Presented at the WISA 2000 Biennial Conference, Sun City, South Africa, 28 May to 1 June 2000

A REVIEW OF THE COMPOSITION OF LEACHATES FROM LANDFILL SITES THROUGHOUT THE DURBAN METROPOLITAN AREA

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ABSTRACT

This paper describes a research project, which has been undertaken to establish a detailed account of leachate quality at landfill sites situated within the boundaries of the Durban Metropolitan Area (the DMA). The DMA incorporates four hazardous waste type landfills and sixteen sites containing municipal solid wastes (MSW). The paper presents numerous determinants to describe the composition of each leachate type, from analytical results obtained during a selected period of regular sampling. The paper considers the significance of the values obtained with a view of assessing the bio-reactive behaviour in each landfill, and the probable treatability of each leachate type. It is envisaged that such work presented in this paper may be carried forward to a nation-wide detailed data-base of leachate quality, which will develop a clearer understanding of calculating the risk, albeit high or very low, associated with the locating of landfill sites. Therefore, the risk of certain pollutants entering into national ground water reserves, may be suitably addressed through appropriate engineering works, and monitored through appropriate geohydrological study methods. Further to this, the works presented in this paper will assist in creating a better understanding of the methods of treatment for such leachates that would have to be adopted - this refers particularly to more remotely situated landfill sites where discharge of leachate to an available sewer line is not an option.
This paper presents the results of a qualitative investigation on the current state of these landfills, focussing, in particular, on the quality characterisation of raw leachate extracted. Variations in leachate quality have been determined within a year and actual data were correlated with factors such as waste type, age, climatic changes and landfill operational or management techniques. The current state of decomposition and polluting potential of each site has been assessed and some suitable treatment and management strategies are considered.

INTRODUCTION

One of the biggest challenges facing South Africa is a need for an environmental policy and an

effective, co-ordinated regulatory framework to control environmental management, to provide the rules to encourage sound waste management and pollution control. A particular area of concern is the potential for contamination of water resources arising from a variety of anthropogenic sources. The South African Minimum Requirements are attempting to establish an uniform national approach to waste disposal.
At present, the regulatory standards, classification of waste disposal sites and the types of waste which may be disposed are still based on techniques mostly developed in other countries.
The uncontrolled increase in urban population is leading, on one side, to an uncontrolled generation of refuse and, on the other, to the development of a new environmental awareness.
Containment of the waste body plus leachate and biogas collection are the most common strategies for municipal solid wastes in some countries.
Some countries apply the *flushing bioreactor* concept: while the outflow of leachate is controlled, a monitored amount of water is permitted to enter the site. Allowing the inflow of water helps to speed the degradation of organic wastes within the site, shortening the period during which monitoring is required (Robinson, 1996). As a consequence, a proper leachate management is required.
This active management approach can develop in South Africa in the near future, perhaps with modifications which allow for the treatment of raw leachate prior to discharge.
The Durban Metropolitan City Council is now directing its strategies on a more *sustainable* landfill management comprising the creation of new engineered landfills and the ongoing monitoring of the existing, unlined landfills or dumps.
The ongoing monitoring of the landfill leachates produced within the DMA and, therefore, the creation of a site-specific database is of primary importance to assess the most suitable treatment strategies and so, to improve landfill management techniques.

This paper presents a preliminary study on the polluting potentials of the landfills in the DMA and aims to pose the basis for a more specific and systematic analysis of the leachate composition which could highlight useful correlations between waste management and environmental pollution.

