Landfill Leachate Disposal with Irrigated Vetiver Grass

Ian Percy[1] and Paul Truong[2]

[1] Tweed Shire Council, Murwillumbah, New South Wales, Australia
[2] Veticon Consulting, Brisbane, Queensland, Australia

Abstract: Stotts Creek Landfill is a major waste depot of the Tweed Shire receiving wastes from both Tweed Heads and Murwillumbah townships and neighboring local government areas. Disposal of leachate is a major concern of the Shire as the landfill site is close to agricultural areas. An effective and low cost leachate disposal system is needed, particularly during summer high rainfall season.

As vetiver grass has a very high water use and nutrient uptake rates, and it is tolerant to elevated levels of heavy metals and other adverse conditions, it is best suited for effluent and leachate disposal.

Leachate quality at Stotts Creek Landfill is low in heavy metals but relatively high in salts and nutrients. Currently leachate and runoff from the landfill site are stored in ponds at the foot of the mound. During dry periods the leachate is irrigated onto the top of the completed waste mound where it evaporates or transpires into the atmosphere. During heavy rainfall the leachate overflows into a system of wetlands and then to a local creek.

Following capping and topsoiling, vetiver has been planted on the surface of the completed waste mound and irrigated with leachate from collecting ponds. An area of 3.5ha has been planted with vetiver in January 2003 and was increased to about 6ha in total late in 2004.

Results to date have been excellent, in the second year thick and tall, 3m high, vetiver growth was recorded. The growth was so vigorous that during the dry period, there was not enough leachate in the ponds to irrigate both the old and new plantings.

Key words: Vetiver, leachate disposal, irrigation, nutrient, phytoremediation.
Email contact: Ian Percy <ianp@tweed.nsw.gov.au> or Paul Truong < truong@uqconnect.net>

1 INTRODUCTION

The Tweed Shire is situated on the most northern shire of New South Wales and covers an area of 1300 square kilometres, with a total population of about 75,000 people, which scattered over most of the shire. There are several large to medium size towns in the shire, including Tweed Heads and Murwillumbah, the capital of the shire. The main business activities of the shire are tourism and agriculture production, tourism is a rapidly expanding industry.

2 THE PROJECT

2.1 Stotts Creek landfill Site

Stotts Creek landfill site is one of the major landfills currently being operated by the Waste Management Section of the Tweed Council. This site receives wastes from the towns of Tweed

Heads and Murwillumbah, and also from the adjacent Byron Shire and City of Gold Coast in Queensland.

This site was started 20 years ago, where both dry and wet wastes were dumped together, compacted with heavy machinery and covered with a thin layer of clay to control odor and vermin. Therefore over the years the mound has gradually built up to the present size of about 35m high and 300m long, with many layers of waste and clay.

2.2 Current treatment system

Currently both leachate and surface water are separated where possible to reduce the volume of leachate. The surface water is discharged to local streams via an artificial wetland, which was constructed to help improve the water quality leaving the site. The leachate is stored in a dam in the lower portion of the site and is irrigated onto completed and partially completed sections of the landfill to provide for evaporation and transpiration into the atmosphere. The amount of leachate able to be disposed of by this method is limited, particularly during high rainfall periods. During periods of heavy rainfall, excess leachate has to be transported off site to Council's effluent treatment plan. Although this practice is very inefficient and costly, it has to be done for Council to comply with Environment Protection Authority License Conditions. Therefore effective disposal of leachate is a major concern to Council.

2.3 Anticipated future need

The tourist industry and population growth in the Shire is expected to grow substantially in the near future; hence an expanded landfill facility is required to service the Shire. The Council is therefore looking for a cost effective and more efficient leachate treatment method than the existing irrigation/transport system to cope with this future need. After looking at various options, Vetiver System is considered to be a more appropriate solution to the Shire requirement.

2.4 Leachate quality

The levels of pollutants in leachate varied greatly due to rainfall and seasonal changes. In general, monitoring over a five year period form 1998 to the end of 2002 indicates that the leachate was high in pH, Chloride and Sulphate salts, mainly sodium chloride; high in nutrients particularly N and relatively low in heavy metals (Table1). However some of these exceeded the guideline levels set up by ANZECC (Table 2).

