

VETIVER SYSTEM FOR INDUSTRIAL WASTEWATER TREATMENT AND DISPOSAL AT GELITA APA, QUEENSLAND, AUSTRALIA

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ABSTRACT:

The disposal of industrial wastewater in Queensland is subjected to the strict environmental guidelines enforced by the Environmental Protection Authority. The most common method of treating industrial wastewater in Queensland is by land irrigation, which is presently based on tropical and subtropical pasture plants. However with limited land area available for irrigation, these plants are not efficient enough to sustainably dispose of all the effluent produced by the industries. Therefore to comply with the new standards, most industries are now under strong pressure to upgrade their treatment processes.

Over the past seven years a series of research projects conducted at GELITA Australia gelatine factory in Beaudesert, Queensland to determine a viable means to achieve these goals. The Vetiver System has been identified as having the potential to meet all the criteria:

- Vetiver has the potential of producing up to 132t/ha/year of dry matter yield as compared to 23 and 20t/ha/year for Kikuyu and Rhodes grass respectively
- With this production vetiver planting has the potential of exporting up to 1920kg/ha/year of N and 198kg/ha/year of P as compared to 687 of N and 77kg/ha/year of P for Kikuyu and 399 of N and 26 of P for Rhodes grass respectively.
- Vetiver growth can respond positively to N supply up to 6 000kg/ha/year and to ensure this extraordinary growth and N uptake, P supply level should be at 250/ha/year.

Computer modelling output based on an assumed maximum annual effluent output of 475 ML/year, and N concentration of 300mg/L and P of 1mg/L, amongst the three grasses, vetiver requires the least land for sustainable irrigation in both N and effluent volume, 72.5, 104 and 153ha when vetiver, Kikuyu (*Pennisetum clandestinum*) and Rhodes grass (*Chloris guyana*) were used, respectively.

Based on the above results the Gelita has developed a long term implementation plan for effluent and other solid waste product disposal.

Keywords: Vetiver, effluent disposal, irrigation, nutrient, fodder

1. INTRODUCTION

GELITA owns and operates a plant for the manufacture of gelatine from cattle skin at a site at Sunny Hills via Beaudesert in Queensland Australia. This plant is situated on a property of 170 hectares, approximately 75 kilometres from Brisbane. The GELITA operation is a medium sized enterprise employing 70 full time staff and producing 2200 tonnes of gelatine each year for an approximate annual turnover of AUD30 million per year. Raw materials are sourced from meatworks across the country and consist of face pieces and scraps of hide of little other commercial value. The manufacturing process is unique to this country and requires a high through put of water

to be effective. GELITA generates approximately 1.3 ML a day of wastewater, which is characteristically high in nitrogen and total dissolved salts.

The Queensland government has applied strict regulations regarding the disposal of this wastewater. In order to meet these regulatory requirements and to fulfil expectations of ESD (Ecologically Sustainable Development), GELITA has undertaken a comprehensive research program to develop optimal disposal methodologies.

2. CURRENT CONSTRAINTS

The GELITA factory extracts gelatine from cattle hide using chemical processes involving strong acids, lime and hydroxides. The site consists of 170 hectares of land with 121 hectares licensed by the Environmental Protection Authority (EPA), for disposal of effluent generated in the production of gelatine. The effluent from the processing plant is highly saline (average 6 dS/m), alkaline and has a high organic matter content. This effluent is further processed in a typical series of anaerobic and aerobic digestive processes to lower the nitrate contents to approximately 300 mg/L of nitrogen and 2 mg/L of phosphorus.

The property has 13 distinct soil types, which range widely in their properties from Rudosol, Dermosol, Vertosol to Sodosol. Of these soil types only the Rudosol alluviums display acceptable characteristics to deal with the long-term application of effluent. Effluent applied to the Sodosol and Vertosol clay soils can result in a surface concentration of salts that affects the root zone and is not considered a long-term sustainable practice. Due to extreme climatic variations over the seven years of operation the planting of pasture and annual crops has not provided a viable operational methodology as concentrations of salts in soil increase proportionately to diminishing rainfall. In order to ensure sustainability of the disposal process, an alternative method was sought that would allow for the “flushing” of salts through the soil profile whilst stripping the nitrogen from the solution. Such a process would meet the EPA requirements and eliminate a real environmental risk to the operation.

