The Use of Vetiver Grass Wetlands for Sewerage Treatment in Australia

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Abstract: The Esk Shire Council has recently installed a Vetiver Grass Wetlands System to treat sewerage effluent at Toogoolawah in South East Queensland. The sewerage treatment plant is situated on a 22-ha site on the northern edge of town.

The aim of this scheme was to improve water quality before the effluent discharges to the natural wetlands. The biggest problem with the quality of the effluent is its high nutrient loading. With the recent changes to license conditions imposed by the Environmental Protection Agency, the existing treatment plant no longer complies with the license and an upgrade of the plant was required.

Instead of traditional upgrades, a new and innovative phyto-remedial technology recently developed in Queensland by the Department of Natural Resources and Mines, is being implemented at Toogoolawah. Under the Vetiver Wetlands System, the effluent is being treated in two stages:

- Preliminary treatment of the pond effluent *in situ* by floating pontoons placed in the ponds, and by vetiver planting around the edges of the three sewerage ponds.
- Main treatment by vetiver wetlands, once the effluent exits the sewerage ponds it passes through a Vetiver Grass contoured wetlands constructed over 3 hectares of the land. The Vetiver Grass wetlands have been constructed in rows following the contours to allow good contact between the grass and the effluent. The Vetiver Grass takes up the water and in particular the grass will remove the nutrients from the water that passes through it.

As Vetiver Grass system is very effective in removing nutrient loads, it is expected that once the wetlands is properly established there should be no release of sewerage effluent from the treatment plant except in times of heavy rainfall.

This scheme will provide a large-scale prototype of possible sewerage treatment schemes that can be used throughout western Queensland and other locations where there is plenty of land and where the local government doesn't want to pay for installing and operating high cost solutions.

Key words: Vetiver Grass, sewerage, effluent, wetlands, sewerage ponds, nutrient removal.

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1 INTRODUCTION

1.1 The Esk Shire

The Esk Shire is situated on the northwestern edge of Brisbane and covers an area of 3946 km^2. However the population of the shire is only about 14,800 people and this is scattered over most of the shire. The shire is 125 km long (running north/south) and 70 kilometres wide. There are several small towns in the shire and these are difficult to service with town water as they are also scattered up and down the shire.

1.2 Toogoolawah

The town of Toogoolawah is situated right in the centre of the shire. The town has a population of approximately 1,000 persons and provides the local people with a quiet rural lifestyle close to the large Capital City of Brisbane (2 million population).

2 THE PROJECT

2.1 Toogoolawah Sewerage Plant

The sewerage scheme for Toogoolawah was built in 1970 and the treatment plant was constructed as a primary sedimentation (Imhoff Tank) followed by three sewerage ponds. The effluent from the ponds was designed to flow down into a swamp area before it overflowed into the local creek. The plant construction was based on a very simple design but it is effective. With the recent changes to license conditions imposed by the Environmental Protection Agency (EPA) the plant no longer complies with the license and so an upgrade of the plant was required. Various options were considered such as a nutrient removal plant, a sand filter or a rock filter. These are expensive options and would require expensive ongoing operational costs. Council then considered a Vetiver Grass wetlands system that would take up most of the water, as well as remove nutrients and heavy metals etc. from the sewerage effluent. The required land had already been purchased and so there was ample room for the Vetiver Grass wetlands.

2.2 License Limit

The main problem with the existing sewerage effluent was that while passing through the three ponds the nutrients were providing an environment for the production of high concentrations of algae. These in turn made the pH rise from 7.5 up 9.2 or higher, the license limit is 8.5. Also the suspended solid counts did not improve (about 85 mg/L) due mainly to the algae counts. The suspended solid license limit is 30 mg/L. The BOD reading does improve through the ponds reducing from 120 mg/L to 29 mg/L. This is close to the license limit of 20 mg/L. The high suspended solids counts are also a cause of high Faecal Coliform counts that occur once or twice a year. Reading over 6000 organisms per 100 ml are recorded while the license limit is 1000 organisms per 100 ml.

