International Journal of the Malay World and Civilisation (Iman) 4(Special Issue 1), 2016: 21 - 28
(http://dx.doi.org/10.17576/IMAN-2016-04SI1-03)

Constructed Wetland for Wastewater Treatment: A Case Study at Frangipani Resort, Langkawi

Pembinaan Wetland untuk Rawatan Air Sisa: Satu Kajian Kes di Frangipani Resort, Langkawi

Mohd Shafiq Asnawi Md. Akhir, Ahmad Aldrie Amir, Mazlin Mokhtar & Anthony Wong Kim Hooi

ABSTRACT

Wetland is a shallow watery area that has slow movement or static hydrology. It usually consists of floating and submerged plants with high level of biodiversity and plays a role in treating water of lakes and rivers. Constructed wetland, on the other hand is a man-made system that imitates the natural wetland in the aspects of structure and function. Some facilities like hotels, resorts and housing areas have taken initiatives to manipulate this ability and build their own constructed wetlands to treat sewage water. For facilities like hotels, a sewage treatment system with low technology, low energy requirements, affordable and easy to maintain is a crucial need. Therefore, it is proposed that constructed wetland is an efficient solution. Frangipani Resort & Spa in Langkawi Geopark is one of the hotels in Malaysia that advanced this eco-technology into their facility since 2009. By having this, enormous benefits are gained especially in the investment of hotel's financial capital in cutting cost of sewage maintenance and water usage. Plus, the system itself would indirectly help to ensure more sustainable wastewater and water resource management when the treated wastewater is reused. Although there are a lot of studies on constructed wetlands that are used to treat wastewaters from municipal, industrial and agricultural areas, there is insufficient study that link constructed wetland and wastewaters from lodging industry. Therefore, this proposed study will focus on (i) how efficient a decent and functional constructed wetland built within a resort can help reduce the maintenance cost, energy usage and pollution from untreated wastewater; and (ii) how significant can the system be to create a resort with sustainable wastewater management which ultimately can be replicated in an urban setting to reduce the stress of wastewater treatment.

Keywords: *Wetland; wastewater treatment; Langkawi*

ABSTRAK

Wetland merupakan kawasan cetek berair yang mempunyai pergerakan air perlahan atau hidrologi statik. Ia biasanya terdiri daripada tumbuhan terapung dan tenggelam dengan tahap biodiversiti yang tinggi dan memainkan peranan dalam merawat air tasik dan sungai. Pembinaan Wetland adalah satu sistem buatan manusia yang meniru tanah lembap semula jadi daripada aspek struktur dan fungsi. Sesetengah kemudahan seperti hotel, pusat peranginan dan kawasan perumahan telah mengambil inisiatif untuk memanipulasi keupayaan ini dan membina wetland mereka sendiri untuk merawat air kumbahan. Untuk kemudahan seperti hotel, sistem rawatan kumbahan dengan teknologi yang rendah, keperluan tenaga yang rendah, murah dan mudah penting untuk mengekalkan keperluannya. Oleh itu, adalah dicadangkan pembinaan tanah lembap dibina adalah penyelesaian yang betul. Frangipani Resort & Spa di Langkawi Geopark adalah salah satu hotel di Malaysia yang menggunakan eko-teknologi ini ke dalam kemudahan mereka sejak tahun 2009. Dengan adanya ini, manfaat besar yang diperoleh terutamanya dalam pelaburan modal kewangan hotel dalam pemotongan kos penyelenggaraan kumbahan dan penggunaan air. Tambahan pula, sistem itu sendiri secara tidak langsung akan membantu untuk memastikan air sisa dan pengurusan sumber air yang lebih mapan apabila air sisa yang dirawat digunakan semula. Walaupun terdapat banyak kajian mengenai pembinaan wetland yang digunakan untuk merawat air buangan daripada kawasan perbandaran, perindustrian dan pertanian, kajian yang masih tidak mencukupi yang menghubungkan kaitan pembinaan di kawasan tanah lembap dan air buangan dari industri penginapan. Oleh itu, kajian yang dicadangkan ini akan memberi tumpuan kepada (i) bagaimana kecekapan tanah lembap yang baik dan berfungsi dibina di dalam resort yang boleh membantu mengurangkan kos penyelenggaraan, penggunaan tenaga dan pencemaran daripada air sisa yang tidak dirawat; dan (ii) bagaimana penting sistem boleh untuk mewujudkan sebuah resort dengan pengurusan air sisa mapan yang akhirnya boleh ditiru dalam persekitaran bandar untuk mengurangkan tekanan rawatan air sisa.

