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Original research article

# Swine wastewater treatment using vertical subsurface flow constructed wetland planted with Napier grass

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A B S T R A C T

This research aims to investigate the pollutant removal efficiencies in swine wastewater using a vertical subsurface flow constructed wetland (VSF CW) planted with two species of Napier grass. The grass productivities were also cultivated and compared in order to provide information for species selection. Twelve treatment units were set up with the VSF CWs planted with Giant Napier grass (*Pennisetum purpureum* cv. King grass) and Dwarf Napier grass (*Pennisetum purpureum* cv. Mott.) with 2 and 5 cm $d^{-1}$ of hydraulic loading rates (HLR). Comparisons of removal efficiency and grass productivity were analyzed using Duncan's Multiple Range Test and t-test at the significant level 0.05. Both species of Napier grass performed more than 70% of removal efficiency of BOD and TKN. The VSF CW planted with Giant Napier grass at 5 cm $d^{-1}$ HLR performed the highest BOD removal efficiency of 94 ± 1%, while the 2 cm $d^{-1}$ HLR removed COD with efficiency of 64 ± 6%. The results also showed the effluent from all treatment units contained averages of BOD, COD, TSS, TKN and pH that followed Thailand's swine wastewater quality standard. Average fresh yields and dry yields were between 4.6 ± 0.4 to 15.2 ± 1.2 and 0.5 ± 0.1 to 2.2 ± 0.1 kg $m^{-2}$, respectively. The dry yields obtained from four cutting cycles in five months of CW system operation were higher than the ones planted with a traditional method, but declined continuously after each cutting cycle. Both species of Napier grass indicated their suitability to be used in the VSF CW for swine wastewater treatment.



## 1. Introduction

Livestock farming, especially on swine farms, causes a large amount of wastewater which contains a high concentration of organic substances, solids and nutrients. Without appropriate wastewater treatment methods, the effluent can contaminate water resources. In order to control water quality of the wastewater discharge from the swine farms, Thailand has developed effluent standards. Currently, only the large-sized swine farms are able to comply with the standards. Many small-sized farms fail to do so due to their budget limitations and lack of ability to operate the complicated systems. A simple operation and low cost wastewater treatment system can be an important alternative to improve water quality for these small-sized swine farms.

Constructed wetland (CW) with plants is known as an effective, low cost, and environmentally friendly wastewater treatment system. Recently, the CWs have been used to treat wastewater from various agricultural activities including from the swine farms [1,2]. Meers et al. [3] and Chen et al. [4] reported that constructed wetlands can be used for treating swine wastewater to reach the discharge standard, and also is considered to be a good alternative treatment system.

Napier grass is a perennial forage crop with high biomass and drought tolerant. It is easy to establish and has been used primarily for grazing [5,6], bio-oil, bio-gas, charcoal, and pulps for paper making. In case of wastewater treatment, Goorahoo et al. [7] reported that Napier grass was used to reduce excess nutrients from diary effluent in order to reuse wastewater for irrigation. The grass showed a decent potential to absorb significant amounts of the excess nutrients in the wastewater. In India, a vertical subsurface flow CW (VSF CW) planted with Napier grass was used to treat greywater in which the effluent reached the USEPA standard for water reuse [8].

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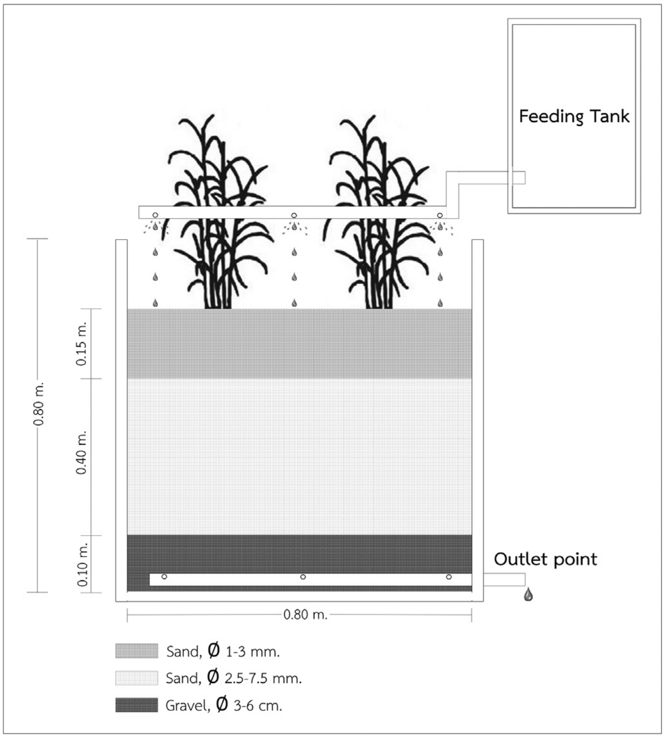


**Fig. 1.** The vertical subsurface flow constructed wetland (VSF CW).

This research aims to investigate the efficiencies of two Napier grass species with different wastewater loading rates for swine wastewater treatment. Also, Napier grass productivities were cultivated, measured, and compared. The results of the study will present an alternative for wastewater treatment of the small-sized swine farmers. If the systems can improve water quality to a desirable level as well as develop extra income from Napier grass productivity, it may encourage the farmers to adopt the wastewater treatment before discharging the effluent into the environment.

