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

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Abstract:

The effectiveness of vetiver grass in treating industrial effluent at GELITA APA in Queensland, Australia was fully reported at the Third International Conference on Vetiver in Guangzhou, China in 2003. As a result of this experience, in the last three years GELITA has launched an extensive R&D program to seek further data to increase the efficacy and application range of VS at the factory and elsewhere in Australia and globally.

This paper describes the current R&D program being conducted at GELITA Beaudesert site and outlines some preliminary results:

1.0 Soil Based Reed Beds

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.

The plant utilised should thrive in water logged conditions, tolerate high levels of pollutants, have a high capacity of absorbing these pollutants, and also have a high biomass production under such adverse conditions. Vetiver grass has all these qualities and holds considerable promise for use in soil based reed beds where high nutrient loads need to be removed.

2.0 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.

3.0 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.

4.0 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.

5.0 Effects of vetiver grass on some soil physical properties

Due to its extensive, deep and penetrating root system, it is expected that some soil physical 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.

6.0 Soil chemical characteristics

The long term impact on soil chemical properties such as pH, salinity level, nutrient levels, organic matter content and cation exchange capacity are also being monitored. Changes in SAR and ESP associated with irrigation are well documented in the literature. The site monitoring will assist in determining if these changes are influenced by the use of vetiver.

The complex interaction of the effluent driven nitrogen cycle, plant growth and leaching have contributed to depressed surface pH levels around 3.5. This low pH does not appear deleterious or inhibitory to the growth of vetiver.

7.0 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.

KEY WORDS: Soil based reed bed, atrazine, evapotranspiration, essential oil

1.0 INTRODUCTION

The effectiveness of vetiver grass in treating industrial effluent at GELITA APA in Queensland, Australia was fully reported at the Third International Conference on Vetiver in Guangzhou, China in 2003. As a result of this experience, in the last three years GELITA has launched an extensive R&D program to seek further data to increase the efficacy and application range of the Vetiver System (VS) at the factory and elsewhere in Australia and globally.

GELITA Australia manufactures food grade gelatine from cattle hide, and in doing so generates 1.3 ML/day of effluent high in nitrogen (ammonia). While interested in using biological systems for effluent purification, GELITA believes that only plants with a high nitrogen uptake capacity will be able to reduce the nitrogen load in their wastewater to an acceptable level. Consequently, a plant was needed which thrives in water logged conditions, tolerates high level of pollutants, has a high capacity of absorbing these pollutants, particularly nitrogen and has also high biomass production under these extremely adverse conditions.

Vetiver grass has all these qualities and holds considerable promise for use in soil based reed beds (SBRB), where high nutrient loads need to be removed.

GELITA Australia has initiated field research in order to:

- demonstrate the suitability of vetiver grass to treat nitrogen rich industrial effluent;
- use the research findings in order to develop and establish a SBRB system that is capable of purifying GELITA's wastewater to a satisfactory level;
- develop a SBRB system using vetiver grass suitable for Australian and world wide applications.