2.5 License Limit

The License Conditions permits the discharge of leachate offsite after a rainfall event of 430 mm over 5 days. Leachate is not permitted to be discharged during lesser rainfall events.

Table 1: Long term average levels of pollutants in Stotts Creek Leachate

Test	Units	Levels (ranges)
pH	-	7.2 - 9.3
Conductivity	μScm^{-1}	199 – 11 150
Alkalinity		256 – 1 262
Redox Potential	Mv	-86 - +144
Dissolved Oxygen	mg/L	0.2 – 30
Nitrate	mg/L	<0.01 – 10.5

Nitrite	mg/L	1.4 – 5.9
Ammonia	mg/L	0.01 – 410
Total N	mg/L	31.8 – 48.1
Total Phosphorus	mg/L	0.04 – 3.5
Chloride	mg/L	215 – 1 700
Fluoride	mg/L	0.2 – 1.1
Sodium	mg/L	153 – 2 680
Calcium	mg/L	<1 – 658
Potassium	mg/L	78 – 1 650
Magnesium	mg/L	20 – 96
Sulphate	mg/L	3.8 – 134
BOD	mg/L	<2 – 640
Total Suspended Solids	mg/L	6 – 3 243
Total Organic Carbon	mg/L	43 – 1440
Aluminum	mg/L	<0.1 – 1.0
Arsenic	mg/L	<0.01 – 0.12
Boron	mg/L	0.5 – 2.1
Cadmium	mg/L	<0.01 – 0.03
Copper	mg/L	<0.01 – 0.06
Chromium	mg/L	0.01 – 0.34
Iron	mg/L	0.09 – 7.0
Lead	mg/L	<0.01 – 0.03
Manganese	mg/L	0.01 – 1.74
Mercury	mg/L	<0.0001 – 0.001
Zinc	mg/L	<0.1 – 0.4

Table 2: ANZECC guideline levels as compared with average levels of pollutants in leachate

Test	**Units**	**Levels (ranges)**	ANZECC
pH	-	7.2 - 9.3	4 – 9
Conductivity	μScm^{-1}	199 – 11 150	750
Total N	mg/L	31.8 – 48.1	0.35
Total Phosphorus	mg/L	0.04 – 3.5	0.025
Chloride	mg/L	215 – 1 700	700
Fluoride	mg/L	0.2 – 1.1	4
Sodium	mg/L	153 – 2 680	460
Sulphate	mg/L	3.8 - 134	1 000
BOD	mg/L	<2 – 640	20
Aluminum	mg/L	<0.1 – 1.0	20
Arsenic	mg/L	<0.01 – 0.12	2
Cadmium	mg/L	<0.01 – 0.03	0.5
Copper	mg/L	<0.01 – 0.06	5
Chromium	mg/L	0.01 – 0.34	1
Iron	mg/L	0.09 – 7.0	10
Lead	mg/L	<0.01 – 0.03	2
Manganese	mg/L	0.01 – 1.74	10
Mercury	mg/L	<0.0001 – 0.001	0.002
Zinc	mg/L	<0.1 – 0.4	5
Total Suspended Solids	mg/L	6 – 3 243	30

2 VETIVER SYSTEM FOR LEACHATE CONTROL

Application of the Vetiver System (VS) for wastewater treatment is a new and innovative phytoremedial technology developed in Queensland by the Department of Natural Resources and Mines, NRM, (Truong and Hart, 2001).

3.1 Vetiver Grass

VS is based on the use of vetiver grass (*Chrysopogon zizanioides* Roberty ex *Vetiveria zizanioides* L. Nash), for various applications, ranging from erosion and sediment control to phytoremediation. Although vetiver grass was introduced to Queensland early in the 1900s from Fiji, to eliminate its weed potential, a sterile cultivar was selected by NRM and registered as Monto Vetiver. Only Monto Vetiver has been approved for use in environmental protection by QEPA

Research conducted by NRM showed that Monto vetiver has a fast and very high capacity for absorption of nutrients, particularly nitrogen and phosphorus in wastewater. In addition it has a very high water use rate and tolerant to elevated levels of salts, heavy metals and agrochemicals in the effluent or leachate (Tables 3 and 4). As a result of these findings, presently VS has been used successfully for these purposes in Australia, China, Thailand and Vietnam (Anon. 1997;Truong and Hart, 2001; Truong, 2000; Truong and Baker, 1998; Xia *et al,* 2000 and Zheng *et al.* 1997).

