STUDY ON THE ABILITY OF *CYPERUS ALTERNIFOLIUS* FOR SLUDGE TREATMENT IN CONSTRUCTED WETLAND

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Abstract

This research was focused on the ability of the *Cyperus alternifolius* plant to remove pollutant in sludge through the constructed wetland. The initial seeding sludge taken from the wastewater treatment plant of Vinh Loc industrial zone was treated by wetland at the increasing loading of 1.52 m^3/m^2.year, 3.04 m^3/m^2.year and 6.08 m^3/m^2.year in that order to adapt gradually and avoid loading shock. The treatment efficiency of pollutant concentration in model with plants was rather high with sludge loading rate of 3.04 m^3/m^2.year. The concentration of TOC, TP and TKN reduced 41 %, 40 % and 47 %, respectively. Besides, during the operation time, *Cyperus alternifolius* has adapted and well developed which is characterized by an increase in the biomass. In general, *Cyperus alternifolius* can treat industrial sludge with high efficiency. So that, this can open a new prospect in the future with planting of *Cyperus alternifolius* for sludge treatment and this also brings high economic efficiency.

Keywords: Sludge treatment wetland, sludge dewatering, reed beds, sludge stabilization, Vertical-flow constructed wetlands.

1. INTRODUCTION

Nowadays, sewage sludge is one of the wastes which can cause heavy pollution to the environment. According to the Department of Natural Resources and Environment of Ho Chi Minh City, the city has nearly 3000 tons of sludge per day, including 2000 tons of sludge from the dredging of canals and drainage network cleaning, 250 tons of sludge from industrial areas, 500 tons of sludge from sewage and septic tank,....

For decades, the sludge treatment technologies have been applied including incineration, stabilization and solidification, landfill disposal or composting. At present, landfill disposal is the most common method with the requirement of large land while the capacity of the landfill is very limited. As a result, finding the appropriate management measures and effective treatment methods for industrial sludge is an urgent problem.

Constructed Wetlands has recently been known to the world as a technological solution for the treatment of sludge (Sludge treatment Wetland) in natural conditions. S.T. Summerfelt et al (2005) studied aquaculture sludge treatment using artificial wetlands; research results showed that wetlands could remove 96 % of TSS, 91 % of total COD, 81 % of soluble COD, 93 % of phosphate, 89 % of TKN and 90 % of TP [3]. Similarly, 1998-2001, The Asian Institute of Technology (AIT) in Bangkok, Thailand carried out a study on faecal sludge dewatering and stabilization in vertical flow constructed wetland [1]. I. M. Kengne et al (2009) conducted a research aiming at assessing the potentials of vertical-flow constructed wetlands vegetated with Echinochloa pyramidalis as technically feasible approach for sludge dewatering; Results showed that at loading rate of 100–200 kg TS/m^2/yr, the system performed well for solid–liquid separation, with an average dry matter content of biosolids 30 % and pollutant removal efficiencies higher than 77 %, 86 %, 90 %, 90 % and 95 % for NH_4^+, TSS, TS, NTK and COD, respectively [2].

With the advantages and applications of constructed wetlands, a study on the ability of *Cyperus alternifolius* for sludge treatment in constructed wetland was carried out to find out an eco friendly, low cost and stable solution and contribute to increasing the value of biodiversity and improving local environmental landscape.

2. MATERIALS AND METHODS

2.1. Experimental model

The experimental setup was arranged as shown in figure 1.

The small-scale experimental wetland was 0.6m length, 0.4 m wide, 0.6 m depth and made of 5 mm thick glass. A 50 mm thick macadam was placed at the bottom and a soil layer of 50 mm was added. The 100 mm thick sand layer was at the top of the model. The effluent was withdrawn through a PVC tube (diameter: 21 mm). The system consist a *Cyperus alternifolius* model and a control model.

