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A Reed Bed System for the Treatment of Domestic Wastewater and Micropollutants

[1,3]Omar Hamed Jehawi, [1]Siti Rozaimah Sheikh Abdullah, [2]Mushrifah Idris, [1]Nurina Anuar, [1]Hassimi Abu Hasan, [1]Nadya Hussin AL Sbani, [1]Nur 'Izzati Ismail

[1]*National University of Malaysia, Department of Chemical and Process Engineering, Faculty of Engineering and Built Environment Bangi, Malaysia*
[2]*National University of Malaysia, Tasik Chini Research Center, Faculty of Science and Technology, Malaysia*
[3]*Al-Mergeb University, Al-Khums, Libya*

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ABSTRACT

Background: Reed Bed Constructed wetlands (RBCWs), an engineered and managed wetland system, are increasingly receiving worldwide attention for domestic wastewater treatment and reclamation. **Objective:** This paper aimed to design reed bed constructed wetlands systems for treatment of domestic sewage with various systems. Additionally it is very useful system for the removal nutrients and micropollutants contaminants of domestic sewage located at Bukit Putri, Universiti Kebangsaan Malaysia (UKM). **Results:** Combination of constructed wetlands enhances contaminants removal efficiency as hybrid constructed wetlands could cover the limitation of each single constructed wetlands. **Conclusion:** It could be concluded that the hybrid constructed wetlands ensure a more stable removal rate of pollutants including micropollutants from domestic wastewaters in comparison with other treatments.

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INTRODUCTION

Nowadays, the global interest for simple, safe, cost-effective and green technology has been developed. Constructed wetland as a natural process, environmentally friendly, ecofriendly with simple construction and low maintenance is one of the interested technique (Vymazal, J., 2002; Rousseau, D.P.L., 2008; Kadlec, R.H., S.D. Wallace, 2009). Constructed wetlands (CWs) as human made basin according to engineering design that create ecological condition same to natural wetlands for treating wastewater in different physical, chemical and biological conditions (Wallace, S.D., R.L. Knight, 2006). All design of CWs are attached growth bioreactor (Kadlec, R.H., 1989) while media material and roots, stems, leaves, and litter of wetland vegetation provide the surface for microbial attachment (USEPA, 1993).

Different types of CWs could be combined together on various configurations to formation combined system, which called "hybrid constructed wetlands". Hybrid CWs are used to achieve higher efficiency wastewater treatment rather than single CW, particularly in removal of nutrients components. Initial experiment of hybrid CW was performed by Seidel in Germany in 1980. Many configurations would be design for hybrid CWs, such as mixture series of flow rate, Surface Flow (SF), Vertical Sub-Surface Flow (VSSF) and Horizontal SSF (HSSF). Further researches were performed to evaluate hybrid CWs application for different wastewaters treatment. This project focuses on applying a Rees Bed Constructed Wetlands (RBCWs) system for domestic wastewater treatment at the different flow rate system. The project is intended to assist local governments in their wastewater treatment decision-making process and propose a study site appropriate mechanism for cleaning and reusing the wastewater.

Problem Statement:

Contaminants around the world have received global attention from last years. In the recent years, it becomes a real problem with increasing human activity. Nutrients (e.g. phosphorous (P), nitrogen (N), magnesium (MG), potassium (K)) and micropollutants (e.g. ibuprofen, ketoprofen, clofibric acid, carbamenzene, flunixin, and tertbutylazine) (Matamoros, V., 2008) contaminants are released to the aquatic ecosystem as a result of variety of human activities. A wide range of contaminants found in the aquatic

Corresponding Author: Omar Hamed Jehawi, National University of Malaysia, Department of Chemical and Process Engineering, Faculty of Engineering and Built Environment Bangi, Malaysia.
Ph: (+60189672290) E-mail: omarjehawi@yahoo.com

environment pose risks to human health through the consumption of sea food, where contaminant content becomes toxic when exposures to environment are significant. The main objective of this study is to investigate the ability of *Scirpus grossus* plants in various hybrid systems to remove nutrients and micropollutants from household sewage at Bukit puteri, "UKM".

Objective of Research:

The overall objective of the study is to investigate the removal of nutrients and micropollutants from domestic wastewater using pilot Reed Beds. Particularly, it will be conducted to:

- determine the capability of aquatic plants for the removal of nutrients and micro pollutants from wastewater using pilot reed bed (*Scirpus grossus*)
- determine the mechanism and kinetic degradation by phytoremediation method
- Compare the removal efficiency of nutrients and micropollutants in two different mode (batch and continuous) of pilot reed beds.
- Optimize a reed bed system of domestic wastewater through phytoremediation.

Pilot- Reed Bed System for Domestic Wastewater:

Reed beds are flexible systems that can be used for single households or for entire communities. In this study, a RBCW system (Figure 1) consisted of four lines where each line has three identical beds that are made of fibreglass tanks (100 cm W x 200 cm L x 100 cm D) with a PVC pipe. Gravels of different sizes were used as the media and were arranged with 10–15 mm, 3–5 mm (river sand), and 30–35 mm gravel, from the top to bottom. Every tank filled with coarse gravel-sand substrate to a depth of 40 cm, a water level kept 10 cm below the surface of the substrate, and a total water depth of 30 cm was used for subsurface flow and 20 cm up to surface of the substrate with free surface flow. All the reed bed tanks were planted with native plants of Malaysia, including *Scripus grossus* (Figure 2), locally known as *rumput menderong*, and operated in different configurations so as to allow the experiments to be carried out at various levels and using different process (batchwise and continuous, subsurface and free flow) to compare the treatment performances and to evaluate the feasibility of using this technology to remove nutrients and micropollutants from domestic wastewater.