3.2 Australian Research Results

A demonstration site was set up in Brisbane to treat effluent discharged from a septic system. Vetiver grass was selected after the failure of other plants including a variety of fast growing tropical grasses and trees, and crops such as sugar cane and banana to absorb the effluent discharge from the septic tank on a public park. After five-month growth, vetiver was more than 2m tall and a stand of about 100 vetiver plants in an area less than 50m^2 have completely dried up the effluent discharge

Groundwater monitoring (collected at 2m depth) showed that after passing through 5 rows of vetiver the levels of total N reduced by 99% (from 93 to 0.7 mg/L), total P by 85% (from 1.3 to 0.2 mg/L), and faecal coliforms by 95% (from 500 to 23 organisms/100mL). These levels are well below the following thresholds set out in ARMCANZ and ANZECC (1997).

- Total Nitrogen <10 mg/L
- Total Phosphorus <1 mg/L
- *E. coli* <100 organisms/100mL

Table 3: Threshold levels of heavy metals to vetiver growth as compared with other species

Heavy Metals	Threshold levels in soil (mgKg^{-1})(a)		Threshold levels in plant (mgKg^{-1})	
	Vetiver	Other plants	Vetiver	Other plants
Arsenic	100-250	2.0	21-72	1-10
Cadmium	20-60	1.5	45-48	5-20
Copper	50-100	Not available	13-15	15
Chromium	200-600	Not available	5-18	0.02-0.20
Lead	>1 500	Not available	>78	Not available
Mercury	>6	Not available	>0.12	Not available
Nickel	100	7-10	347	10-30
Selenium	>74	2-14	>11	Not available

Zinc	>750	Not available	880	Not available

(a) Available elements

3.3 High water use rate

Research conducted to determine water use capacity of vetiver grass showed under wetland conditions, vetiver had the highest water use rate as compared with other wetland plants such as *Iris pseudacorus, Typha spp*, *Schoenoplectus validus*, *Phragmites australis*. At the average consumption rate of 600ml/day/pot over a period of 60 days, vetiver used 7.5 times more water than Typha (Cull *et al.* 2000).

The water use rate of vetiver is also strongly correlated to its dry matter yield. From this correlation it was estimated that for 1kg of dry shoot biomass, vetiver would use 6.86L/day. Under favourable growing conditions, a mature sward of vetiver is expected to yield 41t/ha/3 months, so a hectare of vetiver would potentially use 281KL/ha/day.

Table 4: Salt tolerance level of vetiver grass as compared with some crop and pasture species grown in Australia. (Truong *et al*. 2002)

	Soil EC_{se} (dSm^{-1})	
Plant Species	**Saline Threshold**	**50%Yield Reduction**
Bermuda Grass (*Cynodon dactylon)*	6.9	14.7
Rhodes Grass (C.V. Pioneer) (*Chloris guyana*)	7.0	22.5
Tall Wheat Grass (*Thynopyron elongatum*)	7.5	19.4
Cotton (*Gossypium hirsutum*)	7.7	17.3
Barley (*Hordeum vulgare*)	8.0	18.0
Vetiver (*Vetiveria zizanioides*)	8.0	20.0

3.4 VS for landfill leachate control.

Vetiver grass was first recognised early in the 1990s for having a “super absorbent” characteristics suitable for the treatment of wastewater and leachate generated from landfill in Queensland (Truong and Stone, 1996). Although this technology was used to treat landfill leachate in the past, recently it has been used in a large scale in China and Australia.