THE DURBAN METROPOLITAN AREA (DMA)

Durban is located on the east coast of South Africa, on the 30°S latitude and 30°E longitude. It is a commercial and industrial centre with activities like shipbuilding, petroleum refining, automobile assembly and a seaport.
Latest census results estimate a population of about 2.4 million. The DMA is divided into six local councils which provide services (e.g. waste management) at municipal level namely: Inner West Council, Outer West Council, South Central Council, South Council and North Council.
Durban climate is typically subtropical: warm and humid with a mean annual temperature of 20.5°C. Daily minimum temperature averages between 21°C in summer and 10 °C in winter. Maximum temperatures, on the other hand, average around 17°C and 30 °C in winter and summer, respectively. The relative humidity is very high and often exceeds 70% in summer. Annual precipitation figures range around 1000mm, three-quarters of which falls between October and April as light showers.
The shoreline area and city are typically flat but the terrain becomes rugged and rises inland reaching altitudes of about 425m.

The geological formations that are characteristic of the area are granite gneiss overlain by the arenaceous Table Mountain series of the Cape system, the Glacial dwyka series, the argillaceous and arenaceous Ecca series of the Karroo system.
Other formations, believed to have been formed in the quaternary era , are the Bluff beds, Berea red sand and unconsolidated sand and clay found in the harbour and city.

CLASSIFICATION OF LANDFILLS IN THE DMA

The DMA includes 16 landfill sites (Figure 1) ranging from fully engineered sites, to attenuation landfills, to dumps which have been decommissioned with imminent restorative measures.
The types of landfill sites are listed below:

- High density modern sites: e.g. Bisasar and , Mariannhill
- Old restored sites: e.g. Clermont
- Closed well restored sites: e.g. Inanda
- Hazardous waste sites: e.g. Bulbul drive
- Closed dumps