3 VETIVER SYSTEM

3.1 Introduction

Application of the Vetiver System (VS) for wastewater treatment is a new and innovative phytoremedial technology recently developed in Queensland by the Department of Natural Resources and Mines, NRM, (Truong and Hart, 2001). It is a green and environmentally friendly wastewater treatment technology as well as a natural recycling method. Its end-product has several uses including animal fodder and material for organic farming.

3.2 Vetiver Grass

VS is based on the use of vetiver grass (*Vetiveria zizanioides* (L.) Nash), which 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). Research conducted by NRM showed that Monto vetiver grass 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 agrochemicals and heavy metals in the effluent (Cull *et al*., 2000; Truong and Baker, 1998). As a result of these findings, presently VS has been used successfully for these purposes in Australia, China, Thailand, Vietnam and Senegal (Truong and Hart, 2001; Truong, 2000).

3.3 Effectiveness of Vetiver Grass

A Vetiver Grass system is much more efficient in treating wastewater than other grasses currently used for this purpose in Queensland. For example, at an abattoir near Brisbane, MEDLI model (Model for Effluent Disposal by Land Irrigation) predicted that to sustainably dispose of 2 ml of effluent (155 mg/L of N and 15 mg/L of P) per day, the abattoir would need 178 ha of land if Kikuyu grass was used, but only 87.6 ha would be needed when vetiver grass was used. This land area could be further reduced if the effluent was treated with VS first before irrigation.

3.4 Australian Research Results

A demonstration site was set up at the Beelarong Community Farm at Morningside, Brisbane to obtain quantitative data on the effect of VS in improving its quality under field conditions and also in reducing the volume of effluent. In this NRM and EPA funded project, VS was used to treat the discharge 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. After five-month growth, vetiver was more than 2 m tall and a stand of about 100 vetiver plants in an area less than 50 m^2 have completely dried up the effluent discharge (Fig.1).

Groundwater monitoring (collected at 2 m 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/100 mL), (Truong and Hart, 2001). 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/100 ml

3.5 Chinese Research Results

Vetiver was used to treat polluted river water in central China. The removal percentage of total P was 93.7% after 2-week and more than 99% after 3 weeks. The removal percentage of total N was 58% after 2 weeks, and 71% after 4 weeks. Phosphorous is usually considered to be a key element in water eutrophication (Anon, 1997; Zheng *et al.*, 1997)

3.6 Australian Applications

Following the success of the treatment work at the Beelarong Centre, QEPA has recently approved a similar treatment project for a Caravan Park in Emerald. Currently Veticon Consulting is developing a system using vetiver grass to treat effluent output of out-of-town motels for the *Grafton City Council* in New South Wales (Hart *et al*., 2003).

Teys Bros. Abattoir in Beenleigh and *Davis Gelatine* in Beaudesert have engaged Veticon Consulting to develop a VS suitable to treat large volume of highly concentrated wastewater discharge from these factories. (Photo 1), (Smeal *et al*., 2003). VS has also been used successfully to treat leachate from landfill in Armidale City and Lithgow City in New South Wales, Australia. Currently Veticon Consulting is implementing a leachate treatment project with *Tweed Shire Council* on a large landfill in northern New South Wales (Percy and Truong, 2003).

4 THE MEDLI MODEL FOR VETIVER SYSTEM

A Model for Effluent Disposal by Land Irrigation (MEDLI) is a computer model developed by NRM. This model has direct application on the requirements to treat various types of wastewater including sewerage effluent (Vieritz *et al*., 2003).

Fig. 1 Effectiveness of VS in treating effluent in Brisbane, Australia

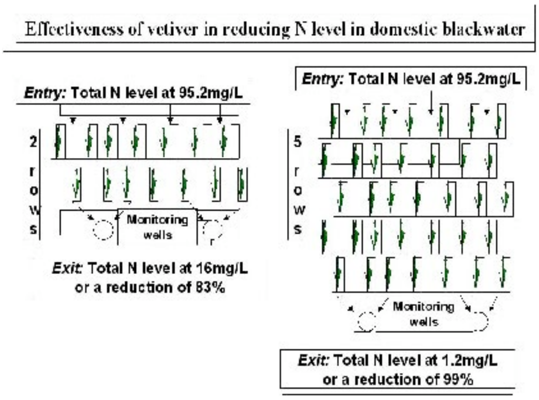

Photo 1 Irrigated with high nutrient effluent domestic from Teys abattoir, vetiver produced vigorous growth (over 2 m high) in 8 months

