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VETIVER SYSTEM: A LOW COST AND NATURAL SOLUTION FOR THE PREVENTION AND TREATMENT OF CONTAMINATED WATER

SISTEMA VETIVER: UNA SOLUCIÓN NATURAL Y DE BAJO COSTOPARA LA PREVENCIÓN Y TRATAMIENTO DE AGUAS CONTAMINADAS

Dr. Paul Truong* and ***Yorlene Cruz Chaves, MBA*****

***** Director, The Vetiver Network International (TVNI) and
Veticon Consulting, Brisbane, Queensland, Australia
email: truong@uqconnect.net

****** TVNI´s Coordinator for Costa Rica
Abonos de Occidente R.L, San Ramón, Alajuela, Costa Rica
Ofic.: + (506)2445-8383 +Cel.: + (506) 8991-9180
Email: cruz.y@vetivercostarica.com

ABSTRACT

The Vetiver System (VS), which is based on the applications of Vetiver Grass *(Chrysopogon zizanioides* L), was researched and developed by *The Vetiver Network International* (TVNI) as an environmental protection tool. Application of VS for environmental protection is a new and innovative phytoremedial technology. VS is being used in more than 100 tropical and subtropical countries in Australia, Asia, Africa and Latin America for treating and disposing polluted wastewater from domestic and industrial discharges due to its effectiveness and low cost natural methods of environmental protection.

Extensive R&D in Australia, China and Thailand over the last 20 years have established that vetiver Grass is non invasive it has a high water and nutrient uptake and thrives under most adverse soil and climatic conditions. Vetiver grass is tolerant to elevated and sometimes toxic levels of salinity, acidity, alkalinity, sodicity as well as a whole range of heavy metals and agrochemicals. Latest research also shows its exceptional ability to absorb and to tolerate extreme levels of nutrients, capable of consuming large quantities of water under wet conditions and to produce a massive growth.

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, handicraft and material for organic farming.

This paper will refer specially sewage and industrial effluent, and landfill leachate treatment and disposal in Australia

Keywords: Pollution, leachate, effluent, toxic waste, heavy metals

1.0 INTRODUCTION

The Vetiver System (VS), which is based on the application of vetiver grass (*Vetiveria zizanioides,* Nash L, reclassified as *Chrysopogon zizanioides,* Roberty L), was first developed by the World Bank for soil and water conservation in India in the 1980s. Further research and development by *The Vetiver Network International* (TVNI) in the last 20 years have established VS as an innovative phytoremedial technology for environmental protection purposes. VS is being used in more than 100 tropical and subtropical countries in Australia, Asia, Africa and Latin America for treating and disposing polluted wastewater from domestic and industrial discharges due to its effectiveness and low cost natural methods.

Extensive R&D in Australia, China, Thailand and recently Venezuela have established that vetiver Grass is non invasive it has a high water and nutrient uptake and thrives under most adverse soil and climatic conditions. Vetiver grass is tolerant to elevated and sometimes toxic levels of salinity, acidity, alkalinity, sodicity as well as a whole range of heavy metals and agrochemicals. Latest research also shows its exceptional ability to absorb and to tolerate extreme levels of nutrients, capable of consuming large quantities of water under wet conditions and to produce a massive growth.

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, handicraft, biofuel and green manure for organic farming.

For these reasons, vetiver grass is known as a wonder grass, a miracle grass and a magic grass in various parts of the world. The two main applications of VS for Environmental Protection are:

- Prevention, Disposal and Treatment of Wastewater.
- Rehabilitation and Treatment of Contaminated Land

This paper only deals with the prevention, disposal and treatment of wastewater by VS.