2.5.1 Landfill leachate treatment overseas

In Guangdong Province, China, the Datianshan landfill was built in 1985; it has a surface area over 23ha and currently takes 2500t of waste a day from Guangzhou City. This landfill is built at a nearby valley, where two earthen walls built across the valley floor with semi-weathered rocks and clay but they are not properly designed and well built as normal dam walls. The city garbage was then dumped and compressed into the space between the two walls. When the garbage reached few meters high, the surface was covered with earth then with heavy plastic sheets to cover the whole surface. When the space was completely filled with wastes the two walls were raised to take more garbage. The walls are now 75m high and 100m long, which had very high pressure caused by both large amount of garbage and heavy machinery working on the surface layer. As a result, large quantity of leachate seeped through the wall causing slippage and erosion in rainy season. Previous attempts to stabilise the wall with both native and imported vegetation have failed because of the toxic nature of the leachate.

Vetiver was planted in November 2000 to stabilise the dam wall and to reduce seeping leachate. Despite the extremely poor soil (crushed weathered rock, highly compacted and extremely poor in nutrients) vetiver established and not only succeeded in stabilizing the dam wall, it has also dried up leachate seepage. Vetiver also grew well on the edge of highly toxic leachate pools; both native and introduced plants were killed (Xia *pers. com*.). In Thailand vetiver was also used successfully to treat landfill leachate seepage.

2.5.2 Landfill leachate treatment in Australia

VS has also been used successfully to treat leachate from landfill seepage in Cleveland and Port Douglas in Queensland; Armidale City and Lithgow City in New South Wales.

3.4 VS for algal bloom control.

Due to its high capacity and fast rate of absorbing N and P nutrients in the effluent, when growing on floating platform conditions, vetiver has also proved very effective in reducing algal growth in stagnant ponds

4 TREATMENT PROCESS AT STOTTS CREEK LANDFIL

The treatment process involves:

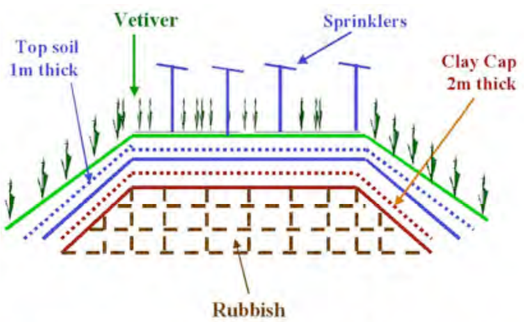
- Some evaporation loss by a high pressure and fine irrigation system and
- Mainly on the extensive land area planted with vetiver grass.

Due to its high water use rate, high absorption of nutrients and high level of tolerance to salinity, alkalinity and pollutants including heavy metals, vetiver is expected dispose of all leachate produced at this site. Based on the water use date presented above, at the peak of its growth stage**, 6ha of vetiver planting would use up to 1.68ML/day, without any surface runoff or deep drainage**.

5 IMPLEMENTATION

5.1 The site

When the designed height was reached, the mound top surface was first capped with a thick layer of impervious clay and then topped up with topsoil and organic mulch. The planting area consists of a short northern slope (100m) of about 15% gradient and a longer (300m) southern slope of 10% gradient, both slopes drain to a flat area near the middle where excess rain water will be collected and drain off the mound to the storage ponds (Fig.1). Because of this gradient vetiver was planted on contour lines to spread irrigated and rain water evenly down slope



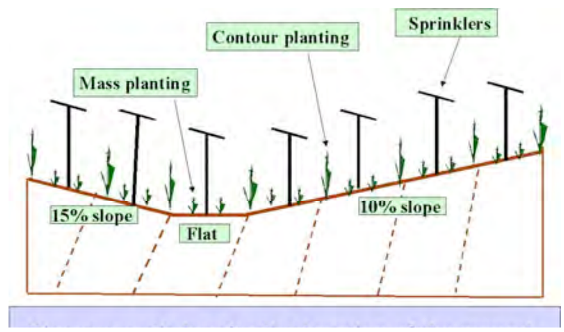


Figure 1: Cross section (left) and longitudinal section (right) of the Stotts Creek landfill mound

5.2 Ground Preparation

The whole area was first surveyed and contour lines marked out before planting. Due to the thick layer of mulch, a small backhoe was used to mix up the mulch and topsoil for planting

5.3 Planting

The total land area on the top of the mound is about 6ha, 3.5ha was planted in 2003 and the remainder in 2004. Vetiver was planted in two patterns:

- Thick contour hedges (10 plants/m) to spread runoff and irrigation water, the contour lines were planted at 0.5m Vertical Interval. Vetiver tube stock was used for the contour lines planting.
- Random pattern in the areas between the hedges planted with bare root slips

The overall planting density is at 5 plants per square metre. Due to the variation in nutrient levels of the leachate, Di-Ammoniun Phosphate was used at the rate of 500kg/ha at planting.