4.1 Results of MEDLI Model Simulation

For the Toogoolawah sewage treatment plant, the MEDLI model simulation predicted that less than 3 ha of land is needed to treat the entire effluent output to comply with EPA licensing conditions. The primary treated effluent previously being discharged from the Toogoolawah had the following characteristics:

- Daily output 0.3 ml
- Nitrogen concentration at 13 mg/L
- Phosphorus level of 5.5 mg/L

However if the effluent is pre-treated in the ponds to reduce N and P concentrations by approximately 10% before releasing into the vetiver plots, the land area needed would be less than 1.5ha

5 TREATMENT PROCESS CHOSEN FOR TOOGOOLAWAH

5.1 Introduction

A two-phase treatment program was adopted:

- Phase 1: Preliminary treatment in the ponds.
- Phase 2: Main treatment by vetiver wetlands.

5.1.1 Phase 1: Preliminary treatment of effluent in the ponds

Floating pontoons have been used successfully to treat piggery effluent ponds in Vietnam (Photo 2), and also recently at the Teys Bros. abattoir in Queensland, where both N and P levels in the pond leachate were sufficiently reduced to eliminate the blue-green algae infestation. The effluent in the three ponds is first treated hydroponically by the vetiver pontoons, which are able to reduce N and particularly P loading of the effluent before releasing it to the wetlands. Preliminary trial indicated that vetiver can be established and grew vigorously on pontoons in Toogoolawah ponds (Photo 3**).**

The 21 floating pontoons were designed so vetiver plants sitting on the pontoons and the roots suspending in the effluent. The size of each pontoon is 2.4 m x 2.4 m with about 300 individual plants placed on each pontoon. The number of pontoons required will depend on the level of nutrient load. The number of pontoons can be increased later to ensure an effective treatment process was achieved. Maintenance program will include replacement of dead plants, regular harvest to encourage new growth and the export of absorbed nutrients.

In addition, vetiver is being planted at the high water level around the ponds to further reduce the nutrient loading and also to stabilise the pond banks.

5.1.2 Phase 2: Main treatment vetiver grass wetlands

After being treated hydroponically in the 3-pond system, effluent is released by trickle irrigation to the main vetiver grass wetlands areas.

For the wetlands, Vetiver grass was planted in rows on approximate contour lines to spread the flood-irrigated effluent, trapping sediment, slowing down flow velocity during storms and increasing infiltration. The interval between rows is at about 12 m. Temporary earth mounds were placed behind these rows to enable the effluent to be held back so that all the young plants receive water. Following full establishment, when the gaps between plants are closed and the rows will take over the work of the mounds so that the earth mounds can be removed (Photo 4).

Photo 2 Vetiver pontoons treating a piggery in an effluent pond in Vietnam

Photo 3 Excellent growth (1.5 m) after 3 months in an effluent pond at Toogoolawah

Two separate areas have been planted and each area is fed with effluent from the treatment ponds by its own pipeline. This means that both areas can be both operated at the same time, or one of them can be taken off line and dried out so that maintenance work can be undertaken on the grass in that area. In between the main rows of vetiver grass there was also planted extra rows to increase the amount of grass in the wetlands. No earth mounds were constructed with the intermediate rows (Fig.2).

Fig. 2 A general outline of the treatment area

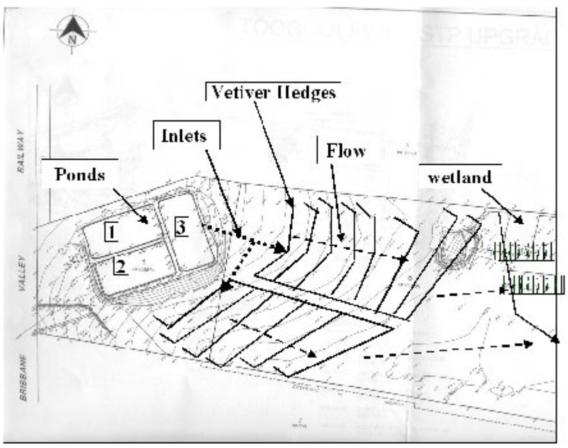

Photo 4 Wetlands planting in progress

Vetiver planting density:

- Planting density of contour rows was approximately 10plants/linear metre.
- Inter-row spaces were planted in rows of approximate 8plants/linear metre.
- Average planting density is 3 plants/m^2

5.2 Anticipated Outcome

Appropriate layout design of these rows will ensure all effluent will remain in the wetlands area during normal sunny days and during high rainfall period all excess flow is directed toward the natural swamp at the lower end of the treatment area.