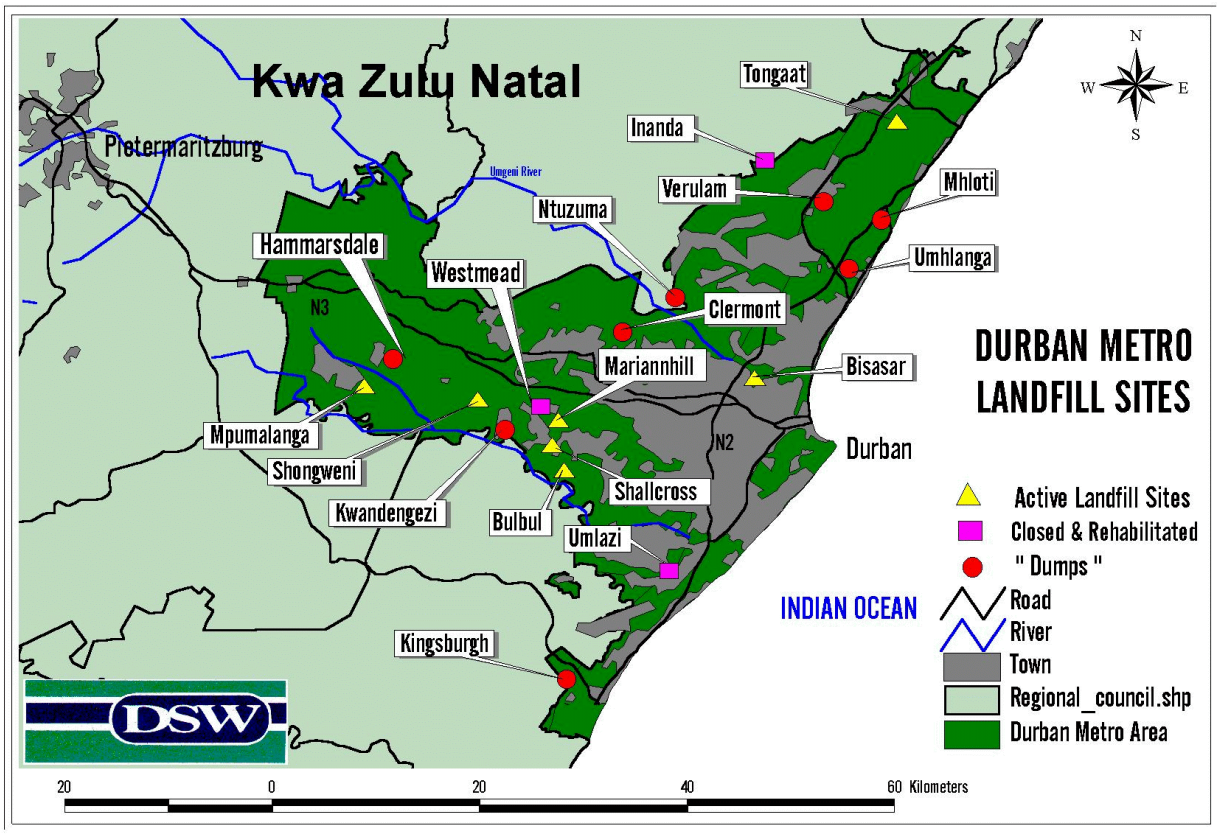

Figure 1: The landfill sites in the Durban Metropolitan area. (Courtesy of DSW)

Table 1 reports the current operational status (according to the Department of Water Affairs and Forestry permit regulations) of the landfills in the DMA.

Table 1: Operational status of the landfills in the DMA.

STAGE	LANDFILLS
Permitted operational	Bisasar, Bulbul, La Mercy, Mariannhill, Mpumalanga and Shongweni
Non permitted, operational	Wyebank (Kloof), Mkumbi, Queensburgh Shallcross and Westville
Closed and rehabilitated according to DWAF Minimum Requirements	Clermont, Inanda, Ntuzuma, Verulam and Westmead
Closed/Defunct landfills	Gillitis, Howard college, Klaarwater, Magabeni, New Germany, Old Westmead, Silverglen, Umlazi and Westville
Closed and programmed for rehabilitation according to DWAF minimum requirements	Adams Mission, Hammersdale, Kingsburgh, Kwandengezi and Umdloti.

An overview of the leachate producing landfills is reported below.

Bisasar Road (DSW)

The Bisasar Road Landfill Site is a 44 hectare general solid waste site located some 7km from central Durban and has been operating for 18 years.
It is operated by the Durban Metropolitan Council through the service unit Durban Solid Waste as an *attenuation landfill*: it is equipped with leachate and landfill gas extraction systems.
Management techniques have greatly been improved since its opening in 1981. Bisasar Road Landfill Site is 40 m above the ground water level which, according to the DWAF Minimum Requirements, need to be preserved carefully (DWAF, 1994).
It is a GLB+ site receiving mainly domestic, commercial and demolition wastes averaging around 3000ton per day and 650 –750 million cubic metres per annum.
It is located on the Ecca group of the Pietermaritzburg geological formation. Because of its carbonaceous shale nature the area was deemed unsuitable for development, hence its selection as a disposal site. With a designed volume of 21million cubic metres about a third has been filled since operations began; the area is expected to serve for other 20 years (Strachan et al, 1998).

DSW management strategy is now evolving towards the so called "piggy back" concept, which implies the vertical extension of the old waste body. This technique involves the provision of a barrier system above the already existing unlined waste body and the creation of contained and fully engineered landfill cells.
The currently operating cell, named the "Randles cell", constructed in February 1999, is designed to meet modern engineering concepts; it is, in fact, lined and equipped with a leachate extraction

system. Leachate from the old waste body and from the Randles cell is collected and stored in tanks from which it is discharged into the sewer line and sent to a nearby wastewater treatment plant. The site is also equipped with a weather station and an odor control system.
Successful leachate treatment trials had been completed and a full scale SBR (Sequence batch reactor) system will be construct in the near future.

