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Original Article

The Use of Earthworms in Lab-scale Constructed Wetlands to Treat Swine Wastewater

Nathasith Chiarawatchai[1] Chackrit Nuengjamnong[2*]

Abstract

This study investigated the effect of adding local earthworms *(Pheretima peguana)* into several configurations of the lab-scale constructed wetlands reactors receiving swine wastewater in terms of their treatment performances, namely a decrease in organic matter, TKN, and solids. The results indicated that the performance of the lab-scale units with earthworms was better in the presence of earthworms. In terms of optimal configuration, the vertical subsurface-flow constructed wetlands with earthworms, sequentially followed by horizontal subsurface-flow constructed wetlands had generally the best treatment performance. This configuration decreased BOD, COD, TVSS, and SS by more than 90%, as well as TKN and TS by more than 85%. Based upon these results, it is recommended that future pilot-scale studies should be configured and operated by using vertical-flow constructed wetlands with earthworms followed by horizontal-flow constructed wetlands.

Keywords : clogging, constructed wetlands, earthworms, swine wastewater, vermicomposting

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บทคัดย่อ

การนำไส้เดือนดินมาใช้ในบึงประดิษฐ์ขนาดทดลองเพื่อบำบัดน้ำเสียจากฟาร์มสุกร

ณัฐสิทธิ์ เจียรวัฒน์ชัย[1] จักรกริศน์ เนื่องจำนงค์[2*]

งานวิจัยนี้มีเป้าหมายหลัก คือ การเปรียบเทียบความแตกต่างของประสิทธิภาพในการบำบัดน้ำเสียจากฟาร์มสุกรโดยการนำไส้เดือนดินท้องถิ่นสายพันธุ์ *Pheretima peguana* มาใช้ในบึงประดิษฐ์ขนาดทดลองหลายรูปแบบในเชิงของการลดค่าสารอินทรีย์ ไนโตรเจน และค่าของแข็งต่างๆ ผลการทดลองชี้ให้เห็นว่าประสิทธิภาพโดยทั่วไปของระบบบำบัดที่มีการนำเอาไส้เดือนดินมาใช้ร่วมด้วย จะสูงกว่าของระบบที่ไม่ได้มีการนำไส้เดือนดินมาใช้ และเมื่อเทียบผลการทดลองในเชิงรูปแบบที่แตกต่างกันของบึงประดิษฐ์พบว่า ระบบที่มีประสิทธิภาพสูงสุดคือระบบแบบน้ำไหลใต้ดินแนวดิ่ง ที่มีการนำไส้เดือนดินมาใช้ร่วมด้วย แล้วตามด้วยระบบแบบน้ำไหลใต้ดินแนวนอน โดยสามารถลดค่าบีโอดี ค่าซีโอดี ค่าของแข็งแขวนลอยระเหยทั้งหมด และค่าของแข็งแขวนลอยได้มากกว่าร้อยละ 90 รวมไปถึงลดค่าทีเคเอ็น และค่าของแข็งทั้งหมดได้มากกว่าร้อยละ 85 ดังนั้น การขยายขนาดของการทดลองขั้นต่อไปให้เป็นแบบขนาดเหมือนจริงโดยใช้ระบบบึงประดิษฐ์แบบน้ำไหลใต้ดินแนวดิ่งร่วมกับการใช้ไส้เดือนดินตามด้วยระบบแบบน้ำไหลใต้ดินแนวนอน สามารถทำให้ขยายผลในทางปฏิบัติได้ต่อไป

คำสำคัญ : การอุดตัน บึงประดิษฐ์ ไส้เดือนดิน น้ำเสียจากฟาร์มสุกร การหมักโดยไส้เดือนดิน