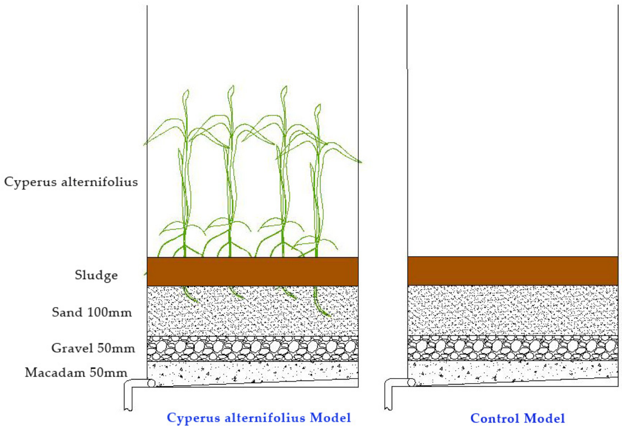


Fig 1: Experimental model

2.2. Material

The object of study is sludge collected from the concentrated wastewater treatment plant of Vinh Loc Industrial zone (Binh Chanh district - HCMC). The seeding sludge was taken after sludge thickening.

Sludge characteristics are shown in table 1.

Table 1: Characteristic of initial seeding sludge

No.	Parameters	Unit	Results	
			Sample 1	Sample 2
1	Humidity	%	96.7	96.94
2	pH	-	6.75	7.09
3	TOC	%	41.29	36.81
4	TP	%	2.04	1.39
5	TKN	%	4.667	4.84

2.3. System operation

Plants growing in the model are the 16^{th} weeks of age *Cyperus alternifolius*. They have a fully developed root system. Number of trees to be planted at a density of 3 plants/tanks (200 mm diameter).

Three sludge loading rates were conducted at the laboratory including 1.52 m^3/m^2.year 3.04 m^3/m^2.year (SLR2), and 6.08 m^3/m^2.year (SLR3), respectively.

Every week, sludge was collected and analysed for pH, TOC, TKN, TP.

Dewatering water was analysised for pH, color, COD, TKN, SS, TP, volume of water from the dewatering process.

The growth of the plants was monitored every week by measuring the height of plants and the number of shoots.

2.4. Analytical methods

The analytical methods of sludge and the percolating liquid of wetland are shown in tables 2 and 3.

Table 2: Sludge analytical methods

No.	Parameters	Unit	Analytical methods
1	pH	-	TCVN 5979-1999
2	TOC	%	Walkley Black
3	TKN	%	TCVN 6498-1999
4	TP	%	TCVN 6499-1999
5	Humidity	%	TCVN 5963-1999
6	Sludge height	Mm	Measure dimension

Table 3: Water analytical methods

No.	Parameters	Unit	Analytical methods
1	pH	-	TCVN 6492-1999
2	SS	mg/l	SMEWW 2450D
3	COD	mg/l	SMEWW 5220C
4	TKN	mg/l	SMEWW 4500N (B&C)
5	TP	mg/l	SMEWW 4500-P D
6	Colour	PtCo	Colorimetric method

3. RESULTS AND DISCUSSION

3.1. Dewatering ability of sludge

The moisture of sludge represents the percentage of water contained in the sludge. The increasing of moisture demonstrates that the dewatering ability decreases. Through three sludge loading rates (SLR), the moisture in *Cyperus alternifolius* model ranged from 81-87 %; 76-85 %, and 82-89 %, respectively, with the increasing of SLR.

The moisture in control model was 87-90 %, 88-91 % and 89-93 %. Compared with the moisture of sludge before treatment (96 %), we found that the moisture of sludge in two models reduced by the evaporation process and part of the water is separated through the filtration systems. In addition, part of the water was used for the growth and the development of plants in the *Cyperus alternifolius* model.

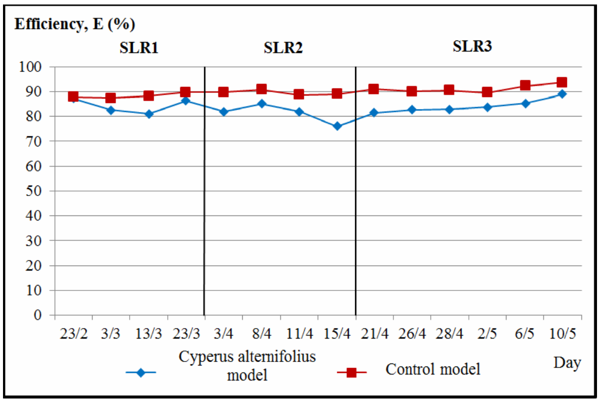


Fig. 2: Moisture variation according to the sludge loading rate and operation time