2.0 SPECIAL CHARACTERISTICS OF VETIVER GRASS.

2.1 General Characteristics of Vetiver Grass (Truong et al. 2008)

- ***Tall, erect and stiff shoots*** can grow up to 3m under favorite conditions
- ***Forming a thick living porous barrier***. When planted close together they form a porous barrier that retards and spreads water flow and acts as a very effective filter, trapping both fine and coarse sediment in runoff water
- ***Deep and Massive Root System.*** Vetiver grass has a deep and massive root system, which is vertical in nature descending 2-3 meters in the first year, ultimately reaching some five meters under tropical conditions. The depth of root structure provides the plant with great tolerance to drought, permits excellent infiltration of soil moisture and penetrates through compacted soil layers (hard pans) and reduces/prevents deep drainage.
- ***Tolerance to extreme climatic variations*** such as prolonged drought, flood, submergence and temperature levels ranging from -14ºC to 55ºC and to thrive under rainfall ranging from 300 mm to 6000 mm per annum.
- ***Ability to re-grow rapidly*** after being affected by drought, frost, fire, saline and other

adverse conditions when the adverse effects are removed.

- ***Highly resistant*** to pests, diseases and fire
- ***Highly tolerant to traffic*** and high grazing pressure as its new shoots develop from the crown below ground level.
- ***Weed Potential*** Vetiver is a non-aggressive plant; it flowers but set no seeds, it produces neither above nor underground stems and it has to be established vegetatively by root (crown) splitting. It is imperative that any plants used for environmental protection purposes will not become a weed in the local environment. A sterile plant such as Vetiver is ideal for this application. In Fiji where vetiver grass was introduced to the country for more than 100 years and has been widely used for soil and water conservation purposes for more than 70 years, vetiver grass has not become a weed in the new environment. Vetiver grass can be killed easily either by spraying with Glyphosate or uprooting and drying out (Truong, P. and Creighton, C. ,1994)

2.2 Special Characteristics of Vetiver Grass Suitable for Wastewater Treatment

- ***Highly tolerant*** to soil high in acidity, alkalinity, salinity, sodicity and magnesium
- ***Highly tolerant to*** Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soil (Truong and Baker, 1998), (Danh et al.2009).)
- **Capable of withstanding extremely** high N supply (10 000KgN/ha/year) and P (1000KgN/ha/year) (Wagner et al.,2003).
- ***Capable of responding*** to very high N supply (6 000KgN/ha/year)
- ***Highly efficient in absorbing*** dissolved nutrients particularly N and P in polluted water (Truong and Hart, 2001)
- ***High level of tolerance*** to herbicides and pesticides such as Diuron or Atrazine herbicides at concentrations up to 2000 mg/L levels. (Cull et al. 2000)
- ***Vetiver grass is both a xerophyte*** (drought tolerant due to its deep and extensive root system) and a hydrophyte (wetland plant due to its well developed sclerenchyma [*air cell*] network). Vetiver thrives under hydroponics conditions. (Truong and Hart, 2001)
- ***High water use rate.*** Under wetland conditions or high water supply Vetiver can use more water than other common wetland plants such as *Typha* spp, (approximately 7.5 times more) and *Phragmites australis* and *Schoenoplectus validus*. Under optimal growing conditions, a hectare of vetiver would potentially use 279KL/ha/day. (Cull et al. 2000)

The summary of vetiver adaptability range is shown on Table 1.

Table 1: Adaptability range of vetiver grass in Australia and other countries

	Australia	Other Countries
Adverse Soil Conditions		
Acidity	pH 3.3	pH 4.2 (with high level soluble Al)
Al level (Al Sat. %)	Between 68% - 87%	
Mn level	> 578 mg/kg	
Alkalinity (highly sodic)	pH 9.5	pH 12.5
Salinity (50% yield reduction)	17.5 $mScm^{-1}$	
Salinity (survived)	47.5 $mScm^{-1}$	
Sodicity	33% (exchange Na)	
Magnesicity	2 400 mg/kg (Mg)	
Heavy Metals		
Arsenic	100 - 250 mg/kg	
Cadmium	20 mg/kg	
Copper	35 - 50 mg/kg	
Chromium	200 - 600 mg/kg	
Nickel	50 - 100 mg/kg	
Mercury	> 6 mg/kg	
Lead	> 1 500 mg/kg	
Selenium	> 74 mg/kg	
Zinc.	>240 mg/kg	
Location	15^0S - 37^0S	41^0N - 38^0S
Climate		
Annual Rainfall (mm)	450 - 4 000	250 - 5 000
Frost (ground temp.)	-11^0C	-14^0C
Heat wave	45^0C	55^0C
Drought (without effective rain)	15 months	
Fertiliser		
Vetiver can be established on very infertile soil due to its strong association with Mycorrhiza	N and P (300 kg/ha DAP)	N and P, farm manure
Palatability	Dairy cows, cattle, horse, rabbits, sheep, kangaroo	Cows, cattle, goats, sheep, pigs, carp
Nutritional Value	N = 1.1 % P = 0.17% K = 2.2%	Crude protein 3.3% Crude fat 0.4% Crude fibre 7.1%

