ENGINEERED WETLANDS FOR WASTEWATER TREATMENT IN SARAWAK: A VIABLE AND SUSTAINABLE SOLUTION

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ABSTRACT

The highly efficient treatment of domestic wastewater is still in its infancy in the state of Sarawak in Malaysia. Most of the wastewater is treated primarily via the individual septic tank (IST), which is a traditional on-site and low level treatment technology. The Urban Stormwater Management Manual, which serves as a guideline for designers in Malaysia and includes recommendations for engineered wetlands is not adhered to in most places in Sarawak. One of the most promising treatment systems for residential areas in Sarawak is the engineered wetland due to its simple construction, operation and maintenance as well as sustainability. Engineered wetlands are environmentally friendly, with high aesthetic and recreational value while being an effective and sustainable means of treatment. A preliminary viability study is presented here to study engineered wetlands as a possible domestic wastewater treatment system in residential areas in Sarawak. From the study, although the operational and maintenance costs of engineered wetlands are lower than electro-mechanical systems, it is higher than ISTs. The land use of engineered wetlands is also larger compared to ISTs. However, engineered wetlands are capable of achieving higher treatment efficiency compared to ISTs, potentially achieving Standard A of the Malaysian Environmental Quality Act 1974. From the survey carried out, 50% of the respondents which include developers are unwilling to pay extra costs for centralized wastewater treatment. Engineered wetlands require larger land area which is costly in urban residential areas. 95% of the respondents feel that it is more urgent to treat stormwater compared to wastewater, since flooding problems are a concern. A total of 77% of the respondents support the concept of engineered wetlands provided the constraints are identified and overcome. To conclude, the engineered wetland is feasible as a wastewater treatment option in Sarawak, with the support of local authorities and various parties.

Keywords: Wastewater treatment; Engineered wetlands; domestic wastewater

INTRODUCTION

Engineered wetlands, which are designed to reproduce wastewater treatment, as to demonstrate the ability of natural wetlands, have been successfully introduced and used to treat waste and stormwater worldwide. Increasing demand on improved receiving water quality, increased loss rates of wetlands around the world and a demand for sustainable development are the driving forces for the implementation of engineered wetlands. As an alternative wastewater treatment solution, in general engineered wetlands require lower technology as well as operational and maintenance costs because they rely on renewable energy sources. In addition, engineered wetlands provide wildlife habitats while enhancing the surrounding with a natural, aesthetically-pleasing view.

Wastewater can be divided into greywater (from sources such as domestic kitchens and bathrooms) and blackwater (from toilet flushes) components. In Sarawak, most greywater and stormwater is discharged directly into the drainage system or receiving body without proper treatment. Treatment of blackwater is mostly by primary treatment via the individual septic tank (IST), which is a traditional on-site and low level treatment technology. This paper presents the viability of engineered wetlands as domestic wastewater treatment in residential housing projects in Sarawak. The benefits or problems and effects of implementing engineered wetlands in the construction project will also be presented.

An engineered wetland is a shallow basin filled with substrate, usually soil or gravel, and planted with vegetation tolerant of saturated conditions, where water is introduced at one end and flows over the surface or through the substrate, and is discharged at the other end through hydraulic structure which controls the depth of the water in the wetland (Davis n.d., p. 17). Wetlands are constructed for one or more of four primary purposes, which include creation of habitat to compensate for natural wetlands converted for agriculture and urban development, water quality improvement, flood control and production of food and fiber (Wetlands International 2003, p. 2). Case studies of two working engineered wetlands in Malaysia, namely Putrajaya Wetland and Kota Kemuning wetland are also briefly presented in this paper.

METHODOLOGY

The viability of engineered wetlands as wastewater and stormwater treatment in residential areas in Sarawak is investigated here via a survey conducted with various engineering consultants, contractors, and local authorities (total of 23 interviewees) from Sarawak. In addition, interviews and site visits are essential tools to gather more relevant information from respective local authorities such as Miri City Council, Department of Irrigation and Drainage (DID), Natural Resources and Environment Board (NREB) and etc. Site visits to Putrajaya and Kota Kemuning wetlands were undertaken as well. The discussion will be focused on areas relevant to the implementation of wetlands as wastewater treatment in the context of residential development in Sarawak such as cost, capacity, land use, efficiency, operation and maintenance, environmental impacts, social impacts, energy and chemical consumption, constructability and practicality of engineered wetlands. All the results gathered are further analyzed, discussed and presented.