5.4 Irrigation System

An overhead spray irrigation system was installed and used immediately after planting each day. This system has a capacity of delivering 1 300L/minute.

5.5 Weeds Control and Maintenance

Under the nutrient rich and irrigated conditions, weed control is needed on this site. After planting, pre-emergent herbicide Atrazine was used to control weed.

Some weed problems were encountered with the first planting, but this was overcome in subsequent planting using a more a more effective pre-emergent herbicides.

6 RESULTS

6.1 Establishment and Growth

Results to date has been excellent, as soon as an area was planted it was irrigated with leachate by overhead spray irrigation and almost 100% establishment was achieved Excellent establishment was obtained on the contour lines with potted vetiver (100%) and very good rate (90%) were also achieved with bare root slips.

6.2 Disposal/irrigation volume and frequency

Based on the pump capacity of delivering 1 300L/minute, and the irrigation frequency of 1 hour every twice a day in summer and once a day in winter. The first planting of 3.5ha has effectively disposed of 4 ML a month in summer and the disposed of 2 ML a month in winter.

6.3 Treatment of algal bloom in leachate storage ponds

A number of floating platforms were used on both the leachate and surface water storage ponds to reduce algal bloom. Results to date are very encouraging with algal growth has been very effectively controlled in both the summer and winter. The vetiver plants are suspended on rafts floating in the ponds and the consumption of the nutrients as well as reducing the algal blooms also promotes the growth of the vetiver plants. This practice also removes the need to water these plants leading to further savings.

7 REFERENCES

ANZECC (Australian and New Zealand Environment and Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. Canberra, Australia.

Anon. 1997. A consideration and preliminary test of using vetiver for water ultrophication control in Taihu Lake in China. Proc. Environmental group, Institute of Soil Science, Academia Sinica, Nanjing. Proc. International Vetiver Workshop, Fuzhou, China October 1997.

Cull RH, Hunter H, Hunter M and Truong P. 2 000. Application of Vetiver Grass Technology in off-site pollution control. II. Tolerance of vetiver grass towards high levels of herbicides under wetland conditions. Proc. Second Intern. Vetiver Conf. Thailand.

Truong P. 2000. The Global Impact of Vetiver Grass Technology on the Environment. Proc. Second International Conference on Vetiver. Thailand.

Truong P, and Stone R.1996. Vetiver grass for landfill rehabilitation: Erosion and leachate control. Report to DNR and Redland Shire Council, Queensland, Australia.

Truong P, and Baker D. 1998. Vetiver Grass System for Environmental Protection. Technical Bulletin No. 1998/1. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong P, and Hart B, 2001. Vetiver System for Wastewater Treatment. Technical Bulletin no. 2001/21. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong P, Gordon I, Amstrong F, and Shepherdson J. 2002. Vetiver grass for saline land rehabilitation under tropical and Mediterranean climate. Eighth National Conference Productive Use of Saline Lands. Perth, Australia.

Xia H, Liu S, and Ao H, 2000. Study on purification and uptake of vetiver grass to garbage leachate. Proc. Second International Conference on Vetiver. Thailand.

Zheng C, Tu C, and Chen H. 1997. Preliminary study on purification of eutrophic water with vetiver. Proc. International Vetiver Workshop, Fuzhou, China.

A Brief Introduction to the First Author

Ian Percy has been employed in Local Government in New South Wales, Australia for almost twenty five years in the fields of Environmental Health, Building Control and Waste Management, the last 19 years at Tweed Shire and the last 10 years in Waste Management.

His major responsibilities include the supervision of the waste collection and disposal contractor and the improvement of the environmental performance of Council's Landfill Operations.