Development of Nitrogen Transformation Model for VFCWs Treating Faecal Sludge

The thousands of tons of faecal sludge currently collected every day from on-site sanitation installations are not properly disposed of, especially in developing countries. In Bangkok, only 8.5 % of the 4600 m³ of FS collected daily are treated in faecal sludge treatment plants [3]. Among the potential low-cost treatment systems, which enhance nutrient and biosolids recovery for reuse purposes [1], the vertical-flow constructed wetland (VFCW) system has proven robust for efficient FS dewatering and quality biosolids production [2]. Atitaya Panuvatvanich[1,2], Thammarat Koottatep[1], Doulaye Koné[2]

Early 1997, three pilot-scale, vertical-flow constructed wetlands were developed at the Asian Institute of Technology (AIT) in Bangkok. Based on the available experimental data, the optimum solids loading rate was established at 250 kg TS/m^2.yr with a 6-day percolate impoundment. The CW units treating faecal sludge achieve 80–96 % removal efficiencies for COD, TS and TKN. The current knowledge on nitrogen transformation within the system could be useful to further develop system design. This study aims at identifying nitrogen transformation pathways and kinetics of processes corresponding to nitrogen compounds, such as organic nitrogen, ammonia nitrogen and nitrate nitrogen in vertical-flow constructed wetland (VFCW) for treating faecal sludge.

Methodology

Experimental setup

Five laboratory-scale VFCWs, located at the Environmental Research Station of the Environmental Engineering and Management Programme of AIT, Thailand, were used for this research.

Lab-scale VFCW units

Each unit, consisting of a square plastic tank, was planted with cattail (Typha augustifolia). The effluent outlet was divided into two groups as shown in Figs. 1a and 1b, without and with water holding in the drainage layer. A PVC pipe was connected to the effluent outlet of three laboratory-scale VFCW units to maintain a constant water level in the drainage layer, as illustrated in Fig. 1b.

Preliminary findings

Figure 3, which indicates influent and effluent nitrogen concentrations in form of org-N, NH_4-N, NO_2-N, and NO_3-N, reveals that 94 % of the influent N concentration is in the form of NH_4-N. After ponding for six days, the TN removal efficiency in Unit 1 was higher than in Unit 2 by about 10 %. Similarly, the TN removal efficiency in Unit 3 is higher than in Units 4 and 5 by about 8 % and 26 %, respectively. This indicates that accumulated sludge may affect total nitrogen removal efficiency of the systems. Moreover, VFCW operated with percolate impounded in large gravel layers does not reveal a significant difference in terms of TN removal efficiency, as compared to a VFCW operated without percolate impoundment.