CASE STUDIES

Putrajaya Wetlands is one of the largest fully constructed freshwater wetland in the tropics (Perbadanan Putrajaya & Putrajaya Holdings Sdn. Bhd. 1999, p. 34). The primary function of the system is to ensure that the water entering the Putrajaya Lake meets the standard set by Perbadanan Putrajaya, and also in flood mitigation, natural flora and fauna conservation and eco-tourism promotion (Perbadanan Putrajaya, 2006). The construction period of Putrajaya Wetlands was March 1997 to August 1998, involving an area of 197 hectares and 12.3 millions wetland plants (Khor 2002, p. 1). The wetland system comprises of 6 arms with 23 cells, where all the arms eventually discharge to the Central Wetland, which make a total of 24 cells before the treated water flows down into Putrajaya Lake (Perbadanan Putrajaya, 2006). The 24 cells are divided by a series of rock filled weirs which are built on the 6 arms, which have different sizes, depths, plants and pollutant load, although the arms are connected. The multi-cell multi-stage system with flood retention capability is designed to allow colonization of water plants. The plants are used for the interception of pollutants and provide a root zone for bacteria and microorganisms, which are important in filtering and removal of pollutant (Salamat & Sahat

2004, p. 190). The stakeholders who are responsible for the water quality include Malaysian Agricultural Research and Development Institute (MARDI), University Putra Malaysia (UPM), IOI Group Golf course and West Country (a developer), University Tenaga Nasional (UNITEN) and Cyberjaya. Various contractors and consultants are involved in areas such as structure and infrastructure, wetland plants, the bird sanctuary and scientific monitoring such as algae and other biological control. Studies are carried out intensively in order to predict the performance of the engineered wetlands.

Kota Kemuning Wetlands, situated in Selangor, is an 8.8 hectares, long and narrow engineered wetland created from an existing low-lying area. The main purpose of Kota Kemuning Wetlands is to provide a solution for drainage problems in this area by receiving a huge volume of stormwater from its catchment area (Wetland International n.d.). The wetland and rooted vegetation function by filtering pollutants, trapping sediment and up take nutrients while dissipating water velocity before it is discharged into Klang River and prevent flash floods due to backflow from the Klang River during heavy rain (Wetland International n.d.). More than 45% of the Kota Kemuning Township is surrounded by award winning parks and lakes. The Wetland Park forms a natural green space with 22 acre Central Lake, 25 acre park land and 8 km continuous jogging track. Although extra cost for engineered wetland has been invested in Kota Kemuning, the wetland has become an attractive selling point for the housing area.

THE VIABILITY OF ENGINEERED WETLANDS AS WASTEWATER TREATMENT IN SARAWAK

From the study, only 9% of the respondents have been involved in projects relevant to engineered wetlands. This shows that the engineered wetland is a relatively new technique in Sarawak since most of the interviewees do not have any experience in this area. Although the Urban Stormwater Manual for Malaysia (MSMA) guidance is not endorsed in Sarawak (Wee L 2008, pers. comm., 9 January), most respondents think that MSMA should be implemented and practiced for sustainable development and also as preventive measurement against flooding in Sarawak. From the study, 95% of the respondents are willing to implement the MSMA.

Cost, Capacity and Land Use. The construction, operation and maintenance cost of engineered wetlands is higher than ISTs, but lower than that of other electro-mechanical treatment systems. According to Craig & Michael (1999, p.78), the costs of engineered wetland include excavation, liner system, gravel, plants, distribution and control structures, fencing and other components. The capacities of engineered wetlands are dependent on the population designed. Naturally, a large flow will require a large wetland. For stormwater treatment, a minimum detention time of 24 hours must be fulfilled according to MSMA. The land use of engineered wetlands is larger compared to that of ISTs. Therefore, engineered wetlands require larger land area, which is expensive in urban areas in Sarawak. A total of 50% of the respondents, comprising various stakeholders in property development and the construction industry have stated that they are unwilling to pay extra costs for the implementation of engineered wetlands as waste and stormwater treatment systems, 23% of the respondents are willing to pay the cost while 27% stated no response to the hypothetical situation (Figure 1). From the interviews, it seems that this situation may be caused by lack of awareness of sustainability and environment-consciousness among the respondents.

