Studies on the Abilities of *Vetiveria zizanioides* and *Cyperus alternifolius* for Pig Farm Wastewater Treatment*

Xindi Liao[1], Shiming Luo[2], Yinbao Wu[1], and Zhisan Wang[1]
[1]*College of Animal Science, South China Agricultural University, Guangzhou 510642, China*
[2]*Institute of Tropical and Subtropical Ecology, South China Agricultural University, Guangzhou 510642, China*

Abstract: *Vetiveria zizanioides* and *Cyperus alternifolius* were measured for their ability to decontaminate pig farm wastewater in 50_38.5_23 cm (L_W_H) plastic boxes. These plants were grown in pig farm wastewater with COD_{Cr} at 825 mg/L, BOD_5 at 500 mg/L, NH_3-N at 130 mg/L and TP 23 at mg/L, *C. alternifolius* and *V. zizanioides* could cut down those index to 64%, 68%, 20% and 18% respectively by hydraulic retention time (HRT) of 4days. Statistical result showed that there were significant differences in COD, BOD and TP between treatments with plants and those without plants.
Key words: *Vetiveria zizanioides*, *Cyperus alternifolius*, pig farm, wastewater treatment, COD, BOD
Email contact: Xindi Liao <xdliao2002@yahoo.com.cn>

1 INTRODUCTION

1.1 Ecological Features of *Vetiveria zizanioides* and *Cyperus alternifolius*

Vetiver (*Vetiveria zizanioides*) is a C_4 plant with a deep root system, high biomass production, high efficiency of photosynthesis, and can be multiplied by tillering. The optimum temperature for vetiver grass was 25-30_. Vetiver can grow both in wetland and upland area (Chen *et al*, 1991). Heat and water are more important than soil texture to vetiver. Vetiver grows fast in regions with high temperature and high rainfall. The growth of root system of vetiver is affected by temperature, rainfall intensity and soil (Chen *et al.*, 1991). Appropriate harvest time promotes the growth of root and tiller. Vetiver is normally harvested two times a year. Young vetiver can be used as feed for fish and cattle.

Umbrella grass (*Cyperus alternifolius*) is a perennial herb, which grows in humid areas or swampland. Umbrella grows fast with strong root system. Its productivity is high and can form a good landscape. Umbrella has strong underground root and erect aerial stem, with hollow core construction and without branching. Umbrella is monoecious with bisexual flower. The blooming stage is from June to July and the maturing stage is from September to October. Umbrella can be easily multiplied by seed, plant division or cutting. Normally, 3-5 divisions can be used for planting as a group in spring (March). The acheme of umbrella in every autumn can develop into seedling in humid area. Umbrella is widely used for landscaping, fencing, paper, hat, basket making and can also be used as a cover plant for protecting slopes from soil erosion.

1.2 Vetiver and Umbrella Developed for Wastewater Treatment

So far vetiver was mostly used for protecting soil and water from erosion in many countries. The China Vetiver Network introduced vetiver grass and studied its adaptation, propagation, morphology, physiology, ecology and application (Xia *et al.*, 1994; Xu, 1998). In recent years, the use of vetiver was involved in the removal of pollutants, including the removal of N and P from wastewater (Zheng *et al.*, 1997; Xu, 1998), the removal of heavy metals (Xia *et al.*, 1999; Xia, 2000) and organic matter, N and P from fish pond sludge by constructed wetland (Steven *et al.*, 1996). The results indicated that vetiver could grow normally in water and removed N, P and heavy metals from municipal sewage. Vetiver was proved to be a suitable plant to purify eutrophic water. However, the study of pig farm wastewater purification by vetiver was not common, and therefore not much is known about the efficiency in the treatment of wastewater from pig farm by vetiver.

Research result showed that umbrella could remove about 36% COD (Chemical Oxygen Demand) from pig farm wastewater (Neuray *et al.*, 1986). However, the study of wastewater purification by umbrella grass was also not known.

