VETIVER SYSTEM FOR PREVENTION AND TREATMENT OF POLLUTED WATER AND CONTAMINATED LAND

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Abstract

The Vetiver System (VS), which is based on the applications of Vetiver Grass *(Chrysopogon zizanioides,* Roberty 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, mining wastes and contaminated lands 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.

Due to its extraordinary morphological and physiological characteristics, vetiver grass has also been used successfully for rehabilitation of coal, gold, lead, zinc, copper, bentonite, bauxite mine waste and phytoremediation of highly contaminated land and solid industrial wastes in Australia, Chile, China, South Africa, Thailand and Venezuela

This paper reviews and updates recent R&D and Applications of the Vetiver System in the prevention and treatment of contaminated water and land.

Keywords: Vetiver grass, leachate, effluent, mine tailings, contaminated land, heavy metals,

1.0 INTRODUCTION

The Vetiver System (VS), which is based on the application of vetiver grass (*Chrysopogon zizanioides,* Roberty L), was first developed by the World Bank for soil and water conservation in India in the 1980s. In addition to its very important application in agricultural lands, scientific research conducted in the last 20 years has clearly demonstrated that VS is also one of the most effective and low cost natural methods of environmental protection. As a result VS is now increasingly being used worldwide for this purpose. For this reason, vetiver grass is known as a wonder grass, a miracle grass and a magic grass in various parts of the world. The four main applications of VS are:

- Environmental protection by:
  - Prevention, Disposal and Treatment of Wastewater.
  - Rehabilitation and Treatment of Contaminated Land
- Stabilisation of Steep Slopes, both dry land and river banks
- Soil and Water Conservation in Agricultural Land

This paper only deals with the environmental protection topics.

2.0 PREVENTION, TREATMENT AND DISPOSAL OF CONTAMINATED WATER (Truong *et al*, 2008).

The Vetiver System is now well accepted and used worldwide for numerous applications. Amongst these, environmental protection applications are the most popular due to its effectiveness, simplicity and low cost.

Earlier research conducted to understand the role of the extraordinary physiological and morphological attributes of vetiver grass in soil and water conservation, discovered that vetiver grass also possesses some unique attributes highly suitable for treating polluted wastewater from industries as well as domestic discharges and contaminated lands from industries and mining.

- VS can reduce the volume or dispose unwanted wastewater by: seepage control, land irrigation and wetland. Successful applications include treatment of:
  - domestic and municipal sewage effluent and landfill leachate
  - industrial wastewater recycling and disposal
  - industrial and mining seepage.
- VS can improve wastewater quality by: trapping debris, sediment and particles, and absorbing pollutants such as nutrients and heavy metals, detoxification of agrochemical in wetlands. Successful applications include wastewater quality improvement of:
  - water runoff from agricultural land
  - water runoff from urban land
- VS can reduce the impact of pollution caused by contaminated lands from industries and mining by land rehabilitation and phytoremediation.
  - water runoff from industrial and mining land

VS has been used in more than 100 countries with in tropical and subtropical climates for the prevention and treatment of polluted water and contaminated land.