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Introduction

Treating swine wastewater in Thailand is of current great concern since pig farming has undergone rapid growth in order to feed the rapidly-increasing population and new culture of diet (TDA, 1997). Subsurface-flow constructed wetlands (SFCWs), either as vertical flow (VSFCWs) or horizontal flow (HSFCWs), are among the treatment technologies applied to treat such wastewater (Lee et al., 2004; Kantawanichkul et al., 2001). Nevertheless, one of the major obstacles for the efficient use of SFCWs, especially in the case of VSFCWs, is pore clogging due to the solid contents in the wastewater (Blazejewski and Murat-Blazejewska, 1995; Crites and Tchobanoglous, 1998). The severity of this problem rises in accordance with the strength of wastewater. Generally, a mitigation measure is to implement rest periods for the unit where no wastewater is added (Breen, 1997). This however decreases the design loading rate of the operation, thereby implying that more surface area is required in order to treat the same volume of wastewater. Since earthworms have been applied to treat the pig manure (Edwards, 2004; Gunadi and Edwards, 2003) and wastewater sludge (Prince et al., 1981), and since burrowing earthworm produce macropores, it is proposed that they can be integrated into VSFCWs treating swine wastewater in order to eliminate clogging problems.

Because earthworms require an aerobic condition (Edwards, 2004), intermittent loading of the VSFCWs is optimal over the anaerobically-operated HSFCWs. As such, VSFCWs can offer a viable habitat for earthworm populations because of their ability to transfer oxygen to the root zone and hence creating aerobic micro-sites within the largely anoxic environment (Brix, 1997). Under anoxic conditions, the earthworms will die. Additionally, the organic matter in wastewater can serve as the carbon source for earthworms, especially if one considers the prior studies with respect to the success regarding vermicomposting of several types of organic wastes. Moreover, the neutral pH environment in the wetland media also provides them a suitable environment, i.e. the optimal pH around the neutral

range. The moisture inherently associated with SFCWs guarantees earthworms will not die due to desiccation (Edwards, 2004). Finally, a preliminary study has shown that earthworms alleviate the clogging within constructed wetlands (Chiarawatchai et al., 2007). Therefore, the aim of this study is to further investigate the effects of earthworms on the treatment performance of various configurations of 2-stages lab-scale SFCWs receiving swine wastewater.

Materials and Methods

The lab-scale reactors were assembled and labeled according to figure 1, in which there were two configurations of the system: VSFCWs followed by HSFCWs and 2-stages VSFCWs. The 1st stage VSFCWs had diameter of 25 cm with 35 cm depth containing different sizes of gravel (25 cm of 1-5 mm gravel, followed by 5 cm of 5-15 mm gravel, and finally 5 cm of 15-25 mm drainage gravel at the bottom). The 2nd stage VSFCWs had diameter of 27 cm, with 35 cm depth containing sand and gravel (from top to bottom, 10 cm of 0.5-0.8 mm sand, followed by 15 cm of 1-5 mm gravel, 5 cm of 5-15 mm gravel, and finally 5 cm of 15-25 mm drainage gravel). The HSFCWs had a depth of 30 cm, a width of 39 cm, a length of 58 cm, and contained 2-3 mm gravel. Image of the experimental-setup is shown in figure 2.