Kata kunci: *Wetland; rawatan air sisa; Langkawi*

INTRODUCTION

Hotels, motels, serviced apartments and hostels provide great services to people on business or holidays. Traditionally, the industry generates high water, energy and waste bills to provide a quality service (City of Melbourne 2007). In this case, hotels and resorts are among others that actively introduce their waste into their surroundings and possess water disposal issues worldwide. Lodging industry in Malaysia, like most of the developing countries, is facing an increase of the generation of waste and of accompanying problems with the disposal of this waste. No government's regulation for hotel's wastewater might be the strong reason behind this. The wastewater from the hotels and resorts usually disposed with little or no treatment. Most hotel owners had their hotels installed with septic tank. Septic tanks usually installed underground and the wastewater is only partially treated by infiltrating into the ground. Some other hotels have taken initiatives to install conventional wastewater treatment system just to maintain the water quality of their premises.

However the application of conventional system causes more harm than good. The method of treatment of this system may be highly effective but it also involves too much unnecessary expense. Conventional water treatment system may require more financial investment to be constructed and high energy consumption during operation which can lead to more financial wastage. The equipment are mainly high-tech machineries will also need frequent technical supervision and maintenance. As a hotel or resort owner, they surely want to avoid having these problems within their facilities.

This is where; the use of ecological based approach plays an important role. One of the most effective methods of this approach is constructed wetlands. Apart from solving the disadvantages of conventional methods, this new eco-technology may also help to recycle the wastewater while conserving the environment at the same time.

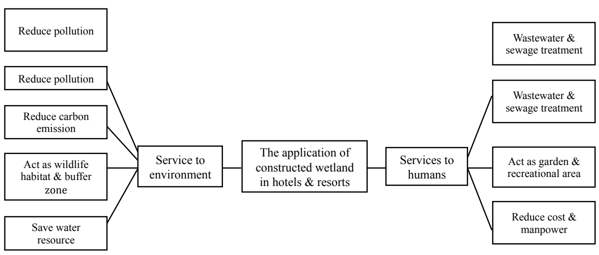

FIGURE 1. The two-way action of constructed wetland built in resorts & hotels area

Frangipani Resort and Spa in Langkawi Geopark is the first resort in Malaysia to use the constructed wetland technology for wastewater treatment. After several years of application and operation, this system has proven its ability to treat the wastewater from the resort including surface runoffs, drains from kitchens and bathrooms and sewage to the acceptable quality which they can reuse it to save the potable water. The significance and the level of efficiency of the system at Frangipani is the main priority in this paper which the knowledge can be used to create more hotels that practice sustainable wastewater management.

NUTRIENTS AND WASTEWATER RECYCLING SYSTEM AT FRANGIPANI RESORT

Frangipani Resort practices the close loop system since 2009 when the owner finally successful to build a constructed wetland with integration of six species of floating and submerging plant to treat the wastewater. The system is the first of its kind to be built in Malaysia. Figure 1 illustrates the system and its major components. Frangipani's constructed wetland was based on surface flow wetland design. This type of wetland imitates the natural wetland and usually has shallow water that flow through various species of plants in the treatment process (Kaldec & Knight 1996). The system built without roof. The crucial part is the hydraulics of the wastewater during treatment which they decided to make intervals for each water channels so that the wastewater can be treated equally and prolong the time of water settlement for each levels of treatment. The size is approximately 0.585 acres (2.369 m^2) with maximum depth of 1.2 meters to 1.7 meters depending on the season. On rainy seasons, the ponds will be flooded and the hydraulics becomes much faster than the dry season.