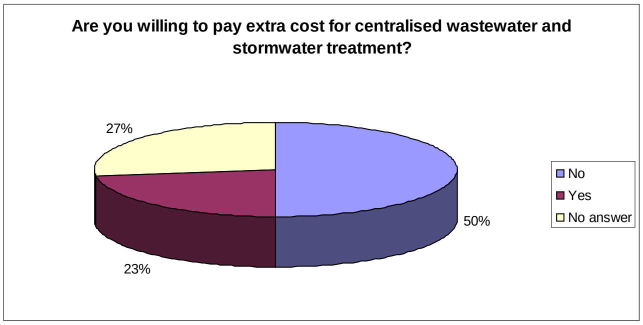

Figure 1: Chart of respondents' willingness to pay extra costs

Operation and Maintenance. Periodic operation and maintenance have to be carried out for engineered wetlands. This includes landscaping and cleaning. The only maintenance work for ISTS is desludging once every 4 years for residential units (Tan, 2006).

Efficiency. Engineered wetlands can achieve Standard A of Environmental Quality Act 1974, which is better than that of septic tanks. Removal of pollutants in engineered wetland is based on a combination of physical biological and chemical processes, which can be expected to achieve 50-90% removal of BOD5, 50-95% of SS, 20-90% removal of total phosphorous and 30-98% removal of nitrogen, all depending on methodology, design and operation (Larsen & Lynghus 2004, p. 40). ISTs are only capable of primary treatment at best. According to Polprasert & Rong (n.d., p.137), engineered wetlands should perform better than natural wetlands of equal area since the bottom is usually graded and the hydraulic regime in the system is controlled. At the same time, the process' reliability is also improved because the vegetation and other system components can be managed according to design requirements.

Energy and Chemical Consumption. Engineered wetlands are usually constructed at low-lying areas to allow gravity flow and do not need electricity to operate. Other hydraulic structures such as weirs may be designed to control the flow of wastewater in the engineered wetlands. Pumps may be needed in centralized wastewater treatment systems in the flat residential areas in Miri, hence electricity has to be taken into consideration. Engineered wetlands generally do not need chemicals to operate.

Environmental and Social Impacts. Engineered wetlands are environmentally friendly waste and stormwater treatment systems, conserving more green spaces, preventing wetland losses and creating a sustainable ecosystem to the residential areas, which add aesthetic and recreational values. However, due to lack of exposure and environment-consciousness local residents may view wastewater treatment and engineered wetlands as undesirable.

Constructability. From the survey, 68% of the respondents think that engineered wetlands are constructible provided the engineering drawings, bill of quantities and specifications are all prepared and reviewed. The remaining 32% of the respondents remain undecided (Figure 2). This uncertainty may be due to lack of prior experience in relevant projects. However, none of the respondents think that engineered wetlands are not constructible. Up to 59% of the respondents think that the construction of engineered wetlands will not cause delays in the overall scheme of the construction project, 9% think that it will cause delays while the remaining

32% are unsure (Figure 3). Delays are possible when land issues, geotechnical and environmental problems occur (Tang K Y 2008, pers. comm., 13 February). Besides, landscaping and time allowance for the plants to mature might cause some delay (Wong T P 2008, pers. comm., 15 February).