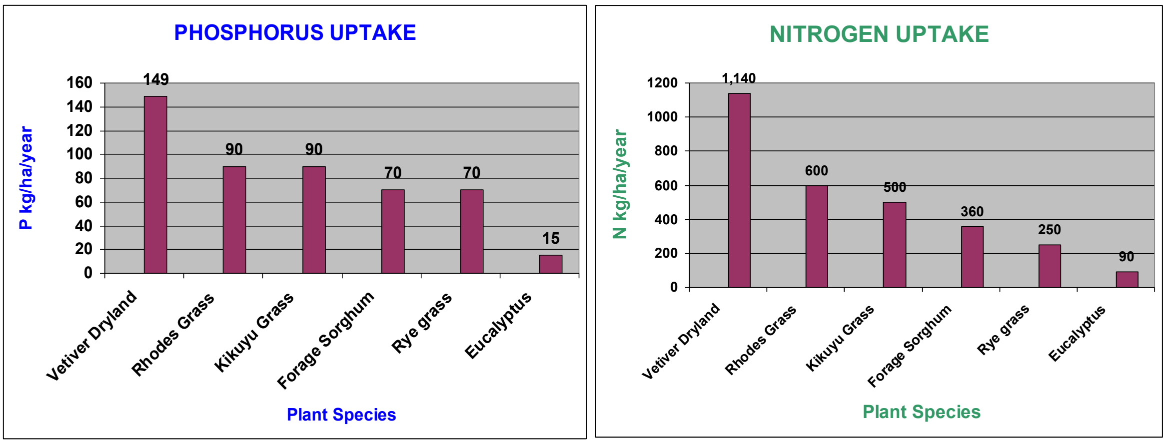
Extensive research in Australia, China and Thailand and in other countries has established vetiver grass possesses some unique characteristics suitable for environmental protection purposes (Truong, 2004). Such as its tolerance to elevated and sometimes toxic levels of salinity, acidity, alkalinity, sodicity as well as a whole range of heavy metals and agrochemicals. Latest research also shows its exceptional ability to absorb and tolerate extreme levels of nutrients (Wagner *et al*. 2003), to consume large quantities of water in the process of producing a massive growth, more than 100t/ha of biomass (Truong and Smeal, 2003). These attributes indicated that vetiver is highly suitable for treating polluted wastewater from industries as well as domestic effluents. Table 1 summarises the unique characteristics of vetiver grass.

2.1 Reducing or Disposing Wastewater

For large-scale reduction or total disposal of wastewater, vegetative methods are the only feasible and practicable method available to date. In the past, trees and pasture species have been used for the disposal of wastewater in Australia, but recently vetiver grass has been found to be more effective than trees and pasture species in the disposal and treatment of landfill leachate, domestic and industrial effluents (Fig.1) Ash and Truong, 2003).

To quantify the water use rate of vetiver, a glasshouse trial showed a good correlation between water use and dry matter yield. From this correlation it was estimated that for ***1kg of dry shoot biomass, vetiver would use 6.86L/day***. If the biomass of 12-week-old vetiver, at the peak of its growth cycle, was 40.7t/ha, a hectare of vetiver would potentially use 279KL/ha/day (Truong and Smeal, 2003).

Fig.1: Higher capacity of uptake N and P than other plants



2.1.1 Disposal of domestic septic effluent:

The first application of the VS for effluent disposal was conducted in Australia in 1996, and subsequent trials demonstrated that planting about 100 vetiver plants in an area less than $50m^2$ have completely dried up the effluent discharge from a toilet block in a park, where other plants such as fast growing tropical grasses and trees, and crops such as sugar cane and banana have failed (Truong and Hart, 2001).

2.1.2 Disposal of industrial wastewater

The disposal of industrial wastewater is subjected to the strict environmental guidelines enforced by the Environmental Protection Authority. The most economical method of treating industrial wastewater is by land irrigation, which is presently based on agriculture crop and forestry 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).

2.1.3 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, China, Mexico, Thailand and the USA 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 landfills.

Case study in Australia

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).

Case study in the USA and Mexico

The on-site utilization of landfill leachate using phytoremediation systems is transforming the way the solid waste industry handles facility-generated liquid waste. The change not only replaces the age-old ‘load, haul and dump’ process where the technology fits, but also represents a truly GREEN, carbon negative, and sustainable approach using trees and grasses. In addition, the approach saves millions of dollars at each site where it is implemented. Leggette, Brashears & Graham, Inc. (LBG) has partnered with Republic Services, Inc. on a number of phytoremediation projects with great success.

USA: Biloxi, MS: The Republic Gulf Pines landfill became a first-of-its-kind project in the Western Hemisphere, when vetiver grass was used for phytoremediation of leachate at this Gulf Coast location.