Maintenance program will include replacement of dead plants, regular harvest to encourage new growth and export of absorbed nutrients. As vetiver grass will be highly enriched with nutrient (as high as 2.4% N). The harvested hay can be used as mulch or composting material, it is also highly palatable so it can be used for fodder as well.

Although MEDLI model indicated only 1.5 ha of land is required for sustainable disposal of the entire output. An area of 3ha has been used for the Vetiver Grass wetlands area, allowing extra capacity to cover extreme events. As a further area of at least 2 ha downslope is also available for vetiver planting, the treatment area could be extended later if the monitoring indicated that the nutrient load of the discharged effluent exceeded the licensed levels.

6 MONITORING PROGRAM

In conjunction with the treatment program, monitoring of both surface and sub-surface flows is also being carried out to ensure adequate treatment and to provide data for the site management such as quantity and frequency of irrigation schedule during summer and winter; and wet and dry periods. Groundwater monitoring wells have been installed at strategic points and are being sampled on regular basis. Service water monitoring is undertaken at the inlet to the plant, at the outlet of the Imhoff tank and lagoons, at the natural wetlands below the Vetiver Grass wetlands and finally at the discharge into the local creek. Two monitoring wells have been installed to monitor the quality of deep groundwater. These are located on the downstream side of the treatment area. Sampling of the local stormwater drain will be also undertaken on a regular basis. It will monitor the exit levels of N and P.

7 IMPLEMENTATION

The wetlands were constructed over a six-month period. The work consisted of the following stages:

7.1 Site Clearing

The site chosen for the wetlands is on a 16.5 ha block of land to the east of the Toogoolawah Sewerage Treatment Plant. About 8 ha of the site are being used for the wetlands. The site was firstly cleared of all trees and bushes. Care was taken to remove all large root systems.

7.2 Ground Preparation

The site was broken up into two areas with a road down the middle. An access road was constructed around the northern side. About 60% of the areas to be planted were prepared. Firstly the ground was sprayed with a herbicide to kill the existing vegetation. The ground was then rotary hoed and then sprayed again using Roundup herbicides.

7.3 Survey

Using a laser level contour rows were pegged out across the slope for each area. These rows were about 12 m apart with a fall of 200 mm between each row. Trenches were then dug along each row with the spoil used to form a mound on the down hill side of the trench.

7.4 Grass Planting

Two types of fertilizer were placed in each row. This included DAP and Muriate of Potash at a rate of 300 kg per hectare for both. The grass was delivered in clumps with about fifty plants in each clump. The grass was planted along the rows about 100 mm apart between each plant. Watering of the plants started immediately after each day of planting. In some cases channels were dug to each row to ensure that water got to every plant. The mound downstream of each row formed a “bay” which was designed to spread the effluent out evenly over the whole bay.

Within each bay further single or double rows were planted about 3 metres apart. The main aim of watering was not to flood the plants for too long. The best results were obtained when the grass was given a good watering and then was given time to dry out. Planting started in early February and was substantially completed by the end of March. It is anticipated that extra plantings will be required during the next twelve months. In total about 25,000 Vetiver Grass plants have been placed in the wetlands so far (Fig.6).

7.5 Pipeline Construction

To feed the sewerage effluent to the wetlands a new outlet chamber and pipeline from the sewerage ponds were constructed. This is a gravity feed system and the 150mm pipeline can deliver about 15 L/sec or about 5 times the average dry weather flows to either area or to both areas at the same time. Valves have been installed to direct water to either or both areas.

7.6 Floating Pontoons

As already described 21 floating pontoons have been placed on the ponds to improve their water quality. Advanced plants were first established in pots before they are placed onto the pontoons. About 300 potted plants are placed onto each pontoon. To remove the nutrients further Vetiver grass was also planted around the edge of the lagoons. About 6000 plants have been used in the pontoons and the same amount was planted around the lagoons.