Mariannhill (DSW)

The Mariannhill landfill is located in Seekoegat about 6km from Pinetown and occupies an area of about 25 ha. This is a general waste landfill with mean waste proportions ranging around 70% domestic, 20 % garden and 10% soil, rubble and tyres totally about 300tonnes per day.
The site is located in a closed valley and completely shield from the public by indigenous vegetation. It was commissioned in July 1997 and is designed to have six cells when complete. Cells are land-formed in terraces with stability slopes of about 30-40^{o}. The first cell was completed in April 1999 and cell 2 is now being filled. Leachate is collected through subsoil cut off drains and discharged into a rectangular concrete filtering reservoir from which, via a sedimentation tank, it is pumped to a nearby waste water treatment plant.

Mpumalanga (Enviroserv)

The Mpumalanga landfill is located some 40km from central Durban. It is operated by Enviroserv Co.and accepts commercial, domestic waste and garden refuse. Daily operations include compaction and cover application. Daily quantities of refuse disposed average around 250 to 300m^3. The site is expected to be operative for other 4years.

Shallcross (DSW)

This is an attenuation landfill operated by DSW. Presently the only types of waste accepted are garden refuse and demolition wastes.

Shongweni (DSW)

Located in Kirkfalls, this is one of the only two landfills, operated by DSW, that accepts hazardous waste. Being an H: h site it accepts low and moderate risk hazardous waste, but also garden refuse, household, commercial waste and demolition waste. Hazardous wastes are mainly liquids and sludges which are deposited at a ratio of 1:9 with solid wastes.
The site is divided into 4 hectare, lined cells, designed using the latest technology specified in the DWAF requirements.
There are already three complete cells, one in operation and another being prepared. The site was commissioned in 1997 and, with the about 200 million cubic metres of volume still available, it will be operated for some other 30 years.
Leachate is collected and discharged into an open 20 million litres dam before being sent to the sewer.

Umlazi (DSW)

This is formerly an H: h site, which now accepts only rubble, ash and soil. Leachate is collected from pipes into an open dam and then pumped into the sewer line for offsite treatment.

La Mercy (DSW)

La Mercy landfill, commonly called the Tongaat landfill, occupies an area of 62000m^2 and is surrounded by sugar plantations. This site was permitted in March 1997 as a GMB+ site and initially operated by the Tongaat Town Board. Due to poor management the landfill began degenerating into a dump. In September 1997 it started being operated by DSW. Leachate is collected by drainage pipes that intercept the major flow lines into an open lined pond. The site initially accepted 60 tons of waste daily but current figures average around 250 tons/day. Annual waste volume recorded averages around 30000tons. The site is expected to close at the end of year 2001.

Inanda (DSW)

The Inanda municipal solid waste landfill is a relatively new site which occupies an area of approximately 18500m^2. It was operated by DSW from October 1996 and closed in December 1996 due to social unrest. The design of the site involved the application the Minimum Requirements lining system, through the use of clay lining with GCL on slopes.

Ntuzuma (DSW)

Very little is recorded on this site. It is a closed GSB+ site and closure was in accordance with the Minimum Requirements as stipulated by DWAF. It is believed to be at least 20 years old.

Bulbul Drive (Waste Services)

Bulbul Drive is operated by Waste Services. It covers an area of about 120000m^2. Located at Silverglen it is designated as a H:h site accepting general, industrial and low hazardous waste in the form of sludges and liquids. Site design involved the use of an H:H liner system consisting of a clay composite liner system, flexible polypropylene and GLC. The site has been operating since 1990 and has already received waste in excess of a million cubic metres. Its projected life is 5 to 7 years. Leachate is collected into an open leachate tank and then aerobically treated in a pond before being discharged into the sewer line. Onsite pretreatment such as cementation and stabilisation of the waste are also applied.