## 2. Materials and methods

The VSF CW used in this research was built from a circular concrete tank with a diameter of 0.8 m and a height of 0.8 m. It was filled with three types of media for plant cultivation and wastewater treatment. From the bottom, a 10 cm height of gravel (3–6 cm in diameter) was lined as a first layer. The second layer was a 40 cm height of coarse sand (2.5–7.5 mm in diameter). The third layer was a 15 cm height of medium sand (1–3 mm in diameter). A feeding tank, which contained swine wastewater, was situated on the top of an experimental unit. A drainage pipe was inserted under the unit as shown in Fig. 1.

Giant Napier grass (*Pennisetum purpureum* cv. King grass) and Dwarf Napier grass (*Pennisetum purpureum* cv. Mott) were selected and planted separately in twelve experimental units. Two control units were set up the same as the experimental units but without the grass. When the grasses acclimated in the experimental system, they were all cut at approximately 5 cm above ground level. The treatment process then was started by loading swine wastewater, which was collected from small-sized swine farms, into the VSF CW with the hydraulic loading rate (HLR) of 2 and 5 cm $d^{-1}$. The HLRs were adapted from Cooper's design criteria for the VSF CW [9] combined with a consideration for the appropriateness of Napier grass growth. The influent was retained and treated in the VSF CW for 2 d before draining it. Then, the systems were suspended for 5 d, before the next wastewater treatment cycle was performed. These VSF CWs were operated continuously for 5 months. Wastewater samples from the influent and effluent were collected every week throughout the operation period. Water quality parameters, namely COD, BOD, TSS, TDS, TKN, DO, EC, Temp and pH, were analyzed according to the analysis methods of Standard Methods for the Examination of Water and Wastewater [10].

During the treatment operation, Napier grasses were cut four times. The first time was at 60 d after the treatment system began. The grasses were cut at approximately 5 cm above the ground. The other three cutting cycles were every 30 d in which the interval is a common practice for the Napier grass harvest [6]. Samples of the Napier grass, then, were taken to analyze for their fresh yield and dry yield.

Duncan's Multiple Range Test (DMRT) was used to compute the statistical differences of the removal efficiency among three different groups of treatments (VSF CWs planted with Giant Napier grass, Dwarf Napier grass, and control unit). The statistical differences for removal efficiency among different two groups of the HLR were compared by t-test. The statistical differences of productivity among different four types of VSF CW and among different cutting cycles were compared using DMRT. All statistical analyses were performed at the 0.05 significant levels.

## 3. Results and discussion

### 3.1. Wastewater treatment efficiency of the VSF CW

Thailand swine wastewater quality standard type C, which occurs on the farms with 50–500 pigs, indicates that COD, BOD, TKN, and TSS should not exceed 400, 100, 200 and 200 mg $L^{-1}$,

**Table 1**
Characteristics of swine wastewater influent.

| Indicators | Unit | Ranges (sample sizes) | Average ± SD | Thailand swine wastewater quality standard[a] |
|---|---|---|---|---|
| Temperature | °C | 30.0–35.0 (21) | 32.0 ± 1.2 | – |
| pH[b] | | 5.91–7.54 (21) | 6.76 | 5.5–9.0 |
| DO | mg $L^{-1}$ | 0.02–3.88 (21) | 1.08 ± 0.99 | – |
| EC | μS $cm^{-1}$ | 565–1469 (20) | 1060 ± 276 | – |
| TDS | mg $L^{-1}$ | 283–735 (20) | 530 ± 139 | – |
| TSS | mg $L^{-1}$ | 21–51 (21) | 31 ± 8 | 200 |
| BOD | mg $L^{-1}$ | 30–210 (15) | 120 ± 59 | 100 |
| COD | mg $L^{-1}$ | 176–872 (15) | 373 ± 209 | 400 |
| TKN | mg $L^{-1}$ | 35–111 (20) | 70 ± 21 | 200 |

Note:
– = Not be determined for the standard.
[a] Standard for effluent of swine farms with 50–500 pigs.
[b] Median is shown instead of average ± SD.