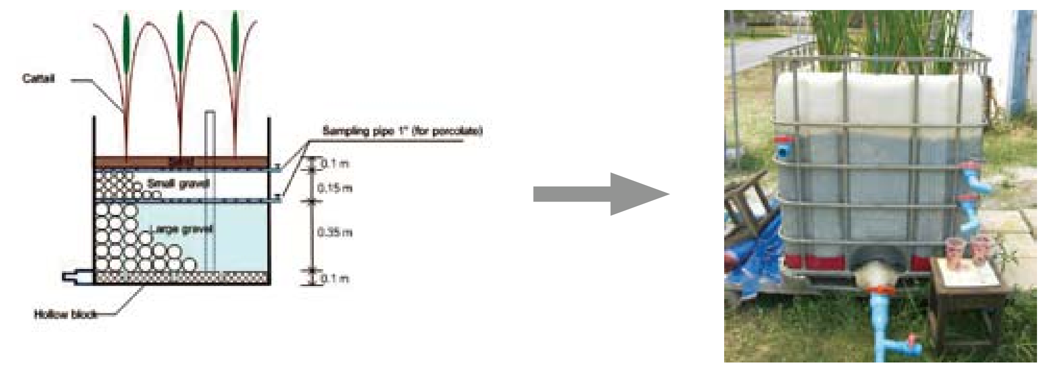

Figure 1a:
Without retained percolate in large gravel layer

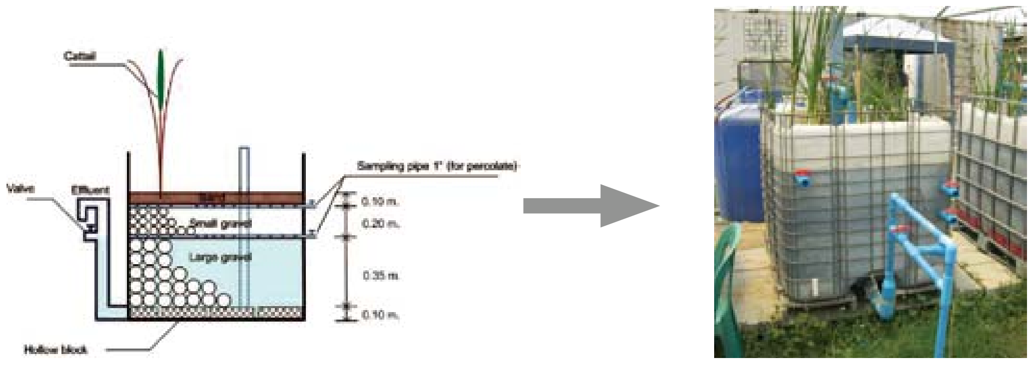

Figure 1b:
With percolate retained in large gravel layer

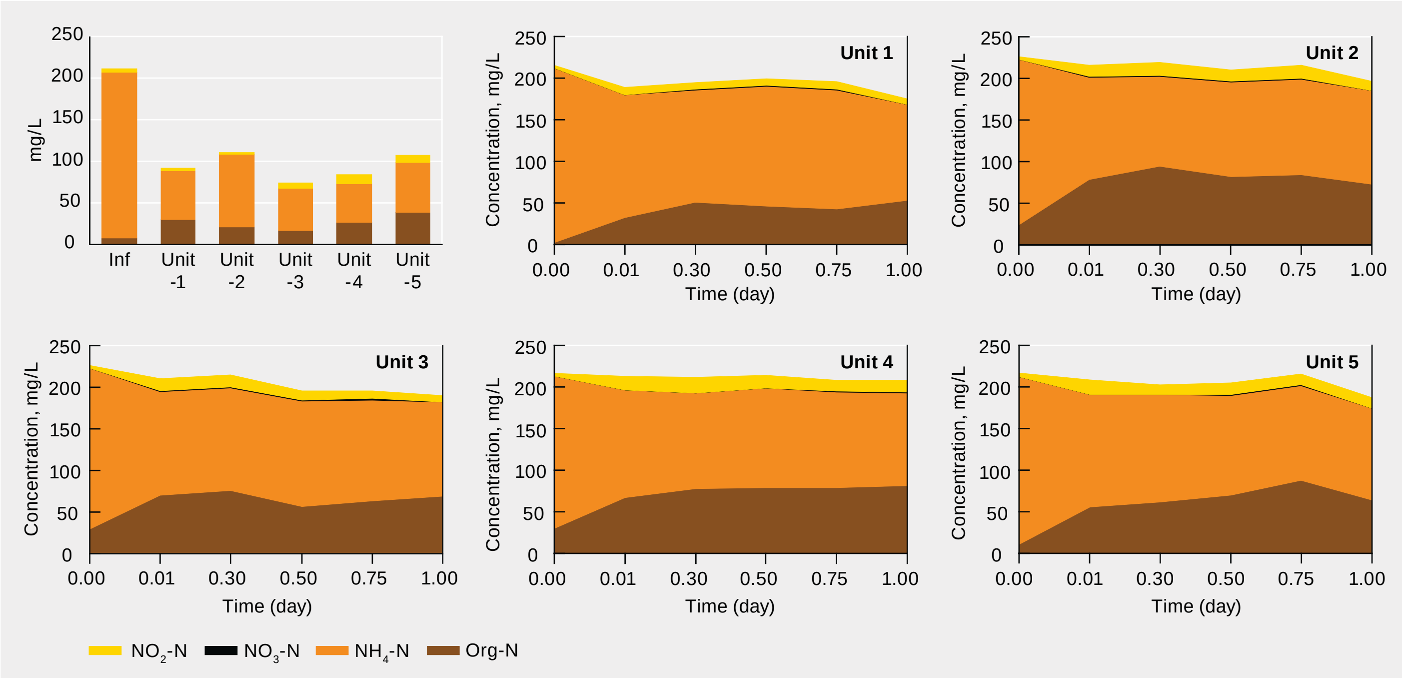

Figure 2 (top left): Profiles of nitrogen compounds after passing the sand layer in lab-scale VFCW units.
Figure 3: N compounds in influent and effluent of each unit (1–5).

With regard to nitrification in the sand layer, preliminary results indicate that approximately 50% of NH_4-N concentrations disappear and NO_2-N concentrations increase by about 80 %. NO_3-N concentrations increase by about 40 % in relation to the influent concentrations (Fig. 2). This indicates that NH_4-N was probably converted through nitrification to NO_2-N and NO_3-N after passing the sand layer. Moreover, plant uptake or another mechanism could be responsible for unrecovered NH_4-N in this layer.

After sludge accumulation at various depths on the top of the VFCW, org-N concentrations increased by about 90 % in relation to the influent concentrations. The results reveal that the different levels of accumulated sludge had no significant effect on nitrogen transformation in the sand layer.

Moreover, the different drainage types, either with or without retained percolate in the system, also had not effect on nitrogen transformation in the sand layers (Table 1).

Further investigations

Based on the preliminary results, the following three investigations will also have to be carried out to identify nitrogen transformation in the vertical-flow constructed wetland:

1) Ammonia volatilisation, nitrification, denitrification, and plant uptake – the main mechanisms for nitrogen transformation.
2) Relationship between sand layer depth and nitrogen conversion.
3) Releakage of nitrogen from accumulated sludge.

Accordingly, ammonia volatilisation, nitrification and denitrification will be examined in new column units and controlled conditions. Two new lab-scale VFCW units at different depths of the sand layer will be set up to investigate the relationship between sand layer depth and nitrogen conversion. Finally, small units will be installed at different depths in the accumulated sludge to study nitrogen releakage.

Type of influent	Drainage type	Units	Depth of accumulated sludge (cm)
AIT wastewater (NH_4^+ concentration adjusted with soluble NH_4Cl solution)	Without impounded percolate in large gravel layer	1	0
		2	10
	With impounded percolate in large gravel layer	3	0
		4	10
		5	20

Table 1: Configuration of experimental unit.

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