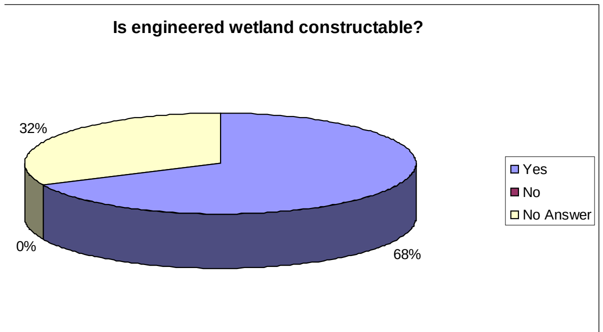

Figure 2: Chart of Perceived Constructability of Engineered Wetlands

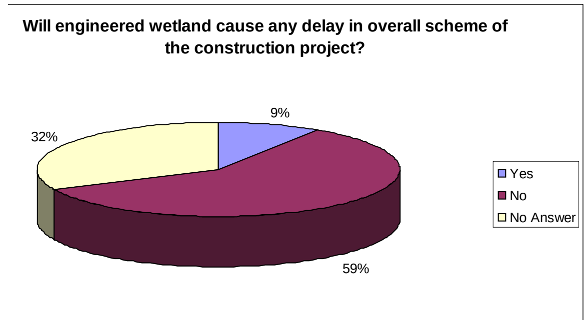

Figure 3: Chart of Perceived Delay in Overall Scheme of the Construction Project

Pacticality. From the survey, 36% of the respondents think that it is practical to implement engineered wetland for waste and stormwater treatments, 32% disagree, while 32% are uncertain (Figure 4). This survey result shows the respondents' lack of knowledge in the field of engineered wetlands which is relatively new in Malaysia. The uncertainty may be due to lack of prior experience. In general, the local public and authorities pay more attention on stormwater treatment in order to mitigate flash floods in low-lying areas. For instance, Department of Irrigation and Drainage (DID) emphasizes quality control for stormwater, by the means of storing the stormwater and discharging it in a controlled manner to attenuate flooding (Harim W 2008, pers. comm., 15 February). However, both the wastewater and stormwater are not treated in the residential areas in Miri. A total of 95% respondents (Figure 5) think that it is more urgent to treat stormwater compared to wastewater, since flash floods are a common occurrence in many areas in Malaysia.

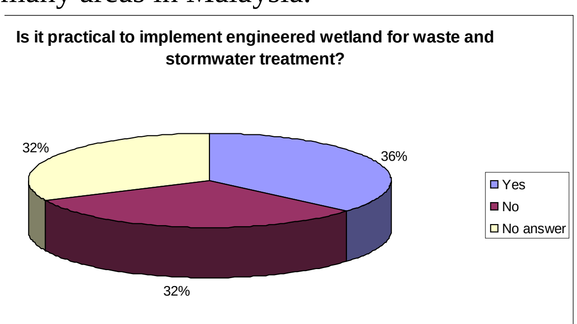

Fig. 4: Chart of Perceived Practicality of Engineered Wetland

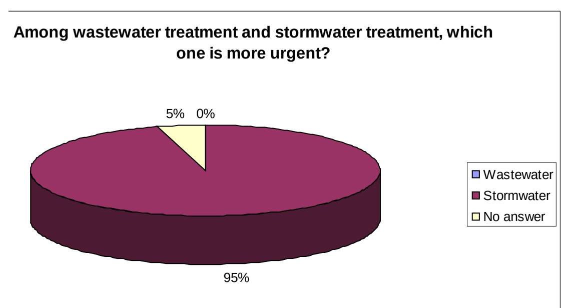

Fig. 5: Chart of Perceived Urgency to Treat Stormwater or Wastewater

A total of 77% of the respondents view engineered wetlands as feasible storm and wastewater treatment systems, 5% do not agree and the remaining 18% are indecisive (Figure 6). To implement engineered wetlands, its viability and constraints need to be identified, while environmental concern is crucial for sustainability (Tan K J 2008, pers. comm., 18 February).

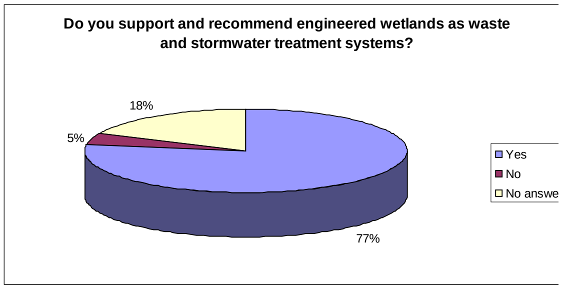

Figure 6: Chart of Respondents' Views of Engineered Wetlands as a Wastewater and Stormwater Treatment System

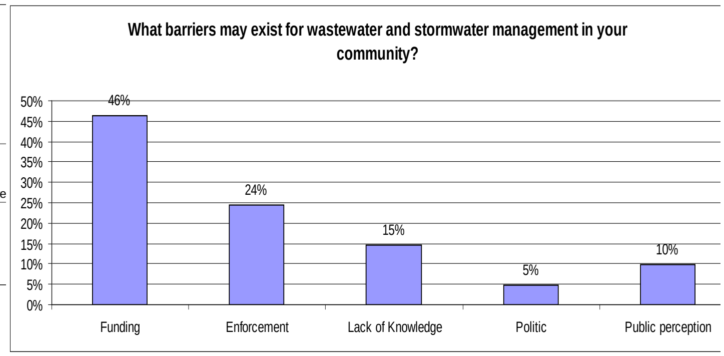

Fig. 7: Perceived Barriers towards Implementation of Engineered Wetland

Respondents were also asked to provide perceived barriers in implementing centralised waste and stormwater management (Figure 7). Funding (46%), enforcement (24%) and lack of knowledge (15%) regarding engineered wetland are the three most significant barriers to implement engineered wetlands. From the interviews, it seems that these barriers may be directly or indirectly linked to government or local authorities' policies and practices. The less prominent barriers appear to be limited by politics (5%) and public perception (10%).