1.3 Research Objective

In recent years, more and more constructed wetlands have been applied to treat wastewater from pig farm over the world (Reaves *et al.*, 1995a,b; Szogi *et al.*, 1995a,b; Hunt *et al.*, 1994; Liao *et al.*, 1995). We have studied the pollutant tolerance of vetiver and umbrella in pig farm wastewater (Liao *et al.*, 1995). The result indicated that both vetiver and umbrella were suitable for the constructed wetland to treat wastewater from pig farm. For this reason, further study on the purification effect of vetiver and umbrella grown in pig farm wastewater in plastic containers, was conducted in Guangzhou, South China.

2 MATERIALS AND METHODS

2.1 Culture System

The culture system consisted of nine plastic containers (length_height_width = 50_23_38.5 cm). Vetiver grass was planted in the first three containers (as three replications) and umbrella grass was planted in the second three containers, after carefully washing all the sand and soil from their roots. Six plants, about the same size and totally 3.65 kg in fresh biomass, were planted in each container. The tested plants had adapted to the water environment before they were removed into the culture systems. The last three containers without plant were used as control. All the containers were covered with foamed boards, which have six holes on each one for holding plants.

The culture system in the greenhouse was kept at an air temperature of 30-34_. The tap water was added to balance the lost water in each container every day.

2.2 Quality of the Wastewater

The pig farm wastewater after anaerobic treatment was diluted with tap water to the following composition (Table 1). 36 L of this diluted wastewater was filled in each of the nine containers.

Table 1 Wastewater concentration (mg/L)

COD_{Cr}	BOD_5	NH_3-N	TP
825.63±15.71	509.89±14.51	134.43± 1.60	24.31± 0.45

2.3 Experimental Procedures and Analysis

The plants were grown for a total period of 8 days. Sampling by siphon was done in the 0, 2^{nd}, 4^{th}, 6^{th} and 8^{th} days, resulting in a hydraulic retention time (HRT) of 0, 2, 4, 6 and 8 days. Water samples were analyzed for chemical oxygen demand (COD), biochemical oxygen demand (BOD), ammonium-nitrogen (NH_3-N) and total phosphorous (TP). The COD, BOD, NH_3-N and TP were measured according to the

3 RESULTS

3.1 Adaptation of Vetiver and Umbrella grass in Pig Farm Wastewater

Adaptation of plant can be reflected in the change of its root growth and top growth during the test period (Table 2).

Plant height, root length and fresh weight increased differently during the 8 days growth in the wastewater, indicating that vetiver and umbrella were able to grow in pig farm wastewater with COD 751.89 mg/L and NH_3-N 134.43 mg/L.

Table 2 The Growth characteristic of Vetiver and Umbrella during the test period

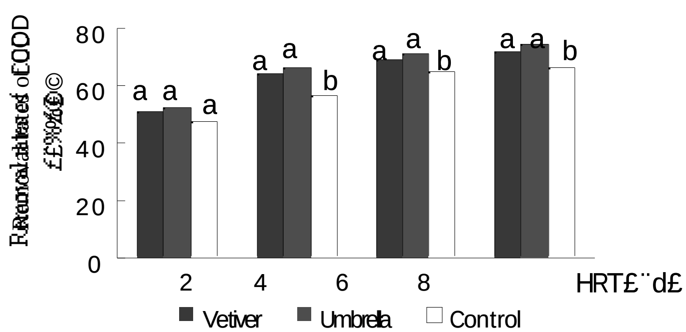
Species	Time	Height of plant (cm)	Length of root (cm)	Fresh weight (g/container)
Vetiver	Day 0	145.2	15.6	3650
	Day 8	150.2	17.7	3940
	Increment	5.0	2.1	290
Umbrella	Day 0	117.1	14.9	3650
	Day 8	128.0	16.0	4004
	Increment	10.9	1.1	354

3.2 The Removal of COD, BOD, NH_3-N and TP

3.2.1 The removal of COD

The removal rates of COD were given in Fig.1 for the period of 8 days both for the planted (vetiver and umbrella) and unplanted containers (control).