3. LICENSING LIMITS FOR NITROGEN AND PHOSPHORUS

Under Queensland law, the treatment of industrial wastewater is administered by the EPA, which has adopted a computer model - MEDLI (Model for Effluent Disposal using Land Irrigation), as a basic tool for industrial wastewater management. MEDLI is a Windows based computer model for designing and analysing effluent disposal systems, which use land irrigation, for a wide range of industries such as piggeries, feedlots, abattoirs, sewage treatment plants, and food processing factories (Truong *et al.*, 2003; Vieritz *et al.*, 2003)

For GELITA, the current licensing limits set out under the EPA permit the irrigation of 3.0ML/day of wastewater with a maximum Nitrogen level of 200mg/L, total Phosphate at 5mg/L and total dissolved salts of 12t/ha/annum.

4. CURRENT MANAGEMENT PRACTICES

To comply with EPA licensing conditions, the GELITA factory effluent output is currently distributed by spray irrigation from hard hose traveling irrigators across 121 hectares of grassland dominated by Rhodes grass. This is “a command and control mode” in which compliance is assessed by comparison with of sample data with fixed criterion. The license controls fail to adapt appropriately to extremes of climatic conditions and production variability. Under a strict licensing

interpretation, the current practice is not adequate in providing a long-term sustainable treatment solution.

5. SEARCHING FOR A MORE INNOVATIVE AND NATURAL SOLUTION

For GELITA, alternative solutions such as chemical treatment plant and transportation to sewage treatment plant were considered but both of which are impractical and most importantly very costly to build and to operate. Therefore a more innovative and natural solution was needed.

Tree planting was one of the earlier options considered, it has been trialed for several years but has not provided an effective solution to the problems faced by the company. To date no data is available for comparison of the effectiveness of the two eucalypt species trialed for N uptake as opposed to that of traditional pasture regimes. Preliminary findings have established that an estimated 16.5 t/ha/year dry matter yield of pasture will result in a N export of 458kg/ha/year from between tree rows if an assumed N level of 2.9% occurs. No further results are expected from these trials for some time. This is not an outcome that meets the company objectives, as the EPA requires an updated farm management program to be submitted by the end of September 2003.

Application of the Vetiver System (VS) for wastewater treatment is a new and innovative phytoremedial technology developed by the Department of Natural Resources and Mines in Queensland, (Truong and Hart, 2001). VS was identified as having the potential to meet all the criteria of both factories.

The vetiver option using MEDLI as a model offers a practicable and cost effective solution. However, to date the application of MEDLI in tropical and subtropical Australia has been restricted to a number of tropical and subtropical crops and pasture grasses. These species have been specially calibrated for MEDLI use, to apply vetiver to MEDLI model it has to be calibrated first.

To obtain this vital information, GELITA Australia with support from the Queensland Department of Natural Resources and Mine, and a grant from the Wallace Genetic Foundation of the US (through The Vetiver Network International), has undertaken a comprehensive research program to calibrate vetiver for MEDLI modelling (Veritz *et al*, 2003).

In addition both companies also conducted other trials with vetiver for erosion and sediment control, wetland establishment, cattle feed and composting. GELITA Australia has a goal of zero waste off site and the trial of vetiver as a bulking material and for odour reduction in the composting process is part of an ongoing research program designed to achieve this outcome.

6.0 RESEARCH AND DEVELOPMENT PROGRAM (Smeal and Truong, 2006).

The program consisted of two projects:

- Calibrating Vetiver grass for the MEDLI model (Truong and Smeal, 2003)
- Providing base line data to assist the development of a suitable strategy for implementation in both companies

6.1 Summary of results in calibrating Vetiver grass for the MEDLI model

- Vetiver planting at Sunny Hills has the potential of producing up to 132t/ha/year of dry matter yield as compared to 23 and 20t/ha/year for Kikuyu and Rhodes grass respectively
- With this production vetiver planting has the potential of exporting up to 1920kg/ha/year of N and 198kg/ha/year of P as compared to 687 of N and 77kg/ha/year of P for Kikuyu and 399 of N and 26 of P for Rhodes grass respectively.

- The harvested dry matter yield of vetiver grown at Sunny Hills was 100t/ha, exporting 1442kgN/ha and 149kgP/ha, as compared with 642 kgN/ha and 72 kgP/ha for Kikuyu; and 373 kgN/ha and 24 kgP/ha for Rhodes, respectively, (Wagner *et al.*, 2003)

6.2 Research and Development for baseline data

In conjunction with the MEDLI calibration program, a series of others trial was conducted at Sunny Hills to determine the effects of other adverse effects on vetiver growth such as soil salinity, high sulphate level, low P and water logging. The followings are summary of results:

- Vetiver growth can respond positively to N supply up to 6 000kg/ha/year and to ensure this extraordinary growth and N uptake, P supply level should be at 250/ha/year.
- Results from both field and pot trials, and anecdotal evidence indicate that endemic “adverse” factors in the soils that commonly affect plant growth such as high acidity, high salinity, high S, Na and Ca, do not adversely affect vetiver growth.
- Data on growth and nitrogen content of mature plants indicate that the deep and extensive root system of vetiver could reduce or eliminate nitrate leaching.
- Nutritional values in Table 1 show that vetiver is highly digestible and comparable with Rhodes grass and Kikuyu.