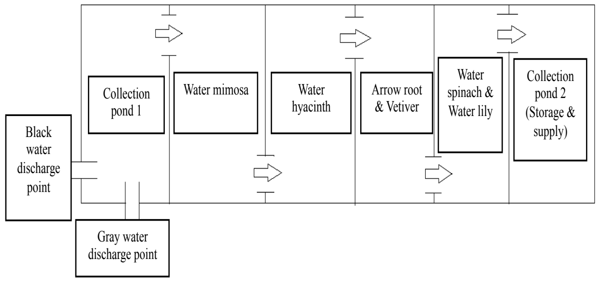

FIGURE 2. Design of Frangipani surface flow constructed wetland

The system began with collection of wastewater in the collection pond. The black water is generated from the sewage that undergone the primary treatment in the septic tanks to separate the water from the sludge. On the other hands, the gray water from kitchen, laundry and bath drains was filtered with net to separate the water from rubbish and solids. The oil and grease trap were installed in the kitchen system to separate the wastewater from grease. Both gray water and black water were pumped into the collection pond using electric pump that is equipped with timer with time interval of 30 minutes. After that they were channeled through the series of plants for secondary treatment and being collected again for storage and supply. The idea is to let the plant taking up nutrients that are essentials for their growth from the polluted water and the water will be cleaned up during the process. No further tertiary treatment using UV light had taken place as the water quality analysis for 4 years (2009-2013) is within the range of quality A and B for Malaysian Department of Environmental standard. The treated wastewater is used to do simple activity especially agricultural irrigation and fish rearing and restricted for drinking.

The uses of different species of plants were actually based on the previous laboratories and field studies that proven their effectiveness in removing chemicals and nutrients from the wastewater. According to Sooknah &Wilkie (2004), most aquatic vegetation is very effective to reduce the level of BOD, COD and nutrients in the wastewater. Frangipani used six species of emergent and floating plants to treat the wastewater. Table 1 shows the species of plants that are used in Frangipani wetland. All of them are weeds and can be easily found in the rivers and lakes in Malaysia. They were arranged based on their function and efficiency rate to remove nutrients and pollution from the wastewater.

TABLE 2. Type of plants used in Frangipani's constructed wetland and their function based on previous study

Plants	Function	Reference
Neptuniaoleracea (Water mimosa)	Helps to reduce total nitrogen & total phosphorus. Absorb organic compound and suspended solids.	Suppadit et al. (2005)
Eichorniacrassipes (Water hyacinth)	Helps to reduce suspended solid, heavy metals, BOD level, nitrogen, phosphorus and pathogen.	Jayaweera et al. (2008) Nesir (2010)
Thaliageniculata (Arrowroot)	Helps to absorb metals like ferum, copper, plumbum and zinc.	Korsah (2011)
Chrysopogonzizanioides (Vetiver)	Helps to absorb nutrients like nitrogen and phosphorus.	Zheng et al. (1997) Wagner et al. (2003)
Ipomoea aquatica (Water spinach)	Helps to absorb nutrients. Prevent algal growth.	Li & Li (2009)
	Helps to reduce BOD and COD level.	Said et al. (1997)
Nymphaeacaerulea (Water lily)	Helps to reduce pH, BOD and COD level.	Muda (2010)

APPROPRIATE WASTEWATER TREATMENT APPROACHES FOR HOTELS AND RESORTS AREA IN DEVELOPING COUNTRIES

The increase in human population has led to advances in urbanization. Urbanization involves the development of facilities and infrastructure standpoint to improve the people's daily lives. Apart from industrial activities, hotels and resorts are also included as one of the examples that facilitate the development of humankind. Therefore, the treatment of waste produced by these facilities is just as central to the challenge of wastewater treatment from other facilities. Sewage treatment should do more than just to prevent pollution and degradation of the natural environment, at least by ensuring a systematic nutrient cycle and water cycle back for productive use. Speaking of that, ecological-based solution like constructed wetland is the key element to maintain the sustainability of water and wastewater management.