Fig. 1 The removal rates of COD



Values with different letters at the same day indicated statistical differences (P<0.05)

There was no significant difference in the removal rate of COD between planted and unplanted treatment for the first 2 days. The removal rates of COD were higher in the planted containers from day 2 to day 8 (Fig. 1). In the vetiver container and in the umbrella container, COD was removed by 64.40±4.42% and 66.09±2.05% respectively under the retention time of 4 days, in contrast with the control container, where only 56.5% was removed.

The changes of COD were given in Fig. 2 both for the planted and unplanted containers.

In Fig.2, COD degradations both in planted and unplanted containers for the period of 8 days are followed exponential function:

$$Y_t=Y_0 \cdot e^{(-kt)}$$

where Y_t denotes COD (mg/L) in the effluent, Y_0 denotes COD (mg/L) in the influent, t denotes HRT (d), and k denotes the degradation coefficient (d^{-1}).

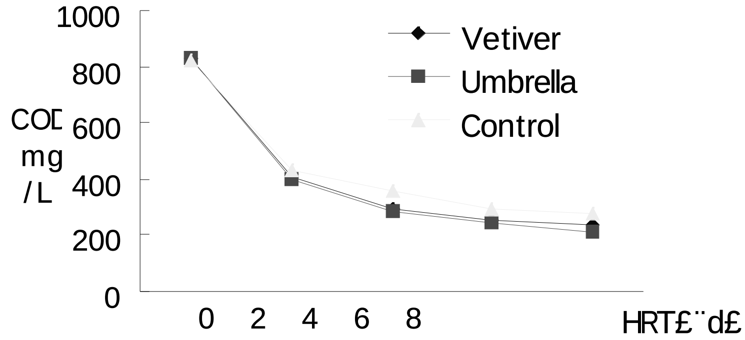
Three regression equations for COD degradation in Fig.2 were as follows:

$Y_t=874.77\cdot e^{(-0.2984\cdot t)}$, $r=0.921^*$ for vetiver

$Y_t=900.80\cdot e^{(-0.3211\cdot t)}$,$r=0.932^*$ for umbrella

$Y_t=863.36\cdot e^{(-0.2576\cdot t)}$, $r=0.924^*$ for control

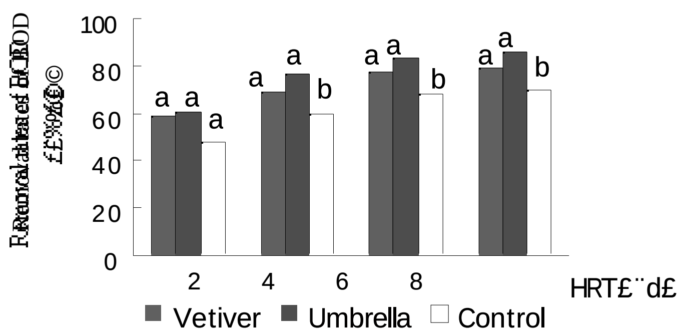
Fig. 2 The changes of COD of wastewater both for the planted and unplanted containers



3.2.2 The removal of BOD

The removal rates of BOD were given in Fig. 3 both for the planted and unplanted (control) containers.

Fig. 3 The removal rates of BOD



Values with different letters at the same day indicated statistical differences (P<0.05).

There was no significant difference in the removal rates of BOD between planted and unplanted containers for the first two days ($P>0.05$). The removal rates of BOD in planted containers were higher than that in unplanted one at the 4th, 6th and 8th day ($P<0.05$ or $P<0.01$) (Fig. 3). The removal rates of BOD in vetiver and umbrella containers were 68.66±1.22% and 76.06±2.37% respectively under the retention time of 4 days, in contrast with the control container, where only 59.9% of BOD was removed.

The degradation tendency of BOD was showed in Fig. 4 both for the planted and unplanted containers. In Fig. 4, BOD degradations both in planted and unplanted containers for the period of 8 days are followed exponential function $Y_t=Y_0\cdot e^{(-kt)}$, where Y_t denotes BOD (mg/L) in the effluent, Y_0 denotes BOD (mg/L) in the influent, t denotes HRT (d), and k denotes the degradation coefficient (d^{-1}).