3.0 IMPROVING WASTEWATER QUALITY

Off-site pollution is the greatest threat to the world environment, this problem is widespread in industrialised nations but it is particularly serious in developing countries, which often do not have enough resources to deal with the problem. Vegetative method is generally the most efficient and commonly used for water quality improvement.

In Australia research studies in sugar cane and cotton farms have shown that vetiver hedges were highly effective in trapping debris, sediment and agro-chemicals in agricultural lands, including particulate-bound nutrients (P, Ca) and herbicides such as diuron, trifluralin, prometryn and fluometuron and pesticides such as α, β and sulfate endosulfan and chlorpyrifos, parathion and profenofos (Truong *et al*. 2000).

4.0 SEWAGE AND INDUSTRIAL EFFLUENT TREATMENT IN AUSTRALIA

For waste water treatment and disposal VS can be applied as dry land planting, wetlands or hydroponics. It is very effective in either disposing the effluent and/or removing contaminants well below the limits set out by the Australian Environmental Protection Authority (EPA) at a fraction of the cost of conventional treatments. In Australia, VS is very effective in treating domestic, community and municipal sewerage effluent, in addition to industrial wastewater.

4.1 Domestic Sewage Effluent Treatment (Truong and Hart, 2001).

In Australia, a project was carried out to demonstrate and to obtain quantitative data on the effect of the VS in reducing the volume of effluent and also improving the quality under field conditions. Groundwater monitoring at a septic tank outlet showed that after passing through 5 rows of vetiver the levels of **total N reduced by 99%** (from 93 to 0.7 mg/L), **total P by 85%** (from 1.3 to 0.2 mg/L), and **faecal Coliforms by 95%** (from 500 to 23 organisms/100mL). These levels are well below the following thresholds used by the Australian EPA:

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

4.2 Community Sewage Effluent Treatment (Truong et al., 2009)

On a small recreational airfield in Queensland, Australia, a planting of 100m^2 with 400 vetiver plants has effectively disposed of a sewage effluent output:

- **Inflow** (surface irrigation)
  - Average daily flow: 1 670L
  - Average total N: 68mg/L
  - Average total P: 10.6mg/L
  - Average Faecal Coliform:>8 000
- **Outflow** (deep drainage at 3m depth)
  - Average daily flow: Only flow after heavy rain
  - Average total N: 0.13mg/L
  - Average total P: 0.152mg/L
  - Average Faecal Coliform:<10

4.3 Municipal Wastewater Treatment (Ash and Truong, 2003).

4.3.1 Sewage Effluent Treatment

The aim of this scheme was to improve water quality of the sewage effluent discharge from a small town (Esk) in Australia. The biggest problem with the quality of the effluent is its high nutrient loading. With the recent changes to license conditions imposed by the EPA, the existing treatment plant no longer complies with the license and an upgrade of the plant was required. Instead of traditional upgrades, the Vetiver System, a new and innovative phyto-remedial technology was implemented 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 ephemeral wetlands, once the effluent exits the sewerage ponds it passes through a Vetiver Grass wetlands. The Vetiver Grass takes up the water and in particular the grass will remove the nutrients from the water that passes through it.