The main idea of Frangipani constructed wetland came from the co-author of this article (AW). After several trial and errors, he finally perfected the system with some helps from local universities. As for the beginning, constructed wetlands need to have special features like low technology and use less energy to make it cost effective and easy to maintain (Cooper et al. 1996). Thus, it can be said that, in order to save the financial capital when building a constructed wetland in a particular area, level of technology and energy requirement need to be carefully considered. Natural wetland uses solar as a main source of energy for regulation of its cycle, and so does the constructed wetland. On top of that, warmer climate will helps to improve treatment rates (Kaldec & Knight 1996). Therefore, such system has a very huge potential in tropical and warm region like Malaysia.

Land requirement is also a matter when building a constructed wetland. Sub-surface flow wetland can be said to be more space effective due to the design that includes gravel media on top of the flowing wastewater compared to surface flow wetland. Although this design holds a record of more intense treatment based on previous study, but because it requires permeable line and gravel media, it is also more expensive to be built (Green & Upton 1992; Steiner et al. 1992; Cooper 1992). In the case of lodging industry, a surface flow wetland may be cheaper, but it also possesses disadvantage for the land requirement.

Constructed wetland, on the other hand can also act as habitat for animals and plants, which can increase the level of diversity within the ecosystem and indirectly increase the buffering capacity of the wetland (Mitsch & Jorgensen 1991). Constructed wetland may benefit from this condition, as the natural increase of biodiversity will allow self -organization of the plants, which can create well-adapted ecosystem to handle pollutions from the wastewater (Odum 1991).

Behind all the advantages and limitations, a well-designed constructed wetland is still can provide inexpensive but highly effective wastewater and sewage treatment. The main advantage of constructed wetlands to the lodging industry is they rely on more natural methods, cheaper in construction and operation cost and can be built at the smaller area with smaller community compared to conventional wastewater treatment plant (Cooper et al. 1996). They can treat more than one type of pollution and produce results that are slightly similar to the advance treatment standard (Reed et al. 1995; Mansor & Lim 2002). Constructed wetland uses little or no electricity and does not need much supervision and maintenance once installed. Compared to that, a conventional treatment plant usually need frequent technical supervision, higher maintenance, more capital investment and uses more energy to operate at optimal condition.

LOADING OF WASTEWATER AND REMOVAL EFFICIENCY OF FRANGIPANI CONSTRUCTED WETLAND

Frangipani's wetland water is always monitored with the help of local universities and private laboratory to ensure the water quality is acceptable under Malaysian standards. The owner had taken initiative to record the water quality data of the system twice which are on January and July of every year. Soon as they finished perfecting the system, they begin to take the data starting from 2009 until now. Results received to date are promising but leave some questions and arguments as to the accuracy of the methods used. Moreover, there were some limitations to the wetland that may affect the overall water quality data.

TABLE 3. Water and wastewater quality standard guideline produced by Department of Environment, Malaysia

Parameter	Unit	DOE Standard A	DOE Standard B
Temperature	^oC	40	40
pH	-	6.0-9.0	5.5-9.0
BOD	mg/L	20	50
COD	mg/L	50	100
Suspended solid	mg/L	50	100
Mercury	mg/L	0.005	0.005
Cadmium	mg/L	0.01	0.02
Arsenic	mg/L	0.05	0.10
Cyanide	mg/L	0.05	0.10
Lead	mg/L	0.10	0.5

Copper	mg/L	0.2	1.0
Manganese	mg/L	0.2	1.0
Nickel	mg/L	0.2	1.0
Tin	mg/L	0.2	1.0
Zinc	mg/L	1.0	1.0
Boron	mg/L	1.0	4.0
Iron	mg/L	1.0	5.0
Phenol	mg/L	0.001	1.0
Sulphide	mg/L	0.5	0.5
Oil and Grease	mg/L	-	10.0