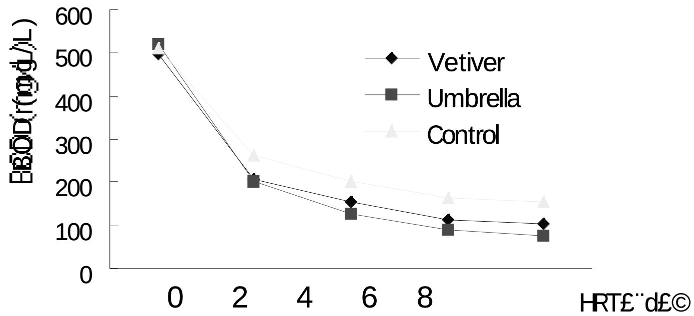
Three regression equations for BOD degradation in Fig.4 were as follows:

$Y_t=550.35\cdot e^{(-0.373\cdot t)}$, $r=0.935^*$ for vetiver

$Y_t=628.45\cdot e^{(-0.4701\cdot t)}$, $r=0.955^*$ for umbrella

$Y_t=553.71\cdot e^{(-0.2872\cdot t)}$, $r=0.933^*$ for control

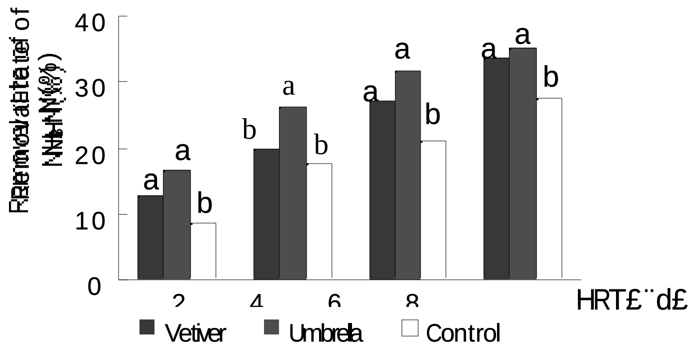
Fig. 4 The changes of BOD



3.2.3 The removal of ammonium nitrogen (NH_3-N)

The removal rates of NH_3-N were showed in Fig. 5 both for the planted and unplanted containers.

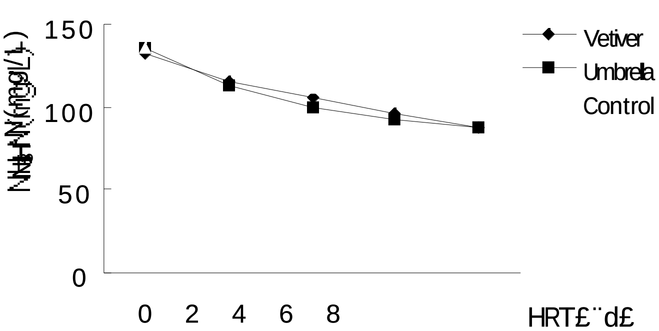
Fig. 5 The removal rates of NH_3-N



Values with different letters at the same day indicated statistical differences ($P<0.05$).

In Fig. 5, the removal rates of ammonium nitrogen in planted containers, increased gradually overtime. They were higher than that in unplanted container (control). The removal rates of ammonium nitrogen in vetiver and umbrella containers were 19.89±3.85% and 26.13±0.90% respectively under the retention time of 4 days, in contrast with the control container, where only 17.5% was removed.

Fig. 6 The NH_3-N concentration changes



In Fig. 6, the concentrations of ammonium nitrogen were decreased through the experiment both for the planted and unplanted containers. There was no significant difference between treatment and control ($P>0.05$).