Primary treated effluent had the following characteristics:

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

Table 2 shows the results obtained after 18 months

Table 2: Effluent quality levels before and after vetiver treatment

Tests	Fresh Influent	Results 2002/03	Results 2004
PH (6.5 to 8.5)*	**7.3 to 8.0**	**9.0 to 10.0**	**7.6 to 9.2**
Dissolved Oxygen (2.0 minimum)*	**0 to 2 mg/l**	**12.5 to 20 mg/l**	**8.1 to 9.2 mg/l**
5 Day BOD (20 - 40 mg/l max)*	**130 to 300 mg/l**	**29 to 70 mg/l**	**7 to 11 mg/l**
Suspended Solids (30 - 60 mg/l max)*	**200 to 500 mg/l**	**45 to 140 mg/l**	**11 to 16 mg/l**
Total Nitrogen (6.0 mg/l max) *	**30 to 80 mg/l**	**13 to 20 mg/l**	**4.1 to 5.7 mg/l**
Total Phosphorous (3.0 mg/l max) *	**10 to 20 mg/l**	**4.6 to 8.8 mg/l**	**1.4 to 3.3 mg/l**

* Licence requirements.

4.3.2 Disposal of landfill leachate:

Disposal of landfill leachate is a major concern to all large cities, as the leachate is often highly contaminated with heavy metals, organic and inorganic pollutants. In Australia and China this problem can be solved by irrigating vetiver planted on the top of the landfill mound and retaining dam wall with leachate collected at the bottom of the dumps. Results to date have been excellent, the growth was so vigorous that during the dry period, there was not enough leachate to irrigate the vetiver. A planting of 3.5ha has effectively disposed of 4 ML a month in summer and 2 ML a month in winter (Percy and Truong, 2005).

4.4 Industrial Wastewater Disposal and Treatment

The key feature of VS in treating polluted water lies in its capacity to quickly absorb nutrients and heavy metals, and its tolerance to very elevated levels of these elements. Although the concentrations of these elements in vetiver plants is often not as high as those of hyper-accumulators, however due to its very fast growth and high yield (dry matter production up to 132t/ha/year), vetiver can remove a much higher quantity of nutrients and heavy metals from contaminated lands than most hyper-accumulators.

In Australia, the disposal of industrial wastewater is subjected to the strict environmental guidelines enforced by the EPA. The most common method of treating industrial wastewater in Australia 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 by adopting VS as a sustainable means of disposing wastewater (Smeal *et al*, 2003).

The following two projects show the high capacity of VS in disposing industrial wastewater:

- **GELITA APA**, a factory producing gelatine from cattle hides, with an effluent output of 1.3 ML/day, and N concentration of 300mg/L and P of 5mg/L and very saline. Computer modelling shows:
  - Effluent volume disposed by:
    - ***Vetiver grass: 1.45ML/day***
    - Kikuyu grass *(Pennesitum clandestinum*): 0.80ML/day
    - Rhodes grass (*Chloris guyana*): 0.73ML/day
  - Land area needed for sustainable irrigation:
    - ***Using vetiver grass: 72.5ha***
    - Using Kikuyu: 104ha and
    - Using Rhodes grass: 153ha.

- **TEYS Bros**, an abattoir processing 300-400 cattle a day, with an effluent output of 1.24ML/day, and N concentration of 170mg/L and P of 32mg/L. Computer modelling shows:
  - Effluent volume disposed by:
    - ***Vetiver grass: 1.24ML/day***
    - Kikuyu grass: 0.75ML/day
  - Land area needed for sustainable irrigation:

Land area needed for sustainable irrigation when Vetiver grass was used is less than 55% that of Kikuyu grass.

The above results were achieved due to vetiver ability to tolerate high nutrient and salt levels in the effluent, high water use rate under wet conditions and producing a very high biomass (dry) up to 132t/ha/year.

5.0 COST EFFECTIVENESS (Ash and Truong, 2003).

Under Australian conditions the followings are cost comparison of various sewage effluent treatment methods of the Municipal (Esk) treatment plant. Saving could be as high as 90%.

- VS ephemeral wetlands, and floating pontoons A$135 000
  (Including the cost of 6ha of land)
- Rock Filter A$250 000
- Sand Filter (alum dosing) A$450 000
- Complete Plant Upgrade with new facilities A$1 500 000

In addition, the saving in operation and maintenance cost between the conventional technology and VS is also very significant.