Hammarsdale (DSW)

The Hammarsdale landfill is located on the eastern side of the Hammarsdale industrial township and overlooks the Cliffdale agricultural holdings. Its operational phase dates back to 1983 when, under the Development and Services Board, it serviced the disposal requirements of the industrial township. Textile industries and chemical plants producing chemicals used by the textile manufacturers are present in the township. Toxic wastes generated from these industries were

generally deposited in a lined sump adjacent to the landfill. With the creation of the DMA, the site began to be operated by DSW in July 1996. Although the site was officially closed at the beginning of 1998 and currently scheduled for restoration, indiscriminate dumping , is still taking place.
The boundaries of the site consist of coarse natural grass. The underlying geology of the area is typically Natal group Sandstone with dolerite dykes and sill intrusions.
The area of the landfill is approximately 5.5 ha with a total estimated volume of about 200000 m^3 of waste.

SAMPLING PROCEDURES

Samples of leachate were collected from leachate storage tanks, ponds and collecting pipes from the sites listed above.
Sites with neither a leachate extraction system nor a storage system leachate sample were taken from boreholes or by opening trenches in the waste body.

Testing intervals were chosen as follows:
a) end the wet season;
b) beginning of the dry season;
c) end of the dry season.

Table 2 shows the complete analytical suite used for the characterisation of the leachate sampled.

Table 2: Analytical suite adopted for leachate monitoring.

pH	Chromium
COD	Manganese
BOD	Iron
Alkalinity	Nickel
Chloride	Copper
Conductivity	Zinc
$N\text{-}NH_4$	Cadmium
NO_3	Lead
NO_2	Mercury
TKN	Arsenic
Sulfates	Total solids
Ortho-phosphates	Volatile solids
Sodium	Total suspended solids
Magnesium	Volatile suspended solids
Potassium	Total dissolved solids
Calcium	Volatile fatty acids

Results

Active - general municipal solid waste - landfills

a) Bisasar Road and Marianhill

Figures 2, 3 and 4 show the variation of some indicators of the leachate composition over the sampling period.

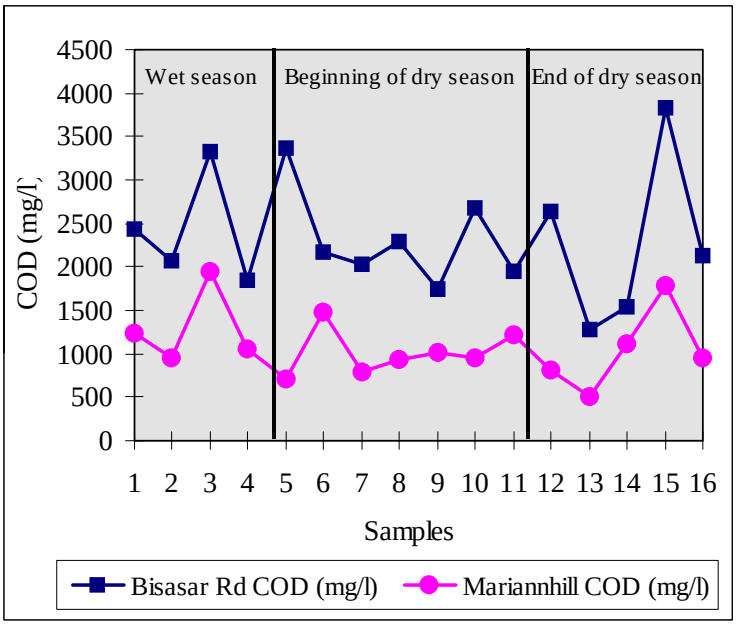

Figure 2: COD concentrations determined at Bisasar and Mariannhill landfills.

