonstrates the migration of the phragmites down the reedbed through the existing bulrushes. The dying off of the bulrushes is clearly visible around Lindsay Strachan who is inspecting the new invasive root systems of the Phragmites deep into bulrush territory!

CONCLUSIONS

The engineering of a landfill leachate treatment plant offers the site operator an economically and environmentally favourable solution to the management, treatment and disposal of contaminated stormwaters and high strength leachates generated by the landfill site. Further to this, the leachate treatment offers significant advantages to the creation of the **landfill conservancy sites** whereby all waters generated within the catchment are managed, treated for reuse and recycled. The scheme certainly represents the application of best available technology yet combined with the implementation of a state-of-the-art solution. The leachate treatment plants has been designed to be robust and flexible to absorb a variance of biological loadings from high volumes (200m3 per day) of low strength or diluted leachates to lower volumes (5m3 per day) of high strength leachates – being characteristically either acetogenic or methanogenic leachate.

The entire treatment process for the leachate treatment plant is fully automated by means of a user-friendly Supervisory Control And Data Acquisition system (SCADA) which manages the operation of all the pumps, valves, aerators, flow-meters and dosing mechanisms. Lastly, polishing treatment is provided by an extensive system of reed beds, where Phragmites (common reed) and Typher (common indigenous wetland specie) plants maximise overall treatment efficiency as treated effluent flows through their root zones producing a well clarified final effluent. Effluent that has reached high quality standards is then discharged to a final irrigation tank for utilisation on site as either dust suppressant water on the site haul roads or irrigation water for the conservancy areas - providing a "zero discharge" solution for the remotely located Buffelsdraai landfill site.

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