2.0 SOIL BASED REED BEDS

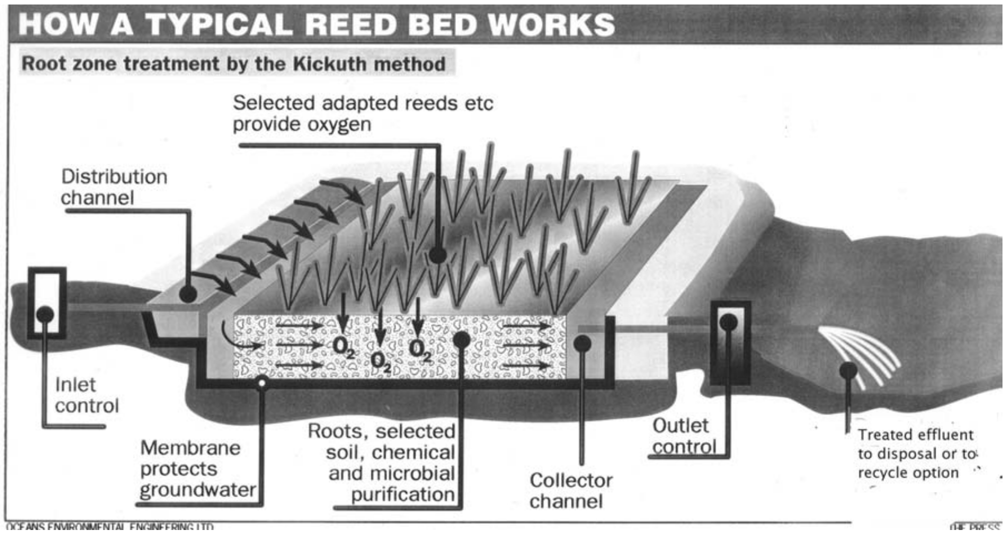
Constructed wetlands using Horizontal Flow (HFW) and Vertical Flow (VFW) systems and aquatic plants have been used with success for the treatment of both industrial and domestic effluent. These wetlands are generally referred to as "reed beds" because they are often planted with reeds.

HFW treats the water at a lower cost than conventional mechanical technology in capital and operating cost terms (Cooper *et al*. 1996). HFW have been used with success for the treatment of light load effluent. However, heavy load wastewater has generally been treated through the use of subsurface flow reed beds, particularly Soil Based Reed Beds (SBRB).

SBRB uses the sub-surface flow system where the wastewater comes into contact with the wide range of micro-organisms that occur in high densities on the surface of the growing media and around the plant roots. The Reed Bed system described here is a soil based plant and micro-biological system in which the effluent moves through the soil fully below the Reed Bed surface, resulting in substantial reduction of nutrients as well as Biological Oxygen Demand, Suspended Solids and Faecal Coliforms. 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 to effectively treat domestic wastewater, as well as a diverse range of highly contaminated industrial, chemical and agricultural effluents.

The SBRB system has three important 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 wastewater leakage.
- **A suitable plant** which ideally should thrive under water logged conditions, tolerate a high level of pollutants, exhibit a high capacity of absorbing these pollutants and have high biomass production under such extremely adverse conditions.
- **Micro-organisms** (fungi and bacteria) in the planted soil and 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.



2.1 Why Vetiver Grass Instead of Phragmites

From the above it is clear that plants used for SBRB should have an extensive root system to penetrate down to the base of the soil to ensure the system is properly aerated by the roots. The most commonly used plant for Reed Bed systems is *Phragmites* sp and in Australia *Phragmites australis*, which is a common wetland plant. However most published results indicate good removal of BOD Nitrogen nutrient loads through *Phragmites* sp reed beds can typically be as low as one tenth that of effluents generated by gelatine processing operations. Given the validated performance of vetiver in dealing with extremely high nitrogen loads GELITA is therefore investigating the potential for substituting vetiver for reeds in a higher rate treatment soil based reed bed. (A detailed full paper is presented at this conference).

In addition *Phragmites australis:*

- Has a relatively shallow root system, (a typical feature of wetland plants)
- Has a slow recovery growth after harvesting as it relies on the growth of new shoots from rhizomes and seeds instead of the old shoots.
- Is also a major weedy pest in all wetlands and waterways in Queensland due to its prolific seeding habit.

In comparison Vetiver grass *(Vetiveria zizanioides)*:

- Thrives under water logged conditions,
- Is tolerant of high level of pollutants, including heavy metals and nutrients (particularly N and P)
- Has a high capacity of absorbing these pollutants:
- Grows well under extremely adverse conditions such as high salinity, high acidity and alkalinity and sodicity.
- Has a prolific and deep root system
- Has high potential biomass production under nutrient rich conditions such as provided by effluent.