Table 1: Nutritional values of Vetiver, Rhodes and Kikuyu grasses at Sunny Hills

Analytes	Units	Vetiver grass			Rhodes	Kikuyu
		<i>Young</i>	<i>Mature</i>	<i>Old</i>	<i>Mature</i>	<i>Mature</i>
Energy (Ruminant)	kCal/kg	522	706	969	563	391
Digestibility	%	51	50	-	44	47
Protein	%	13.1	7.93	6.66	9.89	17.9
Fat	%	3.05	1.30	1.40	1.11	2.56
Calcium	%	0.33	0.24	0.31	0.35	0.33
Magnesium	%	0.19	0.13	0.16	0.13	0.19
Sodium	%	0.12	0.16	0.14	0.16	0.11
Potassium	%	1.51	1.36	1.48	1.61	2.84
Phosphorus	%	0.12	0.06	0.10	0.11	0.43
Iron	mg/kg	186	99	81.40	110	109
Copper	mg/kg	16.5	4.0	10.90	7.23	4.51
Manganese	mg/kg	637	532	348	326	52.4
Zinc	mg/kg	26.5	17.5	27.80	40.3	34.1

Monitoring bores, up to 2m deep, were installed at various distances on a vetiver plot to monitor the efficiency of the vetiver treatment. Table 2 shows total N in seepage was reduced from 170mg/L to 17.5mg/L after going through 20m of vetiver and to 10.6mg/L after 50m. Similarly total P was reduced from 32mg/L to 3.4mg/L and 1.5mg/L respectively.

Table 2: Effectiveness of vetiver planting on quality of effluent seepage

Analytes	Nutrient levels		
	Inlet	Mean levels in monitoring bores	
		20m down slope from inlet	50m down slope from inlet
pH	8.0	6.5	6.3
EC (uS/cm)	2200	1500	1600
Total Kj. N (mg/L)	170	11.0	10.0
Total N (mg/L)	170	17.5	10.6
Total P(mg/L)	32	3.4	1.5

7. RESULTS OF MEDLI SIMULATION

Table 3 shows the MEDLI output based on an assumed maximum annual effluent output of 584ML, N concentration of 300mg/L and 121ha available for irrigation, Amongst the three grasses, vetiver requires the least land for sustainable irrigation in both N and effluent volume.

Table 3: Land area required by the three grasses for irrigation and N disposal

Plants	Land needed for irrigation (ha)	Land needed for N disposal (ha)
<i>Vetiver</i>	80	70
Kikuyu	114	83
Rhodes	130	130

However, in theory, if this land area were used, there would be no runoff or leaching; to promote salt leaching either the land area is reduced or the irrigation volume increases. For example, MEDLI predicts that on the same irrigation regime, to provide 15-20% extra volume for leaching, only 49.5ha is required for irrigation. Some N will also move down the horizons with the extra volume, but vetiver would recover this N with its deep root system as shown above.

The potential for soil salinity, groundwater contamination and eutrophication of the adjacent Logan River has established rigorous parameters for the research program. A means for the transportation of soluble salts through the soil profile via adequate leaching of effluent is required. A reduction from 121 hectares to 50 hectares for the application of the effluent is expected to result in significant cost savings for the operation. The program will however, require the implementation of a rigorous monitoring regime to protect natural assets including soil and ground water.

