CODYHART
CONSULTING PTY LTD
Environmental Monitoring
ACN: 076 662 989 ABN: 2380 9060 895

REPORT

MONTO VETIVER GRASS EFFECTIVENESS IN TREATING SEWAGE EFFLUENT

August to November 2001

for Beelarong Community Farm Association Inc

30 December 2001

1. INTRODUCTION

This report concerns the results of two rounds of water quality testing at the Beelarong Community Farm, Morningside, Brisbane, to ascertain the efficacy of Monto Vetiver Grass in treating blackwater sewage effluent from the on-site worm composting public toilet.

Absorption of the effluent in the absorption bed/evapotranspiration area was not complete using native trees and banana trees; hence the planting of 200 small Monto Vetiver grass plants in late Year 2000. The Vetiver flourished and soon after there were no soggy areas evident in the Vetiver evapotranspiration area.

In May 2001, two shallow groundwater monitoring wells were installed and commissioned as a means of testing the efficacy of Vetiver grass in sub-surface treatment of the blackwater effluent.

Water was sampled from three sampling points:

- SAND - after exit from the final stage of the composting toilet treatment system, the activated sand filter, but pre-entry to the absorption trench area;
- BW1 – a shallow groundwater monitoring well downgradient from the main absorption trench with two rows of Vetiver plants between the trench and the well; and
- BW2 – a shallow groundwater monitoring well downgradient from BW1 and also downgradient from the main absorption trench but with five rows of Vetiver plants between the trench and the well.

Two rounds of sampling was conducted, one round on 19th October 2001 and another on 27th November 2001.

Results demonstrate that Monto Vetiver grass is very effective in treating Beelarong blackwater in an evapotranspiration bed in Spring. In October, total nitrogen pre-treatment was 95 mg/L compared to 16 mg/L after two rows of Vetiver and 1.2 mg/L after five rows of Vetiver. November total nitrogen results were similar. Faecal coliforms pre-treatment were 500 organisms/100mL and post-treatment approximately 50 organisms/ 100 mL in both wells. Total phosphorus was low pre-Vetiver treatment at 1.3 mg/L but declined further with Vetiver treatment.

2. BACKGROUND

The Beelarong Community farm was established to demonstrate how people can move towards a sustainable lifestyle, either in the city or country, using solar power, solar ovens, rainwater and stormwater, reuse of greywater, worm composting toilets and chemical free food production.

Part of this project is the worm composting toilet system also called the “Wastewater Recycling System”. Appendix A has a flow chart that outlines the process of human waste and putrescible kitchen scraps breakdown by worms in a composting toilet. The wastewater from this process is solar pumped to an evapotranspiration area (Photographs A and B).

Photograph A: Rear of worm composting toilet, its solar panel, evapotranspiration bed on left

Originally the evapotranspiration area was planted solely with native plants and banana trees. There were some soggy areas so Keith Burnett contacted Dr Paul Truong of Qld Department of Natural Resources concerning use of Monto Vetiver grass.

In his research and practical applications, Dr Paul Truong has demonstrated the ability of Monto Vetiver grass as an excellent means of erosion control and absorption of both unpolluted and polluted water run-off. Some initial research has been conducted on the absorption of nitrogen and phosphorus from wastewater by Vetiver grass but more research is needed. No information is available concerning Vetiver effects on faecal coliforms which indicate water is contaminated with human faecal material and/or that of other warm blooded animals.

Photograph B: Front of evapotranspiration area, Vetiver grass in background

These groundwater quality tests at Beelarong Community Farm are a contribution to Vetiver grass research. Dr Paul Truong is currently conducting further research into wastewater treatment with Vetiver at other sites, a number in conjunction with Codyhart Consulting. The results to hand are pleasing and corroborate those found in these Beelarong results.