- Has a high water use rate: (7.5 times higher than Typha under wetland conditions)
- Is sterile seeded, reproduces vegetatively and therefore presents no threat of weed potential

2.2 Vetiver Grass in Reed Beds

Summerfelt *et al* (1994) used vetiver grass for both HFW and VFW in a study for the removal and stabilization of aquaculture sludge. Vetiver was selected over other aquatic species because it is tolerant of a wide range of environmental conditions. Results indicated that with vetiver planting, sludge removal and stabilization occurred within both wetland types. Both wetland types, respectively, removed 98-96% TSS, 91-72% total COD, 81-30% dissolved COD, and 82-93% of total N and P.

2.3 Soil Based Reed Bed Design and Construction at GELITA

2.3.1 The soils

Information from literature indicates that various media contain different chemical and physical properties that can result in a higher quality and/or efficiency of wastewater treatment. Therefore three types of medium were used:

- gravely soil
- sandy loam and
- black cracking clay

The gravel would theoretically have a higher infiltration rate than sandy loam and black cracking clay. The higher infiltration rate will essentially cause the wastewater to flow relatively quickly though the system. The faster the flows through the system the more volume the wastewater will be able to treat over time. Thus it is expected that the gravel will have the highest volume of wastewater entering the system. With its low hydraulic conductivity it is expected that the black cracking clay will only treat a very small amount of wastewater at any given time.

2.3.2 The Reed Bed Design

Several factors came into play when the sizing of the SBRB was designed. Limited space, cost, resources and time all played an important part to the scale of the beds. At GELITA the ratio of 10:1 (40m x 4m) was used with a gradient of one percent as recommended by Tchobanoglous (1993). It is expected in the long term this will provide enough gradient to adequately allow the wastewater to flow through the bed but also allow a good retention time for treatment.

2.4 Expected Outcome

It is expected that the Vetiver grass planted in the system will dramatically improve the wastewater treatment process through its many unique characteristics. The efficiency of the SBRBs is determined mainly by the following three factors:

- The quality of the wastewater, which is determined by a number of complex and interdependent variables
- Hydraulic retention time (HRT) is a very important factor as it allows for chemical, biological and physical process to occur within the system.
- The media's infiltration abilities.

It is expected that the HRT for all three beds will vary with the media, climatic and seasonal variations. However, under the same conditions, the gravel bed is more likely to require the lowest HRT to treat the effluent to a certain quality because of the higher porosity. This is due to a mixture of sand, rock and clay, which is more likely contain a good microbial population to enhance the treatment.

2.5 Budget

A significant investment has been made by GELITA in the promotion of vetiver system research and development over the past year, with AUD68, 500 spent in establishing trials and analytical expenditure during 2006. This does not include the expenditure on salaries and fixed costs associated with the development and maintenance of the research sites.

The proposed total budget figure for 2007 research expenditure on vetiver research reflects similar commitment with a further AUD50, 000 to support the extensive field trials on site. These include the reed bed application, concurrent transpiration studies and developing fuller integration of the vetiver system with the current effluent irrigation management system.

Expenditure will be dependant on successful outcomes of the trial beds. Data collated over a minimum of one full seasonal cycle will be required to justify any further expenditure. Decisions regarding major expenditure on desalination options for the site are dependant on the outcomes of these investigations.

Period 2005-2008 **Total** **$150,000**

3.0 AGROCHEMICAL RETENTION AND DISPOSAL

Research has established that pesticides have a deleterious effect on the aquatic ecosystem, particularly biodiversity. There is often serious ecological damage even when the levels of pollutant are not high enough to cause direct toxicity. Nutrient loading from agriculture is not directly toxic to indigenous organisms; however it can produce excessive algal growth resulting in anoxia, hence aquatic ecosystem disturbances. Consequently, fisheries, marine culture, tourism, and recreation can suffer.

3.1 Nutrient and Farm Chemical Contamination

Research has shown that strips of grasses and shrubs are a cost-effective way of reducing sediment, nutrient herbicide and pesticide movement while providing natural habitat renewal. Vegetative filter strips are widely used to reduce sediment, nutrients, and pesticides in run off water along riparian zone in farmlands. They can be common grasses, trees and shrubs planted along waterways.