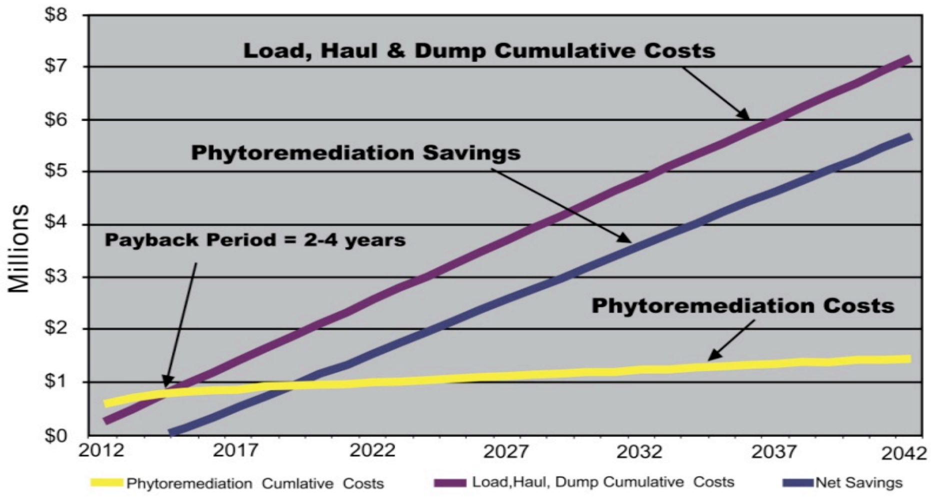
Three acres of vetiver were planted on top of this pre-subtitle D landfill to process approximately three million gallons of leachate per year. The per gallon disposal cost was cut from $0.13 to less than $0.015 per gallon. The project is expected to save $8 million over a standard accrual period compared to traditional off-site disposal methods. This project was recently honoured as a national Grand Prize winner in the American Academy of Environmental Engineers – National Engineering Excellence Competition.

MEXICO: Leon, Poza Rica, and Villahermosa

The first three projects of their kind in Latin America using vetiver grass for phytoremediation of landfill leachate are underway for the largest solid waste company in Mexico, Promotora Ambiental S.A.B. de C.V (PASA) and each pose numerous, site-specific challenges. The Leon landfill is a recently acquired facility in great need of numerous improvements that were left undone by the previous owner. One enormous problem is handling of very strong, fresh domestic / industrial leachate from this active facility. In addition to the 25,000 gallons of leachate produced daily, an additional 15 million gallons is currently stored in lagoons awaiting treatment. The owner is under great political pressure to quickly bring the landfill to acceptable standards. The use of VS phytoremediation to resolve these issues has already eased some pressure and has been a significant step forward towards overall site success. The Poza Rica facility includes using vetiver for three main purposes: stabilization of very steep, highly erodible slopes, the on-site utilization of fresh leachate, and control of leachate outbreaks. Villahermosa is similar to Poza Rica, but the design and operation of an effective system was further complicated due to the extreme rainfall at this facility, which is located along the southern coast of the Gulf of Mexico

2.2 Future Trend

Cost effectiveness: Results from US applications on the last few years, indicate that due to rising conventional leachate disposal cost, haulage and dump management cost, phytoremediation using VS is the most obvious choice to overcome the rising cost. Therefore the future trend is more and more VS application in phytoremediation



Modelling: Computer modelling is now commonly used to determine the land area needed for successful application of VS in large scale wastewater treatment. Major input parameters needed for the modelling process include long term and accurate climate data, soil type and depth, ground water level and accurate quantity and quality of the wastewater input (Truong and Truong, 2011)

To date no model is available for low volume treatment, as these parameters are not easily available or non-available. A paper presents at this Conference ***"Computer model for treatment of small volume wastewater"*** will give a more accurate method of determining the land area needed for this application based on more recent knowledge and experience with VS.

3.0 TREATMENT AND REHABILITATION OF CONTAMINATED LANDS

In term of environmental protection, the most significant breakthroughs in the last 20 years are firstly research leading to the establishment of benchmark tolerance levels of vetiver grass to adverse soil conditions and secondly its tolerance to heavy metal toxicities. These have opened up a new field of application for the rehabilitation of toxic and contaminated lands.

3.1 Mine Rehabilitation and Phytoremediation

With the above extraordinary morphological and physiological characteristics, vetiver grass has been used successfully for steep slope stabilisation and phytoremediation of mine tailings in Australia and other countries (Truong, 2004).