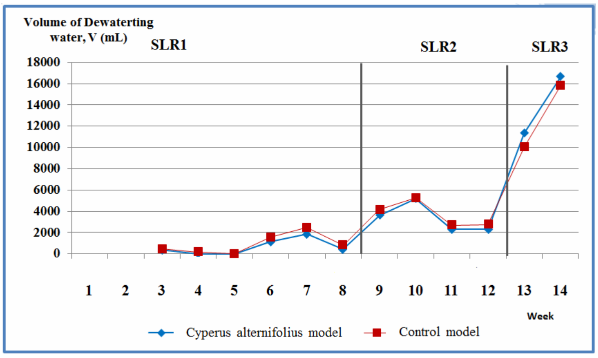


Fig. 3: Volume of percolating liquid of wetlands according to the sludge loading rate and operation time

At the SLR of 1.52 m^3/m^2.year and 3.04 m^3/m^2.year, the percolating liquid volume of Cyperus alternifolius model was lower than that in the control model by plant evapotranspiration (Nielsen 1990; De Maeseneer, 1997). At the first load, after 54 days operation, the percolating water volume of *Cyperus alternifolius* and control model was 3.82 L and 5.49L, respectively.

As a result, plants absorbed 1.676L (about 0031 litres per day). Similarly, at the second load, volume of percolating liquid was 13.45 litres and 14.88 litres corresponding to the *Cyperus alternifolius* model and control model. Thus in the SLR of 3.04 m^3/m^2.year, plants absorbed 0.06 litres per day. The volume of percolating water was lower than the amount of water absorbed by plants.

At SLR of 6.08 m^3/m^2.year, the water percolation from two models increased, but the volume of percolating water in the control model was lower than that in the *Cyperus alternifolius* model. Obviously if operated at high SLR, a dense layer of compressed mud was formed that prevented water percolation in control model. For wetland model, the plants developed and moved, breaking the surface film creates more favorable conditions for water percolation.

3.2. The stability and mineralization of sludge

The mineralization of sludge was presented in figures 4 and 5.

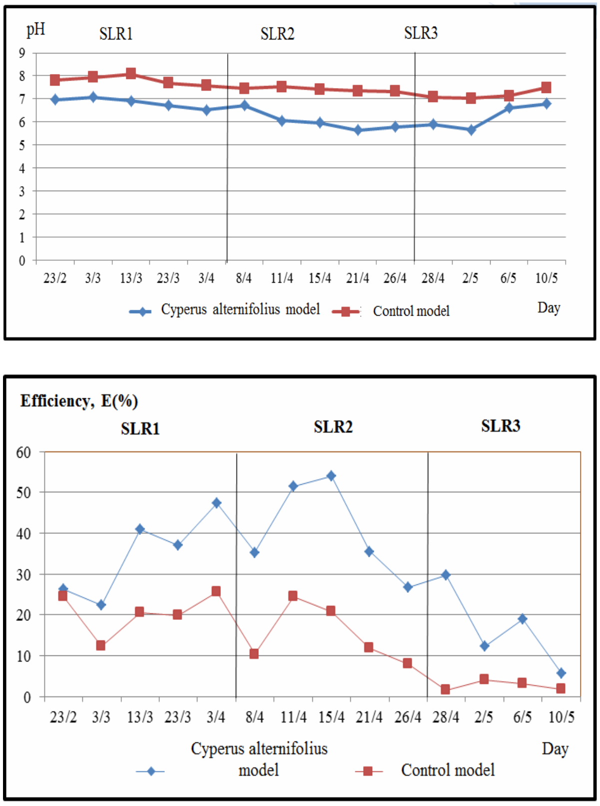
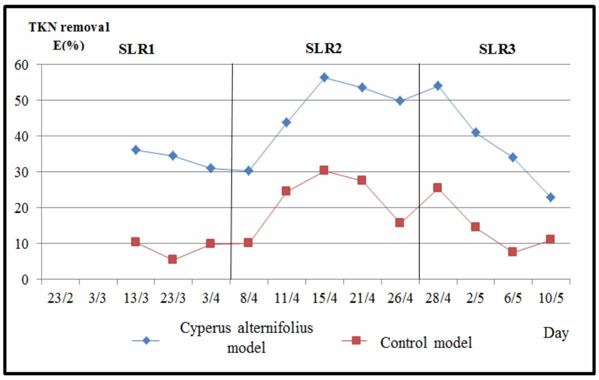