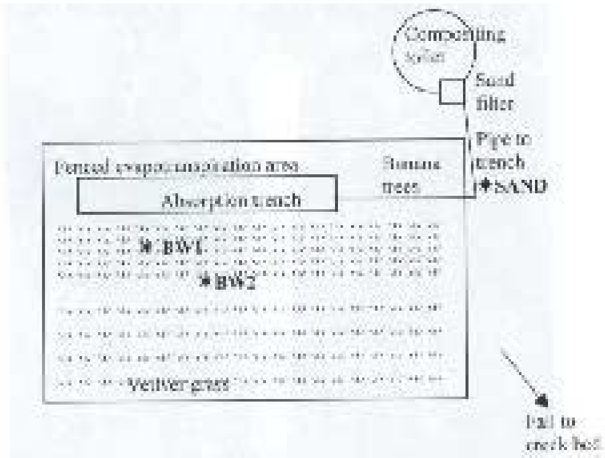
The phytoremediation ability of Vetiver grass is outstanding due to its stiff, erect stem structure and its deep, extensive and penetrating root system. The angle and position of its stems ensure it has greater exposure for photosynthesis than leaves on trees and shrubs. Its fine roots are tightly packed giving greater absorption exposure and they grow to a depth of three to four metres within a year. In early hydroponic experiments by Codyhart, four, two month old Vetiver plants in a 20 L drum of mixed greywater and blackwater over four days of summer temperatures reduced total nitrogen from 100 mg/L to 6 mg/L, total phosphorus from 10 mg/L to 1 mg/L, absorbed 1.1 L of water a day, and reduced faecal coliforms from ≥1600 org/100 mL to 900 org/100 mL.

There was a need to prove the inground efficacy of Vetiver grass in treating the Beelarong composting toilet effluent. Hence the commissioning of Codyhart to conduct a monitoring program.

3. SHALLOW WELL INSTALLATION AND COMMISSIONING

Two shallow groundwater monitoring wells (BW1 and BW2) were installed downgradient from the evapotranspiration absorption trench (Figure 1 and Photographs C and D).

Figure 1: Shallow groundwater monitoring well locations, evapotranspiration area



Photograph C: Well BW1, ground-level and upgradient from BW2

Photograph D: Well BW2, above ground casing, downgradient from well BW1

The aim of the well construction was to sample at the top of the water table relatively close to the deep roots of the Vetiver. This could be accomplished economically without a drilling rig in this flood prone area with a high water table. Well BW1 was drilled with a backhoe auger and well BW2 was drilled with a 100 mm diameter hand auger. Well BW1 was approximately 1.5 m deep and well BW2 2.0 m deep, both sufficient to intersect the top of the standing water table.

The well casings were 50 mm internal diameter 1.5 m Islex brand screens with the top half taped to encourage groundwater inflow was from the bottom of the screened area. Screened, washed river sand 0.8 to 1.5 mm particle size was used as the filter pack from the base of the well to 25 mm above the untaped screen interval. A 20 mm layer of bentonite as a surface water sealant was poured on top of the sand filter pack followed by a 100 mm sand buffer layer followed by mixed concrete to the surface where the final cement slurry was formed into a square pad to provide additional barrier to surface water ingress. Locking caps were placed on both wells.

Well commissioning was undertaken on two separate dates in May 2000 to clean out the well to allow more representative groundwater sampling at later dates. The wells were emptied then rinsed with tap water using a bailer. The process was repeated a number of times on each commissioning occasion until the water cleared. The final rinse was deionised water.

4. SAMPLING

Two rounds of sampling were conducted as follows:

Date	Ex-sand filter	Well BW1	Well BW2
19/10/01	✓	✓	✓
27/11/01		✓	✓

Sampling points (Figure 1) were as follows:

- SAND – ex-sand filter - after exit from the final stage of the composting toilet treatment system, the activated sand filter, but pre-entry to the absorption trench area;
- BW1 – a shallow groundwater monitoring well downgradient from the main absorption trench with two rows of Vetiver plants between the trench and the well; and
- BW2 – a shallow groundwater monitoring well downgradient from BW1 and also downgradient from the main absorption trench but with five rows of Vetiver plants between the trench and the well.

The TPS field lab used by Codyhart Consulting Pty Ltd to take field temperature, pH, electrical conductivity (EC), redox potential (Eh) and dissolved oxygen (DO) values was calibrated so that sampling was conducted within 24 hours of calibration.