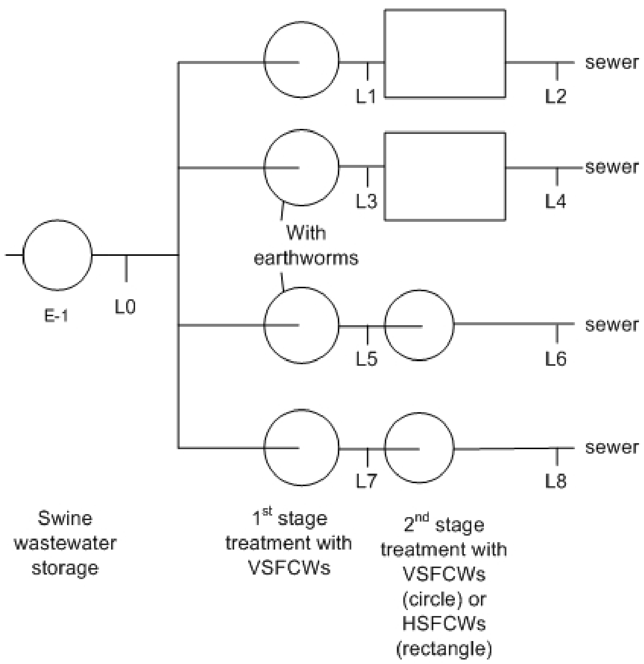

Figure 1 Illustration of the lab-scale constructed wetlands configuration

For each of the two configurations, 25 g of local earthworms *(Pheretima peguana)* as shown in figure 3, were introduced into one of the 1st stage reactor whereas another one was served as a control, meaning without an addition of earthworms, for a comparison purpose. Swine wastewater was taken from The Swine Research Unit farm, Department of Animal Husbandry, Faculty of Veterinary Science, Chulalongkorn University, Nakornpathom province. It was fed into each 1st stage reactor 6 times a day at a hydraulic loading rate (HLR) of 8 cm/d, which is the maximum value recommended by the German guideline for treating wastewater using constructed wetlands system (ATV-DVWK, 2004). Regular feeding was carried out for a month in order to incubate and stabilize the microbiological communities within the system necessary for an effective treatment. Samplings and analyses were conducted once per month. Reactor performance was monitored by the removal of BOD, COD, TKN, TSS, TVSS, and TS during the 6-months of study period, according to the Standard Methods for Water and Wastewater Examination (APHA et al., 1998).

Results

Results from the 1st month are not shown due to inconsistent removal resulting presumably from the fact that the microbial communities had not fully developed and stabilized. The average results for all parameters are

Figure 2 Image of the lab-scale constructed wetlands experimental-setup

Figure 3 Earthworms species *Pheretima peguana*

presented in table 1. The concentration of each parameter could be seen in this table ranging from an influent (L0), the effluent from the 1st stage units (i.e. the influent to the 2nd stage units, L1, L3, L5, L7), to the final effluent (L2, L4, L6, L8). Moreover, the percent decrease of each parameter from each stage is also presented in this table, such as 74% reduction of BOD from the influent (L0) to the effluent from the 1st stage VSFCWs without earthworms (L1). In terms of the overall treatment efficiency, the results are shown in table 2. For instance, BOD removal efficiency ranged from 81% in 2-stages VSFCWs without earthworms to 93% in VSFCWs with earthworms followed by HSFCWs.

Discussion

Results in table 1 illustrated that all units were capable of satisfactorily treating the wastewater. Focusing on the results from VSFCWs-HSFCWs with earthworms configuration (from L0 to L4), the BOD was decreased from approximately 800 to 50 mg/l and the SS decreased from 7100 to 30 mg/l. Whereas the 2-stages VSFCWs had considerably higher organic as well as solid content in the final effluent, in which more than 100 mg/l for BOD and approximately 100 mg/l for SS. The difference in the results of the two configurations is explained by the decreased surface area and length of the 2nd stage VSFCWs (5.73 dm^2) as compared to the 2nd stage HSFCWs (11.7 dm^2).

Table 1 Average results from the analyses at each sampling point (mg/l, unless stated otherwise)

	BOD	COD	TKN	TVSS	SS	TS
L0	823	10627	814	5305	7148	9356
L1	215	552	131	49	347	1732
L2	119	246	94	15	51	1227
L3	131	342	110	25	147	1552
L4	54	236	105	5	31	1207
% reduction L0-L1	73.9	94.8	83.9	99.1	95.1	81.5
% reduction L1-L2	44.7	55.4	28.1	68.9	85.2	29.2
% reduction L0-L3	84.0	96.8	86.5	99.5	97.9	83.4
% reduction L3-L4	58.8	30.9	3.9	80.8	78.8	22.3
L5	140	360	126	36	156	1800
L6	128	250	100	17	91	1669
L7	200	484	100	32	237	1700
L8	155	329	75	19	128	1684
% reduction L0-L5	83.0	96.6	84.5	99.3	97.8	80.8
% reduction L5-L6	8.6	30.6	20.6	52.8	41.7	7.3
% reduction L0-L7	75.7	95.4	87.7	99.4	96.7	81.8
% reduction L7-L8	22.5	32.0	25.0	40.6	46.0	0.9