TABLE 4. Average pH of Frangipani constructed wetland from 2009 until 2013

pH	Station 1	Station 2	Station 3	Station 4
2009	6.56	6.66	6.7	6.77
2010	6.53	6.61	6.6	6.6
2011	6.27	6.72	6.81	6.75
2012	6.3	6.3	6.4	6.4
2013	6.5	6	6.4	6.4
Average	6.432	6.458	6.582	6.584

TABLE 5. Average BOD of Frangipani constructed wetland from 2009 until 2013

BOD (mg/L)	Station 1	Station 2	Station 3	Station 4
2009	13	14	13.4	14.5
2010	18.5	15.2	12	18.2
2011	43.5	25.8	20.3	15.8
2012	48	39	8	10.5
2013	42	40	40	20
Average	33	26.8	18.74	15.8

TABLE 6. Average COD of Frangipani constructed wetland from 2009 until 2013

COD (mg/L)	Station 1	Station 2	Station 3	Station 4
2009	51	50	48	45
2010	41.2	39.4	33.6	36.3
2011	173	93	81.4	63.3
2012	156.7	37.2	46.5	40
2013	147.5	141.6	138.7	130
Average	113.88	72.24	69.64	62.92

Testing showed that the pH of water in Frangipani constructed wetland is within the promising range. Subsequent testing on BOD shows an average of 52% reduction and falls within the range for standard A at the end of the process. COD testing also showed reduction fallen to 45%. In initial years of operation, COD results turned out to be within the range for standard A. However, several years later the results are not so good maybe due to poor maintenance. Recent visit showed that the vegetation were not properly harvested, changed and pruned that may cause the system to be less effective than the initial years. It is also suspected that the design of the system itself, with short distance to the discharge pipes, which cause the water, was not properly treated before reaching the final sampling point.

TABLE 7. Average suspended solids of Frangipani constructed wetland from 2009 until 2013

TSS (mg/L)	Station 1	Station 2	Station 3	Station 4
2009	20	34	28	30
2010	23	53	28	36
2011	17	11	25	27
2012	35	27	26	26
2013	78	31	31	27
Average	34.6	31.2	27.6	29.2

TABLE 8. Average nitrogen of Frangipani constructed wetland from 2009 until 2013

TN (mg/L)	Station 1	Station 2	Station 3	Station 4
2009	-	-	-	-
2010	0.9	0.5	0.1	0.1
2011	0.57	0.02	0.02	0.47
2012	0.02	0.02	0.02	0.02
2013	0.25	0.02	0.05	0.15
Average	0.435	0.14	0.0475	0.185

TABLE 9. Average phosphorus of Frangipani constructed wetland from 2009 until 2013

TP (mg/L)	Station 1	Station 2	Station 3	Station 4
2009	-	-	-	-
2010	1.6	2.2	1.5	1.2
2011	7.2	5.4	2	1.4
2012	2	1	1	1.6
2013	4	1.8	1	1.9
Average	3.7	2.6	1.375	1.525

The average of suspended solid in table 7 also falls within the range of standard A with reduction of 15%. The initial loading of suspended solid is quite low for all the data maybe because of the sludge and solid trap installed in the collection pond at the beginning of the treatment process. Nutrient reduction had declined as well with 57% removal of total nitrogen and 58% removal of total phosphorus. Here, the most basic and main function of all types of plants used can be observed. Although there were no data yet about nutrient uptake by those plants, it may be easy to say that those plants get their needs by removing nutrients from the water.