7.7 Maintenance of Weeds

Because herbicides have not been used since the initial clearing of the site the weed growth has also been vigorous. To overcome this a ride on mower has been used to keep the weeds down between the rows of Vetiver Grass and a Wiper Snipper was used to cut the weeds up close to the rows of grass.

7.8 Nursery

Because there was not enough staff to undertake the planting quickly a small shaded nursery was constructed on site to keep the plants alive during planting and to produce potted plants for the floating pontoons. Whenever the operator of the sewerage treatment plant turns on the effluent reticulation for washing the sides of the Imhoff tank the plants in the nursery are watered automatically. This nursery has proven to be very worthwhile and has been a great help in enabling the project to succeed.

8 RESULTS OF SCHEME SO FAR

8.1 Vetiver Grass Pontoons

Results of a preliminary trial conducted on site with the first 3 pontoons, show that vetiver established and flourished (up to 1.5 m in 3 months) under hydroponic conditions of all three ponds. These pontoons have been removed and the grass harvested to produce about 5 new tillers of grass from each original tiller placed on the pontoons. The pontoons have now become the source of Vetiver grass for the project. Vigorous growth has also been seen in the Vetiver Grass plants that were placed onto the 21 new pontoons (Photo 5) and 2 months later (Photo 6).

Photo 5 New pontoons in March 2003

Photo 6 Two months later

8.2 Growth In The Wetlands

During the planting stage the effluent was flooded onto the wetlands to enable the grass to grow. In most of the areas the growth was good although nothing like the growth of the grass on the floating pontoons. However when the grass was flooded for too long a period of time, for example, more than two days then the grass didn't grow or growth was reduced. During establishment phase, vetiver grass needed moist but not wet conditions so in the early stages it needed time to dry out (Photo7 and 8).

Photo 7 Wetland, one month after planting

Photo 8 One month later

The growth of the Vetiver grass has been varied for the first three months. Where the grass was able to dry out between watering the growth was good. In places where the water lay around the grass the growth was poor. Some of the grass was planted late and so growth is not expected unto spring. The normal operation of the wetlands did not commence until early May and so the real vigorous growth could not be expected until the next summer. In the meantime care was taken not to flood the areas for too long a period (Photo 9 and 10).

Photo 9 Wetland, one month after planting

Photo 10 One month later

8.3 Water Quality

Even at this early stage, there is already evidence that the quality of the effluent is improving in respect to nutrient loads. Previously the total Phosphorous level for the plant effluent varied between 4.6 to 8.8 mg/L and now the results have dropped to 1.2 mg/L. Further details are given in Table 1 below.

Table 1 Preliminary results showing the effects of vetiver treatment in pond effluent and wetlands

Analytes	Previous pond levels (mg/L)	Vetiver treated pond levels (mg/L)	Vetiver treated wetlands levels (mg/L)
pH	9.0 to 9.7	9.4 to 9.7	-
Ammonia (N)	1.7 to 9.1 mg/L	0.07 to 0.57 mg/L	0.6
Total nitrogen (N)	13 to 20 mg/L	6.7 to 7.3 mg/L	6.7
Total phosphorous (P)*	4.6 to 8.8 mg/L	1.2 to 2.1 mg/L	1.2
Dissolved oxygen	12.5 to 20 mg/L	9.3 to 20 mg/L	-
BOD (5 day)	29 to 70 mg/L	32 to 42 mg/L	-
Faecal coliforms	60 to 800 counts / 100 ml	13 to 580 counts / 100 ml	-

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A Brief Introduction to the First Author

Ralph Ash is a senior engineer with the Esk Shire Council. He has an honours degree in Civil Engineering from Sydney University and a Master of Engineering Science Degree from UNSW. He has extensive experience in Local Government Engineering especially in Water and Wastewater fields. He has been a lecturer in Civil Engineering at the QUT in Brisbane and at the University of Technology in PNG. Ralph has been more recently involved in the use of the latest technology in water/wastewater treatment and especially as it relates to the reuse of sewerage effluent. He has worked both in Australia and overseas in Papua New Guinea.