Note; mg/l: milligram per liter; BOD5: Biochemical Oxygen Demand; COD: Chemical Oxygen Demand; TKN: Total Kjeldahl Nitrogen; TVSS: Total Volatile Suspended Solids; SS: Suspended Solids; TS: Total Solids

Table 2 Overall treatment efficiency for each configuration (%)

Configuration	BOD	COD	TKN	TVSS	SS	TS
VSFCWs-HSFCWs without earthworms	85.6	97.7	88.4	99.7	99.3	86.9
VSFCWs-HSFCWs with earthworms	93.4	97.8	87.1	99.9	99.6	87.1
VSFCWs-VSFCWs with earthworms	84.4	97.6	87.7	99.7	98.7	82.2
VSFCWs-VSFCWs without earthworms	81.2	96.9	90.8	99.6	98.2	82.0

With respect to the role of earthworms on the treatment efficiency of the VSFCWs, it is seen in table 1 that the units containing earthworms (L0-L3 and L0-L5) exhibited better BOD removal efficiency than the units without earthworms (L0-L1 and L0-L7). This could be because earthworms and aerobic microbes act symbiotically to accelerate and enhance the decomposition of organic matter (Loehr et al., 1988). Hence, higher BOD removal was observed while applying earthworms into the VSFCWs. This result suggested that earthworms contributed to the wastewater remediation during the treatment process within the VSFCWs.

Comparing the percent removal of each treatment stage, the 1st stage treatment exhibited better removal efficiency with respect to every parameter (70%-99%) relative to the removal efficiency of the 2nd stage reactors. For the 2nd stage reactors, the removal was highly variable, i.e. from 8 % to 68% in terms of organic removal to as low as 1% to 80% in terms of solid removal. This could result from the fact that the 2nd stage units, the organic carbon available for biodegradation was more refractory, and hence less biodegradable. It could also be stated that the role of the 2nd stage was mainly to polish the quality of the effluent. Also in comparison, the reactor with earthworms had a better tendency of treatment performance than the one without earthworms except for the total TKN removal.

After the influent passed through the 1st stage unit, the majority of suspended solids was removed by this system approximately more than 95% in every reactor. The remainder of the TS was in the soluble form that normally could not be effectively removed by VSFCWs. This was observed in the final effluent (after L6 and L8) in that the difference between the TS concentration from both units was very marginal (1669 to 1684 mg/l).

According to table 2, it is seen that the VSFCWs system with earthworms followed by HSFCWs exhibited superior treatment efficiency in most of the parameters than other configurations. Both configurations achieved the COD removal of more than 95%, which was marginally higher than the treatment efficiency of 79-90% using 1-stage VSFCWs (Kantawanichkul et al., 1999). Corresponding explanation for a better efficiency in this study could be due to more stages of treatment units. It was also very efficient to remove BOD, which was 7% better than similar configuration without earthworms and 10% better than both of the configurations utilizing 2-stages VSFCWs.

Only TKN removal was an exception, in which the removal efficiency was less than the 2-stages VSFCWs system without earthworms by approximately 3%. This could be because the feeding pattern for this configuration created an aerobic condition in both stages, allowing a higher level of nitrification. It was worth to remark that the TKN removal by these 2-stages VSFCWs was as efficient as the French 2-stages VSFCWs system designed for treating raw domestic wastewater (Molle et al., 2005). In terms of solid reduction, every configuration provided satisfactory results, in which the TS removal was over 80% and the SS removal was over 98%. It should also be noted that the VSFCWs-HSFCWs configuration had better performance than VSFCWs-VSFCWs configuration.