Fig. 4: pH and TOC removal efficiency during the study period

Compared with the pH of raw sludge, pH in the control model increased (0.72-1.33 unit), while pH in the Cyperus alternifolius model decreased and was lower than the input value (0.97-1.43 unit). The phenomenon of pH decrease was explained by the presence of nitrification process due to oxygen transfer by the plants from the air to the roots and through the cracked surface from the plant's movement creates aerobic conditions, promoting the existence of nitrification bacteria [2].



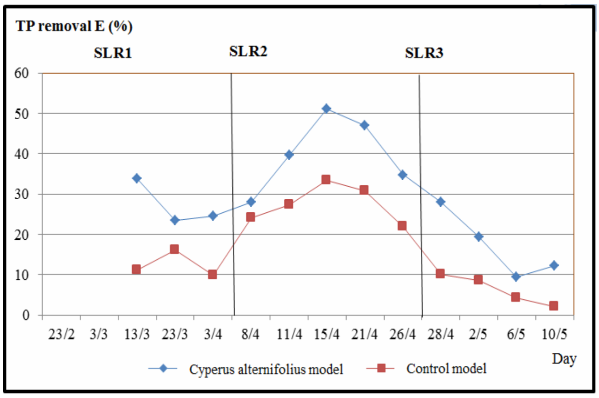


Fig. 5: TKN, TP concentrations during the study period

The rate of N:P of initial industrial sludge was about 3:1, lower than the typical rate for the development of microorganisms (5:1) and the growth of plant (12:1). As the result, the treatment efficiency of phosphor was lower than that of nitrogen in C*yperus alternifolius* model.

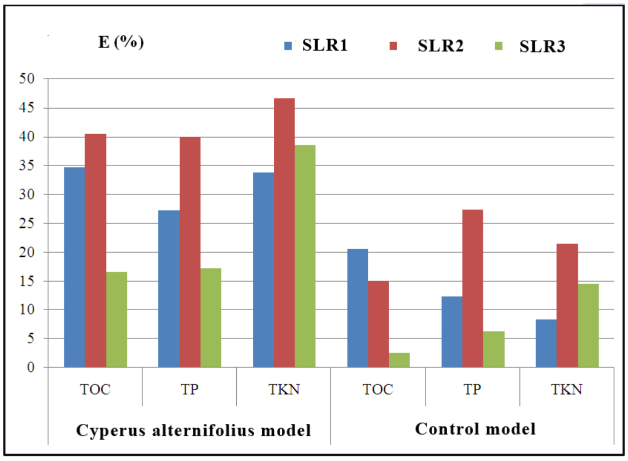


Fig. 6: Average treatment efficiency of two models

Research results showed that, at 3 SLR of 1.52 m^3/m^2.year; 3.04 m^3/m^2.year and 6.08 m^3/m^2.year, the *Cyperus alternifolius* model obtained pollution treatment efficiency better than the control model. To be more specific, the removal efficiency of nitrogen, phosphorus and organic compounds in the *Cyperus alternifolius* model are 33-46 %, 17-40 % and 16-40 % in that order. Besides, the treatment efficiency of the control model varies according to the SLR.

At SLR of 1.52 m^3/m^2.year, the nutrient content of sludge is not sufficient for the growth and development of microorganism and vegetable so the treatment efficiency was not high. At SLR of 3.04 m^3/m^2.year, the treatment efficiency went up drastically indicated that system worked more efficiently and eliminated pollution from sludge components better. The removal of pollutants of this system relies on a combination of sedimentation, filtration, plant uptake and microbial decomposition of the microorganisms on the filter media and root zone. The SLR of 3.04 m^3/m^2.year (120 kg/ m^2.year) was the optimal loading rate among three experiments. This loading rate is corresponding to the previous study results of Uggetti et al. (2009a) [2].