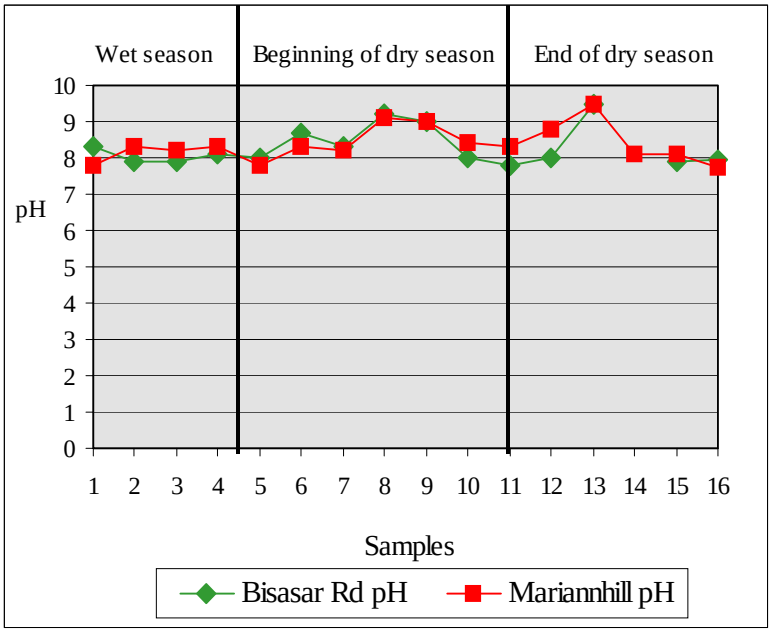

Figure 3: pH determined at Bisasar and Mariannhill landfills.

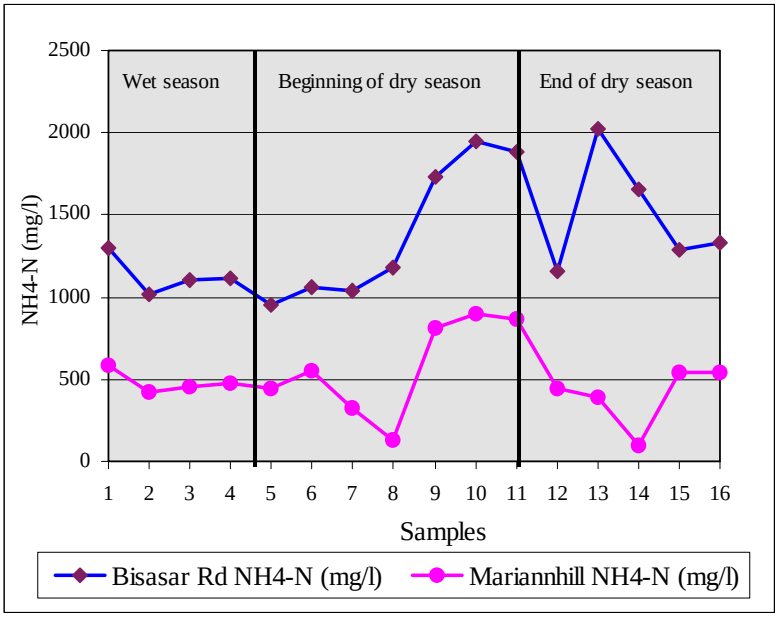

Figure 4: Ammoniacal nitrogen determined at Bisasar and Mariannhill landfills.

The trends observed for Bisasar Road landfill correlate with literature predictions for an old site in its late third or fourth phase of degradation (Quasim and Chang, 1989; Christensen and Kjieldensen, 1989, Robinson, 1993). The strong similarities between Bisasar and Mariannhill, even if the latter is a fairly young landfill (2 years old), indicate that landfill design, engineering practices and a hot-humid climate favorably increased the rate of waste decomposition.
The high level of ammoniacal nitrogen, determined from both sites, indicates that, despite the age for Bisasar or the behavior for Mariannhill, the leachates collected require a specific treatment and should, no longer, be discharged directly into the sewer line.
Positive results had been achieved by treatment trials that DSW recently completed in collaboration with Aspinwall and Co. (UK) using a combined nitrification/denitrification SBR system.

b) La Mercy (Tongaat) landfill
Mean concentrations of pollutants determined at La Mercy are reported in Table 3.

Table 3: Parameters determined at La Mercy.