In Australia: VS has been used successfully to treat coal tailings and rehabilitate coal mine waste, fresh and old gold mine tailings (Truong, 2004).

In China: VS has been used successfully to treat Pb/Zn mine tailings due to its high metal tolerance, furthermore, this grass can be also used for phyto-extraction because of its large biomass. Recent research also suggests that vetiver also has higher tolerance to acid mine drainage (AMD) from a Pb/Zn mine, and wetlands planted with this grass can effectively adjust pH and remove SO_4^{2-}, Cu, Cd, Pb, Zn and Mn from AMD (Shu, 203 and Xia *et al*, 2003).

In South Africa: Roley Nöffke, CEO of Hydromulch, Johannesburg, Republic of South Africa will present a keynote paper: ***Mine and Associated Rehabilitation Projects in Africa and Indian Ocean Islands"*** at this Conference. Numerous projects in Democratic Republic of Congo, Ethiopia, Brazzaville Congo, Guinea, Gabon, Madagascar and South Africa have been successfully rehabilitated using the Vetiver/ Hydroseeding system and has now been extended to local communities in rural areas for rehabilitation in sustainable land management. Also a short overview of the projects reflecting the major strides that have been achieved on erosion & sediment control, bio-engineering & vegetation restoration and community participation in general.

In Thailand: Chomchalow, 2006 reported that vetiver could grow well in lead mine tailings. The application of compost or chemical fertilizer resulted in better growth in height and dry weight than no fertilisers, but did not increase the concentration of lead in the vetiver plant. Higher concentration was found in the root than in the shoot.

4.0 OVERALL ADVANTAGES OF VETIVER SYSTEM APPLICATION

- **Simplicity**: Application of the Vetiver System is rather simple compared with other conventional methods. In addition appropriate initial design, it only requires standard land preparation for planting and weed control in the establishment phase.
- **Low cost:** Application of the Vetiver System in wastewater treatment costs a fraction of conventional methods such as chemical or mechanical treatment. Most of the cost lies in the planting material, with small amounts in fertiliser, herbicides and planting labour.
- **Minimal maintenance:** When properly established, the VS requires practicaly no maintence to keep it functioning. Harvesting two or three time a year to export nutrients and to remove top growth for other usuages is all that needed. This is in sharp contrast to other means which need regular costly maintenance and a skilled operator, often an engineer, to operate efficiently.

5.0 REFERENCES

Ash R. and Truong, P. (2003). The use of vetiver grass wetland for sewerage treatment in Australia. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.

Chomchalow, N, (2006). Review and Update of the Vetiver System R&D in Thailand. Proc. Regional Vetiver Conference, Cantho,Vietnam.

Percy, I. and Truong, P. (2005). Landfill Leachate Disposal with Irrigated Vetiver Grass. Proc, Landfill 2005. National Conf on Landfill, Brisbane, Australia, Sept 2005

Truong, P.N.V. (2004). Vetiver Grass Technology for mine tailings rehabilitation. Ground and Water Bioengineering for Erosion Control and Slope Stabilisation. Editors: D. Barker, A.

Watson, S. Sompatpanit, B. Northcut and A. Maglinao. Published by Science Publishers Inc. NH, USA.

Truong P and Truong N (2011). Recent Advancements in Research, Development and Application of Vetiver System Technology in Environmental Protection. Fifth Intern. Conf. on Vetiver, Lucknow, India, October 2011

Truong, P.N. and Hart, B. (2001). Vetiver system for wastewater treatment. Technical Bulletin No. 2001/2. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong, P. and Smeal (2003). Research, Development and Implementation of Vetiver System for Wastewater Treatment: GELITA Australia. Technical Bulletin No. 2003/3. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Shu Wensheng (2003).Exploring the Potential Utilization of Vetiver in Treating Acid Mine Drainage (AMD). Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.

Xia Hanping, Honghua Ke , Zhaoping Deng and Peng Tan. (2003). Ecological effectiveness of vetiver constructed wetlands in treating oil refined wastewater. Proc. Third International Vetiver Conference, Guangzhou, China, October 2003.

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