From the average performance results in figure 6, the percentage of organic matter, phosphorus and nitrogen transformed by plants were shown in table 4.

Table 4: The percentage of pollutants transformed by plants

	TOC (%)	TP (%)	TKN (%)
SLR 1.52 m^3/m^2.year	14.248	14.87	25.427
SLR 3.04 m^3/m^2.year	25.512	12.614	25.2
SLR 6.08 m^3/m^2.year	14.073	10.97	24.07

As is shown, we found that the best SLR in the *Cyperus alternifolius* model is 3.04 m^3/m^2.year.

When increasing SLR from 1.52 m^3/m^2.year to 6.08 m^3/m^2.year, the treatment efficiency of TN and TP decreased gradually while the treatment efficiency of TOC obtained the maximum value at the SLR of 3.04 m^3/m^2.year. In three measured parameters such as nitrogen, organic matter and phosphorus, the highest nitrogen removal proved that *Cyperus alternifolius* have a practical significance in the removal of nitrogen from industrial sludge.

3.3. Plant growth

The average height of the initial *Cyperus alternifolius* was 34.5 cm. For the first time, the plants showed signs of yellowing, wilting by starting to adapt to the new environment. At this time, the height of plants did not increase significantly. Then, the plants developed well and used nutrients in the sludge as N and P for growth.

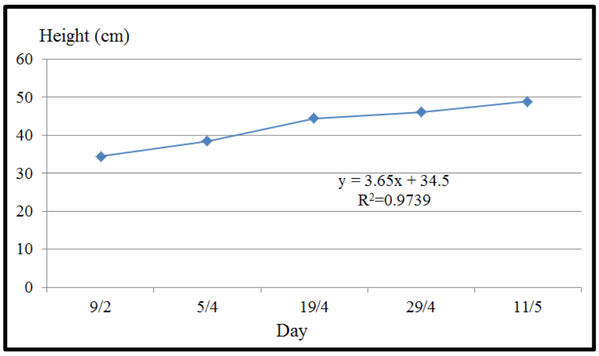


Fig. 7: Height growth of plants with time

The relationship between plant height and time is represented by the equation:

$$y = 3.65x + 34.5 \quad (1)$$

$R^2 = 0.9739$

With: y: Height of plant (cm); x: Time (day)

After 3.5 months, the height rose about 0.16 cm per day. The maximum height was approximately 41-51 cm reached after 3 months.

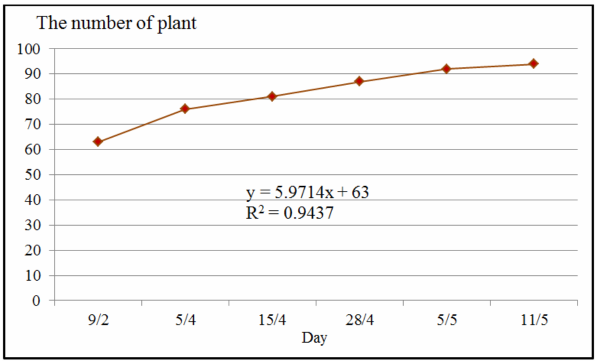


Fig. 8: The number of plant growth with time

Correlation between the number of plant development over time in the study period is represented by the equation:

$$y = 5.9714x + 63 \quad (2)$$

$R^2 = 0.9437$

With: y: Number of plants in the model (trees); x: Time (day).

The number of *Cyperus alternifolius* planted in the initial model was 63, divided into three bushes, planted in a triangle. The growth in the number of plants also affects the use of nutrients in sewage sludge, as well as the transport of oxygen into the material layer increasing the nitrification efficiency.

4. CONCLUSION

Removal efficiency of pollutants in sewage sludge in the constructed wetland is rather good. At SLR 3.04 m^3/m^2.day, the removal efficiency of Cyperus alternifolius model is highest, pollutants removal efficiencies were 41 % for TOC, 40 % for TP and 47 % for TKN.

Research results showed the prospect of applying constructed wetland with *Cyperus alternifolius* to control sludge from industrial zone.

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