LA MERCY LANDFILL SITE			
Parameters	**Mean value**	**Parameters**	**Mean value**
pH	10.03	Sodium (mg/l)	658.25
COD (mg/l)	600	Magnesium (mg/l)	65
BOD (mg/l)	245	Potassium (mg/l)	371
Alkalinity (mg/l)	1271.75	Calcium (mg/l)	90.75
Chloride (mg/l)	1383	Chromium (mg/l)	0.05
Conductivity (mS/m)	670.5	Manganese (mg/l)	1.675
Ammonia (mg/l)	230	Iron (mg/l)	4.825
Nitrites (mg/l)	21.5	Nickel (mg/l)	0.1
Nitrates (mg/l)	10.25	Copper (mg/l)	0.075
TKN (mg/l)	261.75	Zinc (mg/l)	0.125
Sulphates (mg/l)	32.75	Cadmium (mg/l)	0.025
Ortho phosphates (mg/l)	0.175	Lead (mg/l)	0.075
Total solids (mg/l)	3655	Mercury (µg/l)	12.75
Volatile solids (mg/l)	674.5	Arsenic (µg/l)	30.7
TSS (mg/l)	77	VFA (mg/l)	1029
VSS (mg/l)	28	TDS (mg/l)	3388.5

The results reported in Table 3 show that the leachate collected from La Mercy does not pose a threat to the environment, it presents very low concentrations of COD and ammonia, therefore no specific treatment is required, and disposal into the sewer seems the most reasonable “treatment” solution.

Hazardous landfills (Bulbul Dr, Shongweni and Umlazi)

The following figures show the main characteristics of the leachates sampled from the hazardous landfills.

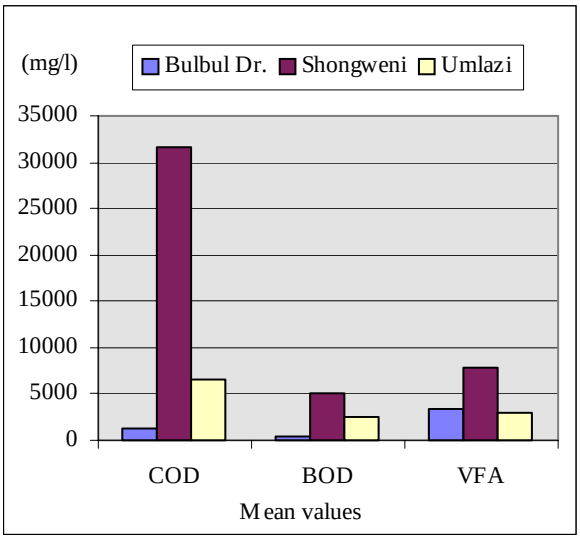

Figure 5: Organic compounds concentrations in the hazardous landfills leachate.

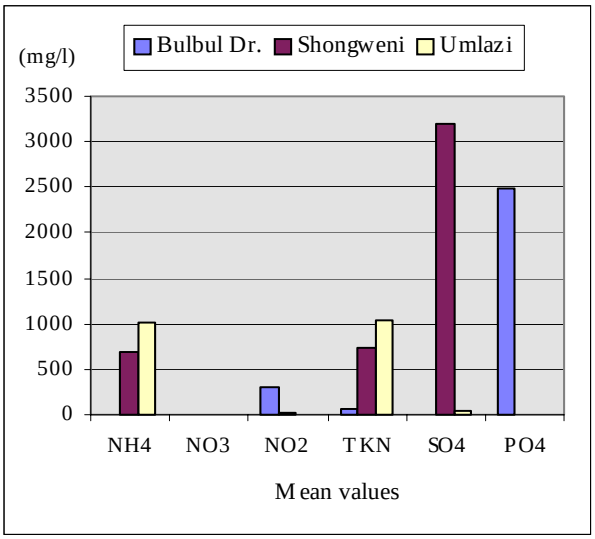

Figure 6: Nitrogen compounds concentrations in the hazardous landfills leachate.