However, Vetiver grass with its unique morphological and physiological attributes has been used extensively around the world for erosion and sediment control in farmlands, mine rehabilitation and wastewater treatment. But more specifically, research in Australia has shown that vetiver grass is highly tolerant to elevated levels of herbicides, particularly Atrazine, and also been shown to reduce the level of Atrazine in the water under wetland environment.

Micro-organisms associated with the plant root zones (rhizosphere) are an important component in biologically recycling nutrients and degrading herbicides and pesticides. Vetiver grass, with its enormous root system, can provide a very favourable habitat for these micro-organisms to develop and breaking down of herbicides such as Atrazine. Atrazine is listed by Extoxnet as being moderately to highly mobile in soils with low clay or organic matter content. Because it does not adsorb strongly to soil particles it has a high potential for groundwater contamination. In the United States, Atrazine is the second most common pesticide found in wells.

This pre-emergent is one of the most commonly used herbicides in Australia and the US for grain crop and sugarcane production. Recently, research conducted at the Laboratory for Environmental Biotechnology, Swiss Federal Institute of Technology Lausanne, Switzerland, has confirmed the Australian results that Vetiver is highly tolerant to elevated levels of Atrazine under hydroponic systems.

The Swiss research also found that roots were able to hyper-accumulate atrazine and that Vetiver resistance to atrazine was best explained by conjugation in the leaves and sequestration in the roots. Vetiver oil was also found to concentrate atrazine, with a comparable value of atrazine partition into octanol.

3.2 Atrazine Capture and Retention Project at GELITA APA

A mature stand of vetiver grass planted on a slightly sloping land on the edge of a farm pond is being used to test the ability of vetiver in trapping both surface and subsurface movement of atrazine. Atrazine was applied on the land above the experimental plot and its levels in the sediment trapped by the vetiver hedges, in the soil, ground water and pond water will be monitored over the next two years. CSIRO derived Fullstop leachate collection devices are installed to collect ground water at various depths.

3.3 Expected Outcomes

- The levels of atrazine in both soil and water are expected to be reduced by the intervention of the vetiver grass filter strips
- To demonstrate the benefits of vetiver grass filter strips on farms in reducing herbicide movement into the aquatic environment

- To develop a simple system suitable for easy adoption by the farming community to improve water quality.
- To promote the adoption of the model GUSED-VBS (Griffith University Soil Erosion & Deposition model – Vegetative Buffer Strip) developed by Griffith University, Brisbane, Australia. (A detailed full paper is presented at this conference).

3.4 Budget

Period over 2-3 year funded by GELITA and TVN **Total** **$29 000**

4.0 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 and high nutrient uptake rates. Anecdotal evidence of field observations or pot trials suggests exceptional transpiration rates of up to 4-10 times greater than normal design rates may be possible.

The evapo-transpiration rate of vetiver reported in the literature varied from 43 mm/day (Jones, 2005), 8-14 mm/day (Truong et al. 2003), and 3.8 mm/day in summer and 1.9 mm/day in winter (Percy and Truong, 2005). If such extreme claims are incorrect, environmental damage could result from undersized effluent irrigation schemes.

To resolve this, the transpiration rates from Vetiver and two comparison grass species is being measured on a study at GELITA APA. Vetiver growth and nutrient uptake parameters have already measured/calibrated in a previous field study at GELITA. The transpiration results will provide the Vetiver water uptake parameters required for designing effluent irrigation schemes. In particular, the results will be used to calibrate MEDLI for vetiver, a model used throughout the industry for designing effluent irrigation schemes.

4.1 Experimental Design

- Twelve lined bays of 3m × 3m in area, 1.45 m deep and 4 m apart, orientated perpendicular to the predominant wind direction.
- 3 treatments × 3 replicates in a fully randomised design
- 3 zero-plant (bare ground) control bays.