$Y_t=143.08 \cdot e^{(-0.0999t)}$, $r=0.996^{**}$ for vetiver

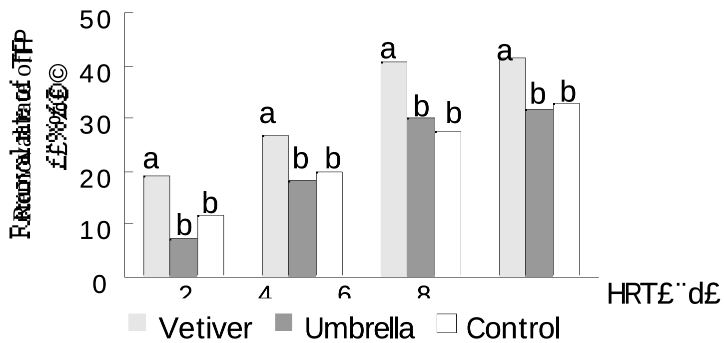
$Y_t=144.10 \cdot e^{(-0.1069t)}$, $r=0.973^{**}$ for umbrella

$Y_t=145.79 \cdot e^{(-0.0804t)}$, $r=0.994^{**}$ for control

3.2.4 The removal of TP

The removal percentages of total phosphorous (TP) are given in Fig. 7 from day zero to the 8th day both for the planted and unplanted containers. The removal rate of TP was higher in vetiver container than in umbrella or unplanted container. However there was no significant difference in the removal rate of TP between umbrella and unplanted container (control). The removal rates remained unchanged from day 6. The removal rates of TP in vetiver and umbrella containers were 26.92±2.89% and 18.32±2.62% respectively under the retention time of 4 days, in contrast with the control container, where only 19.8% of TP was removed.

Fig. 7 The removal rates of TP



Values with different letters at the same day indicated statistical differences ($P<0.05$).

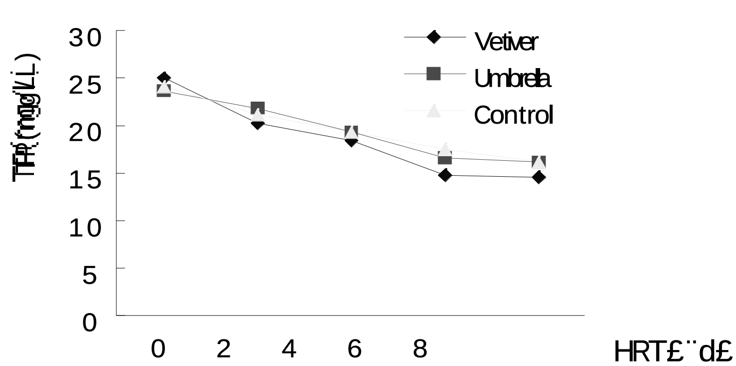
The TP levels are given in Fig. 8 from day 0 to the day 8 day both for the planted and unplanted containers. The concentrations of TP were decreased through the experiment both for the planted and unplanted containers. Three regression equations of the TP degradation in Fig. 8 were as follows:

$Y_t=27.75 \cdot e^{(-0.14t)}$, $r=0.974^{**}$ for vetiver

$Y_t=26.43 \cdot e^{(-0.1044t)}$, $r=0.980^{**}$ for umbrella

$Y_t=26.23 \cdot e^{(-0.0999t)}$, $r=0.997^{**}$ for control

Fig. 8 The TP concentration change



4 DISCUSSION

The adaptations and purification abilities both for the vetiver and umbrella grass were studied under the same climate, same concentration of wastewater and same standing biomass (3.65 kg per container). The results indicate that both vetiver and umbrella grass can grow well in the pig farm wastewater with COD 825 mg/L, BOD 500 mg/L and NH_3-N 130 mg/L. The results also indicate that Vetiver and umbrella grass can significantly influence the removals of COD, BOD and NH_3-N from wastewater. Vetiver showed higher removal rate of TP than umbrella grass. There is no difference in the removal of TP between umbrella container and the control during an 8 days period. The difference for TP removal between vetiver and umbrella is mainly due to their assimilative capacity of P. This experiment was conducted in early autumn. At that time vetiver grew better than umbrella grass.

The purification ability of wastewater treatment system constructed by aquatic plants, is not only due to the nutrients removal taken up by the plants, but also due to the population of microorganism existing in the root zone (Xia, 2000). Vetiver and umbrella grass container system without solid medium in this study was very simple. Higher removal efficiency can be expected to treat wastewater in constructed wetland system with solid medium and planted with vetiver or umbrella grass.