It is interesting to point out that, although Shongweni is a 2 year-old site, as the general waste site at Mariannhill, its leachate presents a much higher polluting potentials. The site is behaving as a young landfill in the early methanogenic stage of decomposition (Andreottola and Cannas, 1989). A further investigation on specific correlations between type of waste, landfill techniques and climatic influences is therefore required to understand this dissimilarity.

The Umlazi landfill, which is an old closed landfill, is probably entering the third stage of degradation (pH 7). The leachate sampled presents quite high levels of ammoniacal nitrogen and still dangerous concentrations of COD. The option of an onsite treatment, such as a pre-treatment in a SBR system and a post treatment in appropriate constructed wetlands should be further investigated.

Closed - general waste landfills (Ntuzuma, Inanda, Pavillion and Hammarsdale)

The following figures show the mean concentrations of some quality indicators for the small closed landfills in the DMA.

The results show very low concentrations of metals and pH ranging around 8.

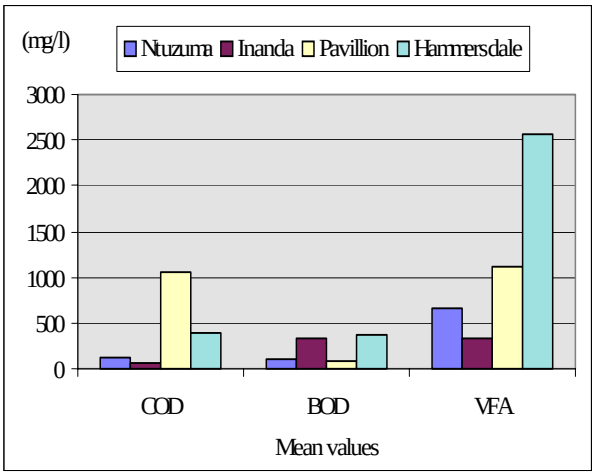

Figure 7: Mean values of the organic compounds concentrations determined in the closed landfills.

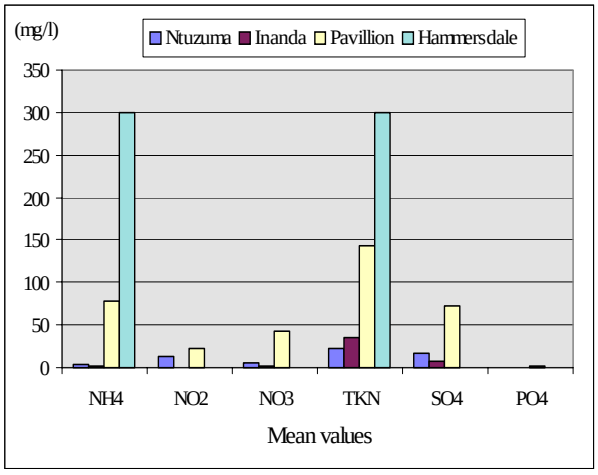

Figure 8: Mean values of the nitrogen compounds concentrations determined in the closed landfills.

The low COD and nitrogen concentrations show that all the landfills, except Pavillion, have reached a high degree of stabilisation. Due to the remote location of some of these closed landfills the disposal of the leachate to the sewer line seems the most appropriate treatment option. The application of constructed wetlands for the treatment on site is currently being investigated in a research projected that the Civil Engineering Programme of Natal University is carrying out in collaboration with DSW.

Conclusions

The major polluting potentials of leachates produced by the landfills in the Durban Metropolitan area arises from organic compounds and ammonia. Heavy metals and cumulative toxins seem to play an

insignificant role. A pattern of quick transition from the early stages of decomposition to advanced methanogenisis has been observed for most of the sites operated by DSW.
The factors inducing this transition require a deeper investigation.
A database should be created to provide ongoing information on waste management, waste decomposition processes and impact of seasonal changes on the production of landfill emissions.

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