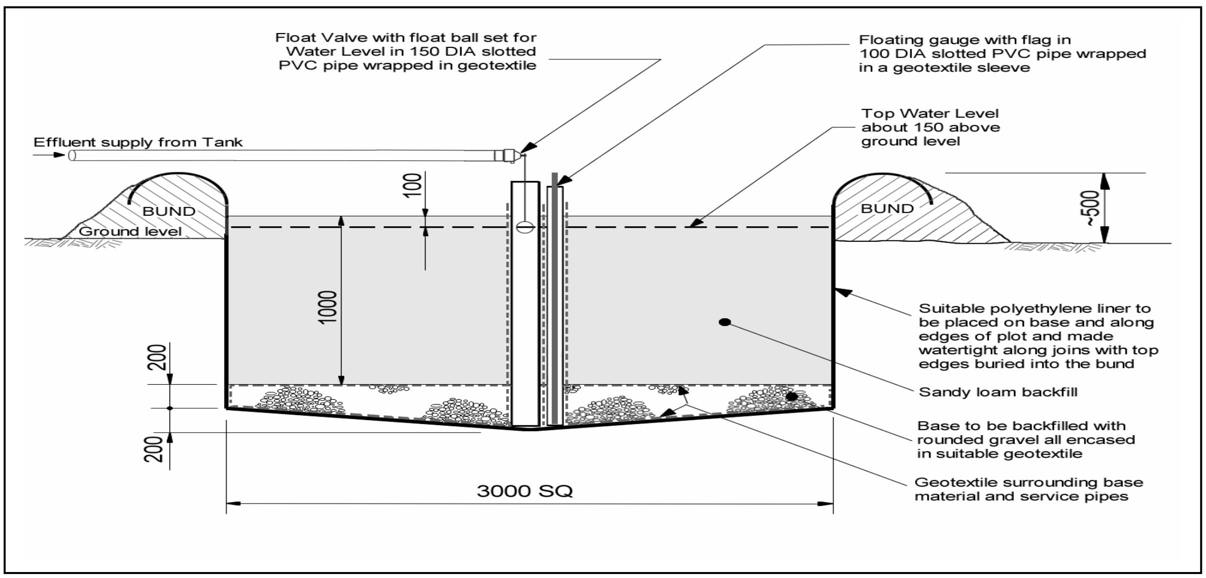
4.2 Treatments

1. Vetiver (*Chrysopogon zizanioides)*
2. Kikuyu *(Pennisetum clandestinum*) – a C4 cool climate plant that may thrive better in winter and data currently available.
3. Broad leaf Cumbungi *(Typha orientalis)* – a C4 wetlands species that is endemic to the area

4.3 Expected Outcomes

- To provide water balance components neede to estimate transpiration and crop coefficient.
- Statistical analysis to determine if Vetiver shows a transpiration rate significantly higher than that of Kikuyu and Typha.
- To provide a measure of shoot biomass yields
- To provide data for MEDLI to model vetiver and kikuyu growth, cover development and transpiration over time for given nutrient status and climate record. Compare predictions of shoot yield and transpiration with those measured.

Plot Design for Transpiration Study (A. Veritiz)



4.4 Budget

Period over 2-3 year funded by GELITA		$20 000
and DNR&W		$ 7 000
	Total	**$27 000**

5.0 VETIVER ESSENTIAL OIL FOR PEST CONTROL AND PHARMACEUTICAL USES

GELITA is not only interested in the use of VS for environmental protection but also its by products, namely its massive shoot and root biomass, 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.