5 SUMMARY

Both vetiver and umbrella significantly influenced the removals of COD, BOD and NH_3-N from pig farm wastewater of COD 825 mg/L, BOD 500 mg/L and NH_3-N 130 mg/L. Vetiver showed higher removal rate of TP than umbrella. In the wastewater treatment system cultured with vetiver or umbrella, the changes of nutrients (Y) over time (t) can be expressed by $Y_t=Y_0 \cdot e^{(-kt)}$.

References

Chen FY, Li F, and Cheng H. 1991. A study on introduction test of vetiver grass. Bulletin of Soil and Water Conservation, 11(3): 60-64

Environmental Protection Agency of National. 1997. The monitoring and analytical methods for water and wastewater (3rd edition). China Environment Science Press, Beijing. 585

Hunt PG, Humenik FJ, Szogi AA, *et al*. 1994. Swine wastewater treatment in constructed wetlands. Environmentally sound agriculture: Proceedings of the Second Conference, Orlando, Florida. 268-275

Liao XD, Wang ZS, and Li QQ. 1995. The application of effluent purification on constructed wetlands in pig farm. Transactions of the CSAE, 11(4): 96-100

Neuray G, and Henrard G. 1986. Use of hydroponic techniques for purifying and utilizing waste waters containing organic matter. Bull. Rech. Agron.Gembloux, (3): 329-334

Reaves RP, DuBowy PJ, Jones DD, *et al*. 1995a. First year performance of an experimental constructed wetland for swine waste treatment in Indiana. Versatility of wetlands in the agricultural landscape: Hyatt Regency, Tampa, Florida, USA. 243-254

Reaves RP, DuBowy PJ, Jones DD, *et al*. 1995b. Constructed wetland treatment of animal waste in Indiana: management implications. Clean water - clean environment - 21st century: team agriculture - working to protect water resources. Volume 2: nutrients. Proceedings Kansas City, Missouri, USA. 179-182

Summerfelt ST, Adler PR, Glenn DM, *et al*. 1996. Aquaculture sludge removal and stabilization within created wetlands. Vetiver Newsletter, Number16: 61-65

Szogi AA, Hunt PG, Humenik FJ, *et al*. 1995a. Constructed wetlands for swine wastewater treatment in the Eastern Coastal Plain, USA. Versatility of wetlands in the agricultural landscape: Hyatt Regency, Tampa, Florida, USA. 675-682

Szogi AA, Hunt PG, Humenik FG, *et al*. 1995b. Treatment of swine wastewater by constructed wetlands. Clean water - clean environment - 21st century: team agriculture - working to protect water resources. Volume 2: nutrients. Proceedings Kansas City, Missouri, USA. 227-230

Xia HP. 2000. Uptake efficiency of *Vetiveria zizanioides* and *Althernanthera philoxeroides* to N, P, and Cl in Garbage Leachates. Acta Phytoecologica Sinica, 24(5): 613-616

Xia HP, Ao HX, and He DQ. 1994. Effect of environmental factors on vetiver grass growth. Chinese Journal of Ecology, 13(2): 23-26

Xia HP, Wang QL, and Kong GH. 1999. Phyto-toxicity of garbage leachates and effectiveness of plant purification for them. Acta Phytoecologica Sinica, 23(4): 289-301

Xu LY. 1998. Vetiver Research and Development. Beijing: China Agricultural Science and Technology Press. 76-82, 147-152

Zheng CR, Tu C, and Chen HM. 1997. Preliminary experiment on purification of eutrophic water with vetiver. The International Vetiver Workshop, Fuzhou, China. 40

A Brief Introduction to the First Author

Dr. Xindi Liao, is an Associate Professor of the College of Animal Science, South China Agricultural University, Guangzhou city, China. His field of research is in livestock waste management, particularly in the use of constructed wetland for treatment of livestock wastewater. So far he has published two monographs and over 20 academic papers in the aspect of animal waste management.