6.0 SEWAGE AND INDUSTRIAL EFFLUENT TREATMENT IN OTHER COUNTRIES

- **In Chile**, VS is currently being evaluated for the treatment of wastewater from a very large pig farm near Santiago. This effluent has very high content of N, P and heavy metals (P. Molina pers. com).
- **In Venezuela.** VS is currently being used to dispose wastewater from beer breweries and animal farms, as well as polluted water in lakes and dams (O. Luque pers. com).
- **In China** the disposal of wastewater from intensive animal farms is one of the biggest problems in densely populated areas. China is the largest pig raising country in the world. In 1998 Guangdong Province had more than 1600 pig farms with more than 130 farms producing over 10,000 commercial pigs each year. These large piggeries produce 100-150 tons of wastewater each day, which included pig manure collected from slatted floors, containing high nutrient loads (Liao *et al*, 2003)**.**

Nutrients and heavy metals from pig farm are key sources of water pollution. Wastewater from pig farm contains very high N and P and also Cu and Zn, which are used as growth promoters in the feeds. The results showed that vetiver had a very strong purifying ability. Its ratio of uptake and purification of Cu and Zn was >90%; As and N>75%; Pb was between 30% -71% and P was between 15-58%. The purifying effects of vetiver to heavy metals, and N and P from a pig farm were ranked as Zn>Cu>As>N>Pb>Hg>P (Xuhui *et al*., 2003).

- **In Vietnam**, VS was used to treat wastewater from a sea food processing factory in the Mekong Delta a demonstration trial was set up to determine the treatment time required to retain effluent in the vetiver field to reduce nitrate and phosphate concentrations in effluent to acceptable levels. The experiment started when plants were 7 months old. Water samples were taken for analysis at 24 hour interval for 3 days. Analytical results showed that total N content in wastewater was reduced by 88% and 91% after 48 and 72 hours of treatment, respectively. While the total P was reduced by to 80% and 82% after 48 and 72 hours of treatment. The amount of total N and P removed in 48 and 72 hour treatments were not significantly different (Luu *et al*, 2006).

VS is also being used to treat wastewater from paper and fertiliser factories in the north and pig farms in South Vietnam

- **In Thailand,** the most active field of vetiver research in the last few years has been the treatment of wastewater, which indicates that the problem of wastewater is a serious one in Thailand. Different types of wastewater, including leachate and effluent: (i) domestic wastewater (ii) food manufacturer, (iii) shrimp pond, (iv) whisky distillery, (v) paper mill, (vi) rice mill, (vii) tapioca flour mill, (viii) dairy plant, (.ix) battery manufacturer, (x) lamp-shade manufacturer, (xi) printing ink manufacturer, and (xii) garbage landfill. All the wastewaters are of high BOD and COD, some are eutrophicated waters with high amounts of N, P, and K; some are high in heavy metal contamination. Various approaches have been attempted, e.g. through constructed wetland, with combination of other aquatic plants, in combination with chemical treatment (PAC) after sedimentation, etc. Vetiver has been found to be able to solve this problem effectively at a low cost based on simple technology (Chomchalow, 2006).

In one study, where vetiver was grown in domestic effluent, the capacity to reduce: total N (92%), nitrate (49%)), K (14%)), Na (3%)), Bicarbonate (42%)), EC (5%)),TSS (82%) and BOD (75%). The efficiency of wastewater treatment was found to increase with the age of vetiver plant, and the highest was at 3 months of age (Chomchalow, 2006, cit. Techapinyawat 2005).

- **In Singapore** a very large constructed wetland using vetiver grass is being built to treat and/or dispose leachate from an old landfill preventing it coming to a water reservoir

7.0 FUTURE TREND

As water shortage is looming worldwide, wastewater should be considered as a resource rather than a problem. ***The current trend is to recycle wastewater for domestic and industrial uses,*** instead of disposal. Therefore the potential of VS is enormous as a simple, hygienic and low cost means of treating and recycling wastewater resulting from human activities.

The most recent and significant development on the use of vetiver for wastewater treatment is its use in a Soil Based Reed Beds, new application, which the output water quality and quantity can be adjusted to provide a desired standard. This system is now under development and tested at GELITA APA, Australia.

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