SUGGESTIONS FOR DESIGN EVOLUTION AND METHOD USED

There were several limitations in the design and methods at the Frangipani constructed wetland. Some suggestions for more effective wastewater treatment:

1. Maintenance and service guideline have to be upgraded and emphasized on the operation especially filter replacement, plant harvesting and pruning, water hydraulics and cleanliness of the whole wetland area. Maintenance workers also need to undergo training and given instruction about the importance of every steps in the guideline to ensure the system to function effectively.
2. The wetland will need to be covered at least to prevent storm water or surface runoff to enter the wetland from different point and cause inconsistencies of the data and the water quality, as it will be reused. In this case, a plastic cover that is similar to the one at the green house would be suitable. There is also a need to cover the pool with net to prevent mosquito breeding that will cause serious health problems to the guests later.
3. Aeration is important as it can help to lower nitrogen loading and oxygen demand of the wastewater. To achieve this, pumps need to be installed to increase oxygen uptake before it enters the collection pond. The disadvantage of this method is it may require the use of electrical pump that can increase cost of electrical usage.

Therefore, for more intense treatment, a vertical flow wetland design may results in better aeration and lowers the nitrogen and oxygen demand of the wastewater without having to put more use on electrical pump.

4. Data collection to monitor the performance of the wetland will have to be analyse frequently. In this case, a monthly reading is sufficient to observe the trend of the data considering the high cost to analyze water samples at private laboratories. Since the wetland relying more on natural methods, monitoring is compulsory to ensure its long lasting capability.
5. The use of weed species as treatment media is practical yet risky to the surrounding environment. Some of the weeds like *Eichorniacrassipes* (Water hyacinth) were known for their extremely tough survival characteristics and invading features. They can grow fast and cause problems to the surrounding vegetation and overall function of the wetland itself like pipe clogging if not properly controlled. There were studies about the effectiveness of these weed species to remove pollutions from any kind of wastewater but very little had mentioned about the after effects of the weeds to the environment and daily lives. Therefore, it is suggested here that these weed species are replaced with typical native wetland species that has the same pollution removal efficiency so that no environmental and physical problems occur at the surrounding area.
6. The goal of having constructed wetland in one's facility must be set to not only have high level of pollution removal and producing treated wastewater with and good water quality results, but also concentrate on how far is the treated wastewater can be recycled so that it can be used on more activities. Further researches have to be done to produce treated wastewater that can reach that level so less dependency for the tap water can be achieved.

CONCLUSION

Constructed wetland could be an opportunity and effective solution for hotels and resorts in urban setting to save their financial investment and help to conserve the environment at the same time. This new ecological based approach might be low in technology but it has proven its ability to treat wastewater up to the same level as the conventional system. On top of that, by having this eco-technology, it offers some new important alternatives that can help to solve one of the biggest 21st century urbanization problems, the sustainability of wastewater management. We cannot afford to throw away the wastewater after realizing that this resource can be recycled to save our potable water from overuse. Nevertheless, there are still much more to do before the wastewater can truly reach that level and this will be the challenge for the scientists to answer.

REFERENCE

City of Melbourne. 2007. *Water Wise Hotels Toolkit March 2007*. Melbourne: Melbourne City Council.

Cooper, P.F. 1992. The Use of Reed Bed Systems to Treat Domestic Sewage: The present Situation in the United Kingdom. In *Constructed Wetlands for Water Quality Improvement*, edited by Moshiri, G.A. Boca Raton: Lewis Publishers.

Cooper, P.F., Job, G.D. and Schutes, R.B.E. 1996. *Reed Beds and Constructed Wetlands for Wastewater Treatment.* United Kingdom: WRcSwindon.

Green, M.B. and Upton, J. 1992. Reed bed treatment for small communities: U.K. Experience. In *Constructed Wetlands for Water Quality Improvement*, edited by Moshiri, G.A. Boca Raton: Lewis Publishers.

Jayaweera, M.W., Kasturiarachchi, J.C., Kularatne, R.K. & Wijeyekoon, S.L. 2008. Contribution of water hyacinth (*eichorniacrassipes*) grown under different nutrient conditions to fe-removal mechanisms in constructed wetlands. *Journal of Environment Management* 87(3): 450-460.

Kaldec, R. and Knight R. 1996. *Treatment Wetlands.* Boca Raton: Lewis Publishers.CRC Press.