Samples were collected at the SAND sampling point by activating the sand filter pump and collecting samples in a polyethylene beaker. Field values were taken four times, that is, four separate beakers of water were filled, the values of the field analytes were then tested and noted on the field parameter form. Sample bottles were filled for faecal coliform samples first and then the nutrient samples. The nutrient samples to be analysed by Codyhart were immediately put on ice with no acid preservation because they were to analysed that evening. The faecal coliform samples were put on ice in an esky for transport at the completion of sampling to ALS laboratory, Stafford.

The water levels in wells BW1 and BW2 were measured before commencement of sampling using an electronic dip meter and noted on the field parameter form. The BW1 and BW2 groundwater samples were extracted using a teflon bailer and bottom emptying device. Samples were poured into the sample containers and transported for analysis in a similar manner to that for SAND samples. An acid preserved duplicate nutrient sample was taken as a split sample from BW2 for analysis by ALS as a means of reviewing the reliability of Codyhart analyses.

An anemometer, thermometer and compass were used to determine air temperature, wind speed and wind direction and their values noted on the field parameter form. The sampling team wore disposable gloves throughout the sampling process. Decontamination of the sampling beakers, field lab probes and Teflon bailer was undertaken after sampling at each sampling point using consecutive rinses of (1) tap water (2) Extran rinse (3) tap water (4) deionised water.

Field parameter forms for 19th October 2001 sampling are found in Appendix B and those for 27th November 2001 are found in Appendix C.

5. ANALYSES

Codyhart Consulting conducted the field analyte analyses (dissolved oxygen, electrical conductivity, pH, redox potential and temperature on-site; and nitrite, nitrate, ammonia, total nitrogen and total phosphorus on the evening of sampling.

Australian Laboratory Services (ALS), Stafford, Brisbane, conducted duplicate analyses for well BW2 nutrients (nitrite + nitrate, total kjeldahl nitrogen, total phosphorus) on both sampling occasions to validate the reliability of the Codyhart nutrient analyses.

ALS on-forwarded the faecal coliform analyses to Simmonds and Bristow, Yeronga.

6. QUALITY ASSURANCE

Sampling procedures documented by Codyhart Consulting Pty Ltd were followed.

The low electrical conductivity of the deionised water used for rinsing equipment was verified at the start of the day and noted on the field parameter form for each sampling point.

Field analyte readings were taken four times using consecutive beakers of sample water. Repeated readings noted the natural variation from sample to sample and also acted as a quality control check because results should be reasonably close with values not exceeding a Relative

Percentage Deviation (RPD) of 20% where RPD = {(A-B)/ [(A+B)/2]} x 100. Review of the Beelarong field parameter forms reveal that the RPD of 20% for each analyte was not exceeded during sampling except for dissolved oxygen on three occasions, redox potential on three occasions and electrical conductivity on one occasion. Rapid variation in dissolved oxygen and redox potential readings are likely as water is extracted from its normal environment. Electrical conductivity values are commonly stable but in well BW2 may have varied due to well stratification.

A field blank test of EC was conducted at each sampling point, that is, after the final deionised water decontamination rinse, deionised water was swilled in a sampling beaker or the decontaminated bailer and its EC tested. Results were noted on the field parameter forms.

Each sampling round, a split sample from BW2 for nutrient analyses was forwarded to the laboratory to test the accuracy of the Codyhart analyses conducted with Hach equipment and methodologies. An RPD of ≤20% is the aim. The total phosphorus split duplicate from the October sampling round achieved the ≤20% RPD, and all nitrogen compounds achieved the ≤20% RPD in the November sampling round. Even though the total phosphorus in November and all nitrogen compounds in October did not achieve the ≤20% RPD, the concentrations were low ones and thus validated that in-ground Vetiver treatment of sewage is effective.