STEPS TOWARDS IMPLEMENTATION OF ENGINEERED WETLANDS

In a study of stormwater management, Lariyah et al. (2004, p. 490) states that the government should appropriate the construction cost of infiltration facilities in its budget to provide subsidy for local authorities to actively encourage the construction of such facilities. Local authorities can install such facilities for the public with the subsidy and also offer subsidy to the residents who install the facilities. Similarly for wastewater treatment, such subsidies can motivate and encourage the relevant stakeholders and accelerate the acceptance of engineered wetlands in Malaysia.

Evaluation based on financial consideration in terms of capital and operation and maintenance cost is subjected to net present value analysis based upon a discount rate that is reflective of the present market rate for borrowing of funds (Ministry of Housing and Local Government Sewerage Services Department 2000, p. 116). First stage costs represent a realistic investment to meet predictable capacity requirements over the short term. Hence, it is important to evaluate the first stage capital cost expenditures.

Evaluation based on technical consideration should be based on reliability, adaptability and acceptability regarding issues such as effects of construction and operations (Ministry of Housing and Local Government Sewerage Services Department 2000, p. 118). Reliability is the overall probability of failure of engineered wetlands due to problems with vegetation, structural or mechanical failure of components, unavailability of spare parts, operational faults and errors and etc. Adaptability refers to the flexibility of the treatment system to cope with increasing or decreasing capacities. A multistage implementation of facilities should be more adaptable. Oversized facilities may be more difficult to maintain and operate could impose high costs. Acceptability is the public acceptance of the engineered wetlands treatment system, which includes the disposal of effluents. The general public's perception is that wastewater should not seen out in the open.

Evaluation based on environmental consideration should be include important environmental issues such as water, influent and effluent quality, aesthetics as affected by sewage pumping and treatment facilities, and by effluent disposal.

Issues regarding engineered wetlands as wastewater treatment need deliberation and assessment of impacts such as reliability in meeting the effluent standards, ease of construction without disrupting the surrounding areas adversely, siting compatibility, and noise, odour, water quality and visual impacts during the operation. Once engineered wetlands are selected as the preferred wastewater treatment option, the financial and non-financial factors should be examined in more detail to identify possible problems and optimize the option. Improvements can be made by staging the work (immediate works, short term works and long term works), integration of the work with anticipated changes in regulation such as the changes of effluent quality or sludge characteristics, and details of methods of processes to be used to rehabilitate sewers or to upgrade the engineered wetlands. Local or other tropical case studies of engineered wetlands as wastewater and stormwater treatment should be made as main references in order to implement engineered wetlands in residential areas in Sarawak. Case studies provide useful design criteria, design components, treatment performance results and other information such as costs and land use. A more comprehensive viability study of engineered wetlands as wastewater and stormwater treatment systems can be carried out.

Education and exposure to wetlands are important for the public, especially for the younger generation, in order to increase understanding of the sustainable and environmentally - friendly treatment system. From the survey conducted, engineered wetlands as wastewater and stormwater treatment are mostly recommended and supported by the interviewees. However, public acceptance of engineered wetlands in Sarawak is low due to the lack of understanding about the potential benefits of engineered wetlands. Putrajaya and Kota Kemuning wetlands allow the public to embrace nature and appreciate the associated treatment features.

CONCLUSIONS

Engineered wetlands are viable as a sustainable wastewater and stormwater treatment option in residential areas in Sarawak, with the support of local authorities and developers. Being simple in installation and operation, engineered wetlands seem to be a cost-effective alternative to the conventional treatment. Compared to ISTs, the construction, operational and maintenance costs of engineered wetlands are higher, but lower than electro-mechanical treatment systems. A larger land area is required for engineered wetlands compared to ISTs and compact electro-mechanical treatment systems. However, engineered wetlands are capable of achieving Standard A of the Malaysian Environmental Quality Act 1974, which show higher efficiency compared to ISTs. Case studies including Putrajaya and Kota Kemuning wetlands are essential supporting evidences to prove that engineered wetlands are viable as wastewater and stormwater treatments.

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