8.0 CURRENT VETIVER SYSTEM RESEARCH, DEVELOPMENT AND APPLICATIONS AT GELITA APA

8.1 Soil Based Reed Beds (SBRB)

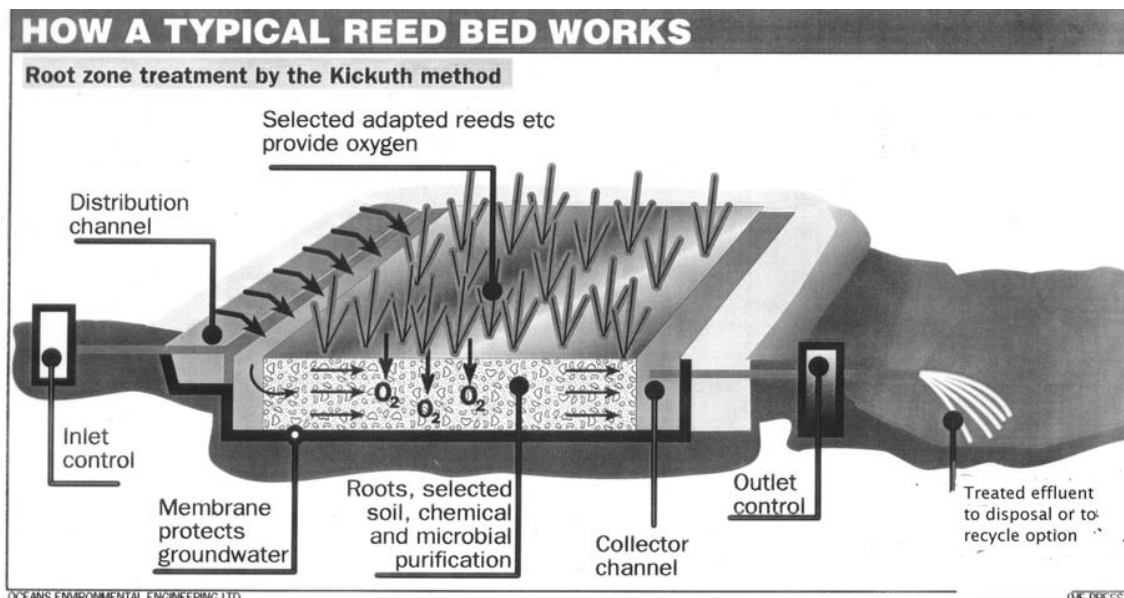
A sub-surface flow soil based reed bed (or constructed wetland /reed bed) is a combination of three interdependent elements: the growing media, the plants and the micro-organisms. In this

system the wastewater comes into contact with a wide range of micro-organisms that occur in high densities on the surface of the growing media and around the plant roots. Systems constructed correctly from these three components offer sustainable long term treatment capabilities.

SBRBs have been used widely throughout the world to effectively treat domestic wastewater, as well as a diverse range of highly contaminated industrial, chemical and agricultural effluents. The Reed Beds system described here is a soil based plant and micro-biological system in which the effluent moves through the soil fully below the Reed Beds surface. This wastewater treatment approach was originally developed in Germany over 30 years ago. SBRB systems have since been developed and refined through hundreds of successful applications around the world. This includes substantial reduction of nutrients (i.e. total nitrogen and phosphorus) as well as Biological Oxygen Demand (BOD), Suspended Solids (SS) and Faecal Coliforms (FC). SBRB systems now provide high performance, reliability, long life and very low running costs, as well as an environmentally friendly treatment solution. (Smeal *et al*, 2006).

The SBRB system has three simple components, which interact in a complex manner to provide an ideal medium for wastewater treatment. The treatment involves:

- **A shallow bed of soil** (between 0.5 and 1.5m deep) in which reeds are planted, contained by a waterproof membrane to prevent the wastewater leakage.
- **A suitable plant** which ideally should thrive under water logged conditions, tolerate high level of pollutants, high capacity of absorbing these pollutant and has high biomass production under these extremely adverse conditions.
- **Micro-organisms** (fungi and bacteria) in the soil which provide most of the treatment. The “reeds” root and rhizome systems bring air into the soil immediately surrounding them. Further away, the environment is anaerobic. These aerobic and anaerobic zones host an appropriate range of micro-organisms responsible for the impressive performance of SBRB systems.



8.2 Agrochemical Retention and Disposal

Literature has established that herbicides and pesticides have a deleterious effect on the aquatic flora and fauna ecosystem, particularly biodiversity. There is often serious ecological damage even when the levels of pollutant are not high enough to cause direct toxicity.

Vegetative filter strips are cost-effective and widely used to reduce sediment, nutrients, herbicide and pesticides in run off water along riparian zone in farmlands, while providing natural habitat renewal. This project aims to use vetiver filter strips to measure and evaluate its role in reducing Atrazine movement into the aquatic environment.

The movement of various concentrations of Atrazine through the soil is being determined by analysis of soil leachate collected via devices located at depths ranging from 30cm to 1.2 m in transects across a slope to a trap dam. The dam water will also be analysed for the presence of the herbicide (Cull *et al.*, 2 000).