ALS laboratories employ a comprehensive quality control program covering both sample preparation and analysis. For the Beelarong duplicate samples, ALS conducted the following quality assurance analyses:

1. A method blank of all analytes. A known analyte free matrix was processed and analysed in the same manner as the samples. The method blank conducted at the same time as Beelarong analyses showed no trace of analytes picked up in the laboratory.
2. A Lot Control Spike (LCS) of nitrite + nitrate, total kjeldahl nitrogen and total phosphorus. A spike of target analytes is placed into a known, interference free matrix that is processed as per a set of 20 samples of similar matrix (a sample lot) which may be from different batches but are processed together for Quality Control purposes. The known true value of the spiked concentration is compared with its tested result (% recovery), to note the accuracy of the equipment and methodology. No more than 20% on either side of 100% is generally

regarded as acceptable. Recoveries noted for the Beelarong sample lot (Appendices B and C) are well within the 20% variance recovery criteria.

3. A check (retest) of all analytes of 1 in 20 samples of the sample lot which included the Beelarong samples. Minimal differences are sought with differences generally acceptable if they have an RPD of no more than 20%. This is an in-house ALS test that is not reported on the final results form (Appendix C) because they may not be Beelarong samples but rather those of another client.

Barbara Hart of Codyhart has received training in Hach methodologies from a water quality chemist. ALS has been registered with NATA since 1976. It is also certified to ISO 9002 Quality Management Systems for the provision of inorganic and organic environmental services. Simmonds and Bristow is NATA registered for coliform tests.

Chain of custody forms were completed to document the lack of tampering with sample containers and samples on their way to the laboratory. Copies are given in Appendices B and C.

7. WATER QUALITY RESULTS

Full results are given in Table 1 taken from original results given in Appendices B and C. Table 2 is a simpler list of results. Figure 2 graphs October 2001 nitrate, total nitrogen, faecal coliforms, and total phosphorus as a visual, quantitative expression of the effectiveness of in-ground Vetiver treatment of sewage.

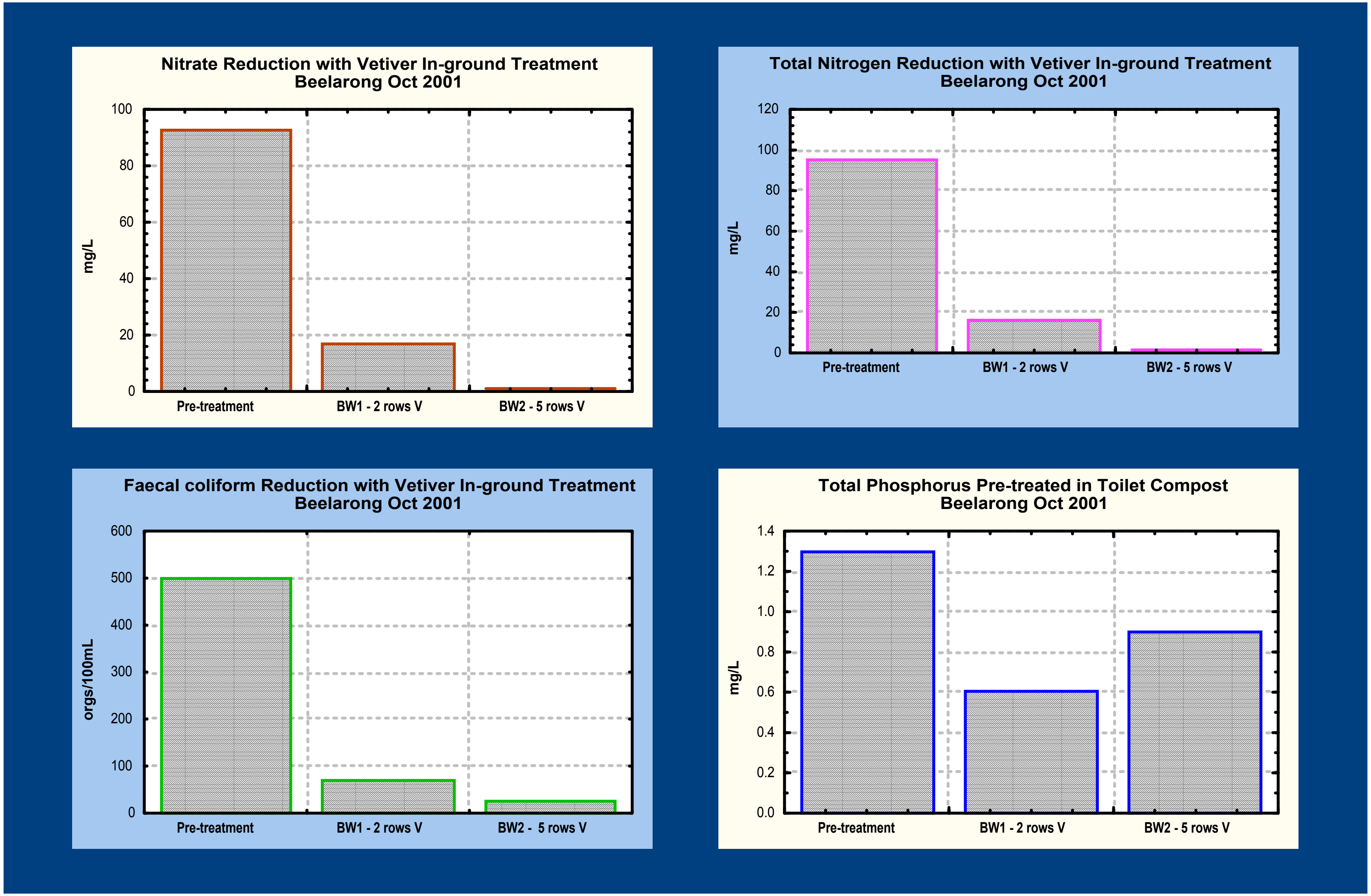
Table 1: Full results Beelarong Community Farm, Morningside, Brisbane - 2001