Korsah, P.E. 2011. Phytoremediation of irrigation water using *Lymnocharisflava*, *Typhalatifolia* and *Thaliageniculata* in constructed wetland. Masters Thesis. Kwame Nkrumah University of Science and Technology.

Li, W. & Li, Z. 2009. In situ nutrient removal from aquaculture wastewater by aquatic vegetable *Ipomoeaaquatica* on floating beds. *Water Science & Technology* 59(10):1937-1943.

Mansor, M. and Lim, P.E. 2002. *Constructed Wetlands: Design, Management and Education*. Pulau Pinang: Penerbit Universiti Sains Malaysia.

Mitsch, W.J. and Jorgensen, S. 1991. *Ecological Engineering: An Introduction to Ecotechnology.* New York: Wiley & Sons.

Muda, S.A. 2010. Effects of *Nymphaeacaerulea* on wastewater quality from palm oil production. Bachelor Thesis. Universiti Malaysia Pahang.

Nesir, N. 2010. Potential Use of Water Hyacinth (*Eichorniacrassipes*) for Wastewater

Odum, H.T. 1991. Ecological engineering and self-organization. In *Ecological Engineering: An Introduction to Ecotechnology*, edited by Mitsch, W. J. and Jorgensen, S. New York: Wiley & Sons.

Reed, S.C., Crites, R.W. and E.J. Middlebrooks. 1995. *Natural Systems for Waste Management and Treatment*. 2nd edition. New York: McGraw-Hill.

Said, M.M.I., Hashim, N., Aziz, A.F. & Miskam, L.H. 1997. Comparison of domestic wastewater treatment using water hyacinth (*Eichorniacrassipes*) and water convolvulus (*Ipomoea aquatica*). *Jurnal Kejuruteraan Awam* 10(1): 21-25.

Sooknah, R.D. & Wilkie, A.C. 2004. Nutrient removal by floating aquatic macrophytes cultured in anaerobically digested flushed dairy manure wastewater. *Ecosystem Engineering* 22: 27–42.

Steiner, G.R., Watson, J.T. and Choate, K.D. 1992. General design, construction and operation guidelines for small constructed wetlands wastewater treatment systems. In *Constructed Wetlands for Water Quality Improvement*, edited by Moshiri, G.A. Boca Raton: Lewis Publishers.

Suppadit, T., Phoochinda, W., & Bunsirichai, P. 2005. Treatment of effluent from shrimp farm by using water mimosa *(NeptuniaoleraceaLour*). *J. ISSAAS* 11(2): 1-11

Treatment in Serbia. Retrieved on: 13 April 2013 www.balwois.com/balwois/administration/full-paper/ffp-623.pdf.

Wagner, S., Truong, P. Vieritz, A & Smeal, C. 2003 Response of vetiver grass to extreme nitrogen and phosphorus supply. Proceeding of the 3rd International Vetiver Conference, Guangzhou, China. October 2003.

Zheng, C., Tu, C., & Chen, H. 1997. Preliminary study on purification of eutrophic water with vetiver. Proceedings of International Vetiver Workshop, Fuzhou, China. 21-26 Oct 1997.

Mohd Shafiq Asnawi Md. Akhir
Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia,
43600 UKM, Bangi,
Selangor Darul Ehsan, Malaysia.

Ahmad Aldrie Amir
Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia,
43600 UKM, Bangi,
Selangor Darul Ehsan, Malaysia.
E-mail: aldrie@ukm.edu.my

Mazlin Mokhtar
Institute for Environment and Development (LESTARI)
Universiti Kebangsaan Malaysia,
43600 UKM, Bangi,
Selangor Darul Ehsan, Malaysia.
E-mail: mazlin@ukm.edu.my

Anthony Wong Kim H
Frangipani Resort & Spa,
Jalan Pantai Tengah, Pantai Tengah,
07100 Langkawi,
Kedah Darul Aman, Malaysia.
E-mail: rsvn@frangipanilangkawi.com

Received: 05 June 2015
Accepted: 21 September 2015