Conclusion

The treatment performance of the lab-scale reactors containing earthworms was in most cases better than the ones without earthworms. In terms of the configuration, the VSFCWs with earthworms sequentially followed by HSFCWs had generally the best treatment performance. Therefore, it is recommended that designs

for further studies scaling up from lab-scale constructed wetlands to pilot-scale constructed wetlands should be based on this configuration.

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References

APHA (American Public Health Association), AWWA (American Water Works Association), and WPCF (Water Pollution Control Federation). 1998. Standard Methods for Water and Wastewater Examination. 20th ed. Washington D.C.

ATV-DVWK. 2004. Principles for the design, construction, and operation of constructed wetland for the treatment of municipal wastewater. Deutsche Vereinigung f?r Wasserwirtschaft, Abwasser und Abfall e.V., Guideline A 262 draft. 25pp. (In German).

Blazejewski, R. and Murat-Blazejewska, S. 1995. Soil clogging phenomena in constructed wetlands with subsurface flow. Water Science and Technology. 35 (5): 183-188.

Breen, P.F. 1997. The performance of vertical flow experimental wetland under a range of operational formats and environmental conditions. Water Science and Technology. 35(5):167-174.

Brix H. 1997. Do macrophytes play a role in constructed treatment wetlands? Water Science and Technology. 35(5):11-17.

Chiarawatchai, C., Nuengjamnong C., Rachdawong, P. and Otterpohl, R. 2007. Potential study of using earthworms as an enhancement to treat swine wastewater. Thai J. Vet. Med. 37(4): 25-32.

Crites, R. and Tchobanoglous, G. 1998. Small and decentralized wastewater management systems. International ed. Singapore: McGraw-Hill Press. 1083 pp.

Edwards, C.A. 2004. Earthworm Ecology. 2nd ed. Florida: CRC Press LLC. 441 pp.

Gunadi, B. and Edwards, C.A. 2003. The effects of multiple applications of different organic wastes on the growth, fecundity, and survival of Eisenia fetida (Savigny) (Lumbricidae). Pedobiologia. 47: 321-329.

Kantawanichkul, S., Neamkam, P. and Shutes, R.B.E. 2001. Nitrogen removal in a combined system: vertical vegetated bed over horizontal flow sand bed. Water Science and Technology. 44(11/12):137-142.

Kantawanichkul, S., Pilaila, S., Tanapiyawanich, W., Tikampornpittaya, W. and Kamkrua, S. 1999. Wastewater treatment by tropical plants in vertical-flow constructed wetlands. Water Science and Technology. 40(3): 173-178.

Lee, C.Y., Lee, C.C., Lee, F.Y., Tseng, S.K. and Liao, C.J. 2004. Performance of subsurface flow constructed wetland taking pretreated swine effluent under heavy loads. Bioresource Technology. 92: 173-179.

Loehr T.C., Lee Y.C., Liang J.B. and Tan D. 1988. Stabilization of liquid municipal sludge using earthworms. In: Edwards C.A., Neuhauser E.F. (eds.), Earthworms in Waste and Environmental Management. SPB, Academic Pub., The Hague, 95-110.

Molle, P., Lienard, A., Boutin, C., Merlin, G. and Iwema, A. 2005. How to treat raw sewage with constructed wetlands: an overview of the French systems. Water Science and Technology. 51(9): 11-21.

Prince, A.B., Donovan, J.F. and Bates, J.E. 1981. Vermicomposting of municipal solid waste and municipal wastewater sludges. In: Workshop on the Role of Earthworms in the Stabilization of Organic Residues. Vol. I Proc. Kalamazoo, MI: Beech Leaf Press. 207-219.

TDA (Thailand Department of Agriculture). 1997. Strategies and working plans for livestock development during the 8th National Development Plan, Bangkok, Thailand.