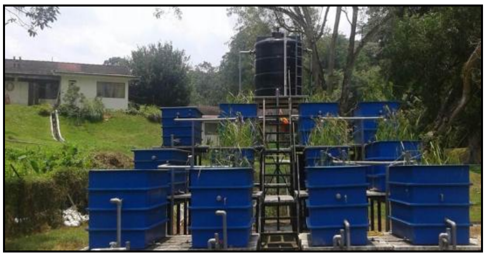

Fig. 1: Reed bed pilot-scale systems at Bukit Putri in UKM.

Fig. 2: Native (*Scirpus grossus*) plants.

Domestic sewage of Bukit Putri in UKM is generated by more than 110 households from toilets and kitchens that were channelled into a sedimentation tank. A pump was installed to pump the domestic sewage from the middle level of the sedimentation tank into the designed reed beds for treatment to avoid the presence of sludge.

Types and the Most Applied Systems of CWs:

CW systems are classified into two types of systems: Vertical Flow (VF) and the Horizontal Flow (HF), The HF system has two types: Surface Flow (SF) and Sub-Surface Flow (SSF).

(a) SURFACE FLOW (SF) -The majority of CW treatment systems are surface flow, SF systems are used is extensively in North America. These constructed wastewater treatments systems are used mostly to treat municipal wastewater, with large flow of wastewater for nutrient removal. For SF systems as depicted in Figure 3, these applications normally utilise influent sewage waters flowing across a tank or a channel that enhances aquatic plants, and water is available at a relatively shallow depth above the gravel surface. Substrates are generally native soil and geotechnical substances to avoid leaks (Reed, 1995).

(b) SUB-SURFACE FLOW SYSTEM (SSFs) - The SSFs, currently used in Australia and Europe, includes sand based technologywith sand and gravel beds materials available all over the world.

In a vegetated treatment system (Figure 4), SSFs have inlet from one end to the other end through permeable beds, which consists of three layers of gravel-sand. These beds will support the growth of rooted emergent plants. Domestic sewage flows by gravel-sand subsurface through the root part of the plants about 10-15 cm below the gravel surface. A lot of microorganisms inhabit the gravel materials (Sim, C.H., 2003) in SSF in which this condition is not available in SF.

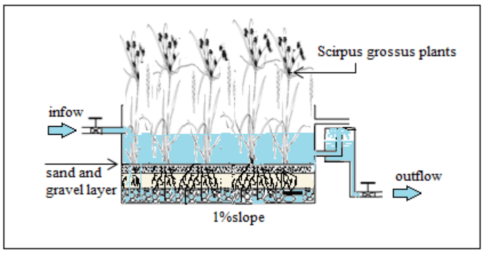

Fig. 3: Schematic cross-section of a surface flow constructed wetland system (Kadlec, R.H., R.L. Knight, 1996).

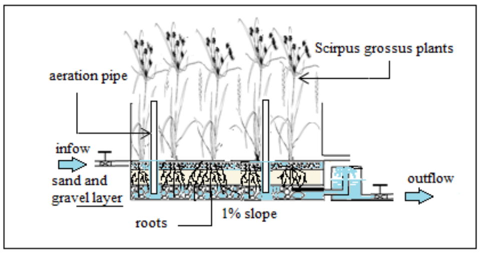

Fig. 4: Schematic cross-section of a horizontal flow beds (HFBs) (Morel, A., S. Diener, 2006).

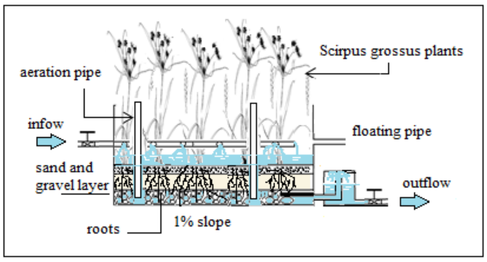

Fig. 5: Schematic cross-section of a vertical flow system VFB (Morel, A., S. Diener, 2006).

(i) HORIZONTAL FLOW REED BEDs (HFRBs) SYSTEM – As the primary design of SSF CWs were for Horizontal Flow Beds (HFBs), they are still until now the most common type of subsurface flow CWs. HFBs are an interesting option, especially in hybrid system.

In application process, the sewage is fed slowly onto the end of tank through the porous media under gravel surface in a horizontal path at the exit end (Figure 4). The sewage wastewater is kept flooded with the gravel surface lower than 10 cm below the gravel surface. A standpipe is used to control the level of water in the tank. For continuous processes operation, the submerged height of the gravel-sand bed should be lower than one-third of the total height of the gravel-sand bed to avoid anaerobic thresholds (Hoffmann, H., 2011). The oxygen supply plays a significant role in contaminants removal processes.

(ii) VERTICAL FLOW REED BEDs (VFRBs) **–** VFRBs are more appropriate than HFRBs, if there is a space constraint since they have best removal efficiency and, thus, less space required than others.

In application process, domestic sewage is intermittently flow onto the substrate surface, and then passes vertically down through the gravel-sand layer towards to the exit drain (Figure 5). The treatment CWs is characterised by intermittent short-term loading intervals and long hydraulic retention time, during which the domestic sewage flow through the gravel-sand filter and the surface dries out. The intermittent batch loading promotes the oxygen supply through the media and fill the free spaces (Hoffmann, H., 2011).

Conclusions:

The use of RBCWs to remove nutrients and micropollutants from domestic sewage is relatively new application in Malaysia. RBCWs can be successfully used for both secondary and tertiary treatments. This system tends to be more cost-effective than conventional sewage treatment system. Therefore, removal efficiency in CWs is affected by a number of factors, including availability of plants, the season, oxygen levels in a wetland and hydraulic residence time.

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