8.3 Evapo-transpiration of Vetiver Grass

Vetiver has been gaining popularity as a plant ideally suited for effluent irrigation areas due its capacity to tolerate both drought and water logged conditions, high biomass production, high nutrient uptake rates and exceptional transpiration rates based on anecdotal evidence of field observations. Therefore a properly designed experiment has been set up to measure the transpiration rates which will provide the water uptake parameters required for designing effluent irrigation schemes.

A comparison of several species of grasses including vetiver, kikuyu and typha will be undertaken to establish effective determination of plant water use. Each of the species is suited to wetland conditions and the local climate. In particular, the results will be used to calibrate Model of Effluent Distribution by Land Irrigation (MEDLI) for vetiver.

8.4 Vetiver Essential Oil for Pest Control and Pharmaceutical Uses

To make the most of the VS, GELITA is also interested in the uses of vetiver by-products: its massive biomass and particularly its essential oil, which can produce ingredients for pest control and possible pharmaceutical uses.

GELITA APA is in partnership with the University of New South Wales, Sydney, exploring these possibilities by developing/refining new essential oil extraction methods and using both root and leaves for this process. In addition to *V. zizanioides*, other Australian native vetiver species will also be included in this project.

8.5 Effects of vetiver grass on some soil physical and chemical properties

Due to its extensive, deep and penetrating root system, it is expected that some soil physical and chemical parameters such as water infiltration rates and soil bulk density would be improved under vetiver cultivation. An extensive soil sampling program is being conducted to compare some of these parameters between vetiver planted land and original soils.

Preliminary results indicate that vetiver planting has increased water infiltration rate in heavy and compacted clay soil. Of particular interest is the potential for increased deep leaching of chloride deposits in plough pan zones.

9.0 FUTURE PLANS

Modular reed beds to BSD to facilitate water purification for process reuse

Subject to satisfactory outcomes of trials demonstrating that vetiver reed beds are capable of dealing with significantly higher than typical design loadings of nitrogen, the development of a series of 6 modular beds to treat up to 1.5 ML of effluent a day will be considered. The beds will comprise an impermeable plastic liner of heat welded 2mm HDPE with an aspect ratio of 10:1. Each module will be 10m wide by 100m long with the potential to operate either in series with, or independently of the others.

Centre pivot irrigation on clay under vetiver

Subject to the outcomes of monitoring of soils chemistry and structure of irrigated clays planted to vetiver, a computer controlled centre pivot irrigation system may be established. The system will irrigate vetiver planted on heavy clays with herring bone contours to promote lateral drainage of runoff. Nitrogen in effluent will be stripped by vetiver and the concentrated saline runoff will drain through vetiver swards to an evaporation pond. Deep drainage of nitrogen and salts would not occur, thus protecting ground water resources.

Vetiver pontoons on effluent storage ponds

The use of floating vetiver pontoons to treat effluent storage ponds is becoming more common. The development of a pontoon system will provide GELITA with a nursery for potted vetiver. If the potting media is free of contaminants, the vetiver slips are free of competition and will grow without the need for pre-emergent herbicides.

10. REFERENCES

- Cull, R.H., Hunter, H., Hunter, M. and Truong, P.N. (2000). 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, January 2000
- Smeal, C. and Truong, P. (2006) Current Vetiver System Research, Development and Applications At Gelita APA, Australia. Proc. Fourth International Vetiver Conference, Caracas, Venezuela, Oct 2006.
- Smeal, C., Truong, P., Biala J. and Butler A. (2006). Application Of Vetiver Grass In Soil Based Reed Beds For Effluent Treatment At Gelita APA, Australia. Proc. Fourth International Vetiver Conference, Caracas, Venezuela, Oct 2006
- 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, and Smeal C. (2003). Research, Development and Implementation of Vetiver System for industrial wastewater treatment, GELITA APA. Technical Bulletin no. 2003/3. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.
- Truong, P., Truong, S. and Smeal, C (2003). Application of the vetiver system in computer modelling for industrial wastewater disposal. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.
- Truong P, Tran Tan Van and Pinners, E. (2008). Vetiver System Applications: A Technical Manual. The Vetiver Network International publication. www.vetiver.org

- Vieritz A, Truong P, Gardner T and Smeal C. (2003). Modelling Monto vetiver growth and nutrient uptake for effluent irrigation schemes. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.
- Wagner S, Truong P, Vieritz A and Smeal C. (2003). Response of Vetiver Grass to Extreme Nitrogen and Phosphorus Supply. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.