	Dissolved Oxygen (DO) (mg/L)	**Electrical conductivity (EC)** (µS/cm)	**pH** (standard units)	**Redox potential (Eh)** (mV)	**Temperature** (°C)	**Ammonia as a measure of ammonium ions as N** (mg/L)	**Nitrite as N** (mg/L)	**Nitrate as N** (mg/L)	**Total Nitrogen** (mg/L)	**Total Phosphorus** (mg/L)	**Faecal coliforms** (orgs/100mL)	***E. coli*** (orgs/100mL)
SAND (pre-Vetiver treatment) (19/10/01)	3.95	1,346	4.85	+274	22.5	4.86	0.015	92.8	95.2	1.3	500	500
BW1 (2 rows Vetiver treatment) (19/10/01)	1.65	1414	5.72	+243	22.8	0.51	0.050	16.7	16.0	0.6	70	70
BW2 (5 rows Vetiver treatment) (19/10/01)	4.77	5020	4.28	+249	24.9	0.22	0.007	0.70	1.2	0.9	23	23
SAND (pre-Vetiver treatment) (27/11/01)	Not	tested										
BW1 (2 rows Vetiver treatment) (27/11/01)	2.35	1,856	5.94	+170	23.0	0.78	0.012	4.2	9.4	0.24	50	50
BW2 (5 rows Vetiver treatment) (27/11/01)	3.93	10,220	3.72	+210	23.7	0.33	0.007	3.4	3.4	0.20	50	<2

Table 2: Succinct results Beelarong Community Farm, Morningside, Brisbane - 2001

	Nitrate as N (mg/L)	**Total Nitrogen** (mg/L)	**Faecal coliforms** (orgs/100mL)	**Total Phosphorus** (mg/L)
SAND (pre-Vetiver treatment) (19/10/01)	92.8	95.2	500	1.3
BW1 (2 rows Vetiver treatment) (19/10/01)	16.7	16.0	70	0.6
BW2 (5 rows Vetiver treatment) (19/10/01)	0.70	1.2	23	0.9
SAND (pre-Vetiver treatment) (27/11/01)				
BW1 (2 rows Vetiver treatment) (27/11/01)	4.2	9.4	50	0.24
BW2 (5 rows Vetiver treatment) (27/11/01)	3.4	3.4	50	0.20

Figure 2: Vetiver treatment of sewage effluent, Beelarong October 2001



8. DISCUSSION

Results demonstrate that Monto Vetiver grass is very effective in treating Beelarong blackwater in an evapotranspiration bed in Spring.