Literature search has indicated that extensive researches have been conducted on vetiver essential oils (VO) for its Antibacterial, Antifungal, Antioxidant and Anti-inflammatory attributes. Currently, VO used as natural insecticides, cosmeceuticals, and aromatherapeutic agents. VO composed of over 300 compounds: sesquiterpenes and their derivatives; khusimol; α-vetivone and β-vetivone, and the major odorous constituents: α-vetivone and β-vetivone are repellent to insect. Recently, two compounds were found to possess strong antioxidant activities. Therefore VO has received great interest from academic institutions, pharmaceutical companies and agro-business

5.1 Project Plan

5.1.1 Development of methodology for purification of Vetiver essential oil for pest control and other uses

- The main goal of study is to develop efficient method of purification of α-vetivone and β-vetivone and other interested compounds by selecting the most effective extraction method from *Vetiveria zizanioides* and three Australian natives species: *Vetiveria elongata Types1 and 2 and Vetiveria filipes*
- Purify α-vetivone and β-vetivone from VO.
- Scale-up production

5.1.2 Effects of heavy metals in contaminated soils on quality and quantity of VO

Vetiver grass is now widely used for mine rehabilitation and effluent disposal and VO can be extracted as a by product from the above uses. Therefore the contamination of heavy metal and other chemicals on both the quality and quantity of the VO are important.

A pot trial will be conducted by growing vetiver in soil treated with high levels of Pb, Zinc and Fe, the three heavy metals that are taken up most by vetiver.

5.2 EXPECTED RESULTS

- Determination of the best extraction methods in term of high oil yield of α-vetivone and β-vetivone and may be of other components as well.
- Determination which Vetiver species has high content of α-vetivone and β-vetivone and other components and at which stage of growth.
- Determine whether VO can be extracted from leaves
- Whether heavy metals and other chemicals will affect the quality and quantity of VO
- Whether VO contains heavy metals and other chemicals or not

5.3 Budget

Over two year period $10,000

6.0 EFFECTS OF VETIVER GRASS ON SOME SOIL PHYSICAL PROPERTIES

Due to its extensive, deep and penetrating root system, it is expected that some soil physical parameters such as hydraulic conductivity (water infiltration rates) and soil bulk density would be improved under vetiver cultivation.

Work undertaken in Vietnam has indicated that the "flushing" of mobile salts below the root zone can be enhanced by the use of vetiver. The effect of vetiver on hydraulic conductivity of soils and the potential for improved leaching of salts under irrigation regimes is being examined.

6.1 Project

The aim of this project was to acquire information relating to hydraulic conductivity and soil chemistry on various soils within the GELITA property in order to gain a better understanding of the effluent disposal system using vetiver grass. This project provides knowledge into how the VS affects the soil profile chemically and physically. These soil-water parameters, will aid in the determination of appropriate irrigation management and monitoring programs that aim to keep environmental and aesthetic impacts to a minimum.

Over the space of the last two years several measured soil physical properties including K_{sat}, have altered significantly. This is believed to be largely due to changes in methodology rather than changes in land use.

6.2 Methods

- Determining saturated hydraulic conductivity values for various soil types by Guelph Permeameter.
- Collecting leachate from the various soils by leachate collectors.
- Collecting soil samples twice by the Tube Sampling method and analyzing them for chemical composition.
- Undertaking a comparative analysis of the chemical and physical mass balances within the soil profile.

6.3 Preliminary Results

- On the black cracking clay saturated hydraulic conductivity values were higher in vetiver plots than those from non vetiver plots; this was mostly likely due to the old root pathways or the cracks in the soil by vetiver roots.
- Within the vetiver plot a large increase in salt accumulation at around 0.6m depth was recorded at the first sampling, but this was greatly diminished at the second sampling.
- Outside the vetiver plot, the soil salinity profile was similar to that of inside the vetiver plot, but this was not diminished at the second sampling. In addition there was an increase in salt concentration with depth in the soil profile outside the vetiver plot.

6.4 Budget **$28 000**

7.0 FUTURE PLAN

7.1 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.

The choice of media, aspect ratio and critical hydraulic retention time will be established during the trial phase. Final water quality at the storage dam should be appropriate for use in desalination processes such as reverse osmosis if required.

7.2 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.

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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.

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