In relation to the analyses conducted in Spring for this Beelarong Vetiver grass evapotranspiration bed study, typical effluent quality after nutrient removal and further advanced wastewater treatment in Australian sewerage systems is as follows:

- Total Nitrogen <10 mg/L
- Total Phosphorus <1 mg/L
- *E. coli* <100 organisms/100mL (ARMCANZ and ANZECC, 1997:42)

Groundwater quality in well BW1 (2 rows of Vetiver treatment) met all these criteria except for Total Nitrogen on the first sampling occasion. Well BW2 (5 rows of Vetiver treatment) met all criteria on both sampling occasions.

The results also compare well to other studies of groundwater downgradient from septic tanks. For example, Rawlinson (1994:42,43) reports a 1993 study at Benalla in Victoria where septic tank densities exceed 15 septic tanks per square kilometre. Nitrate levels were up to 17 mg/L in both the upper aquifer (10 metres) and lower aquifer (20 meters). *E. coli*, which are used as a general indicator of the possibility of pathogenic bacteria, were contaminating groundwater up to 170 metres away. However, it should not be forgotten that the sub-surface environment without Vetiver assists in the degeneration of pathogenic bacteria. For example, Toze *et. al* (2001:43) report that five species of enteric bacteria had removal times in groundwater of 3 to 33 days.

The total nitrogen was predominantly nitrate indicating that the worm composting had already carried out much initial treatment of the raw blackwater. The organic nitrogen has been mineralised to release ammonium ions which in turn have been bio-oxidised, that is nitrified, to nitrate. Nitrate is the nitrogen compound of concern in groundwater, hence the need to use plants such as Vetiver to uptake it. Nitrate is soluble, mobile and stable which means that is readily leached to groundwaters. It has an active role in the eutrophication process of water bodies, and in drinking water, it poses a threat to human and animal health.

The low, pre-Vetiver treatment, phosphorus loadings in the effluent suggest a combination of two factors: a low quantity of kitchen scraps and other vegetable compost and biological, chemical and physical processes in the worm composting process that reduces its loading.

The results indicate that with increasing rows of Vetiver, the treatment is better. Given that well BW2 is only in the middle of the Beelarong Vetiver evapotranspiration bed, the bed appears to have more than double the Monto Vetiver grass plants required to effectively treat the composting toilet effluent to a very high standard.

Beelarong blackwater treatment is likely to take longer in winter, the worst case scenario, due to less nitrate removal when Vetiver is growing less actively. However, initial results by Codyhart on this matter in another research study suggest that treatment time may double in winter. Given the large planting of Vetiver in the evapotranspiration bed with many more Vetiver plants downgradient of the wells, it appears that even in winter, there are sufficient Vetiver plants to completely treat the Beelarong effluent. Trimming of the Vetiver as per Dr Paul Truong's instructions will remove some of the nitrogen loading in the Vetiver plants and activate further plant transpiration and nitrate removal from the evapotranspiration bed.

9. CONCLUSION

This report details and reviews water monitoring to ascertain the effectiveness of in-ground Monto Vetiver grass treatment of blackwater effluent from the worm composting toilet at the Beelarong Community Farm, Morningside, Brisbane, Australia.

Small Monto Vetiver grass was planted in an evapotranspiration bed downgradient of the worm composting toilet and sand filter in late Year 2000 and had grown to approximately 1.8 metres in height at the commencement of sampling in October 2001. Pre-Vetiver treatment effluent samples were taken from a pipe at the exit to the sand filter. Groundwater samples were taken from two shallow wells installed in the Vetiver evapotranspiration bed.

Spring results for total nitrogen, nitrate and *E. coli*, a pathogen indicator, reduced dramatically from pre-Vetiver treatment to post-Vetiver treatment. The greater the number of Vetiver rows intervening between the absorption trench and the wells, the better the treatment. Total phosphorus concentration was low before entering the evapotranspiration bed, but there was still some total phosphorus reduction in the wells.

Vetiver grass is also likely to be a highly effective treatment of effluent in the worst case scenario, winter. Although plant evapotranspiration is at its minimum in winter, there are many more Vetiver plants downgradient of the shallow wells where the sampling was conducted to treat the effluent as it moves downgradient.

10. BIBLIOGRAPHY

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