AN APPROACH FOR SMALL COMMUNITY WASTEWATER MANAGEMENT USING CONSTRUCTED WETLANDS

Sasitharan R., Weerakoon G. M. P. R, Jinadasa K. B. S. N., Mowjood M.I.M.
University of Peradeniya

ABSTRACT**:** Natural streams in developing countries are frequently vulnerable to potential health hazardous exceeding ambient water quality standards due to contamination by human excreta and other pollutants. Improper excreta disposal methods are commonly due to lack of awareness of the importance of good sanitation practices and personnel hygiene and traditional habits. This is noted specially among low income and less educated groups of people.

The present study was carried out in a tea estate community in the Melfort Estate, Pusselawa, Sri Lanka to identify the causes of pollution in a contaminated drainage stream which runs through a cluster of line houses and to seek possible remedial measures using constructed wetland systems. As the first step of this study, a questionnaire survey was conducted in the selected catchment to identify the possible causes for human excreta pollution of the stream. Second, water quality examinations were carried out to quantify the pollution level of the selected stream. Following this the applicability of constructed wetlands for the treatment of the stream water was evaluated by diverting part of the stream water to two wetland models of 8m x 1m x 0.6m (Length x Width x Depth) dimensions.

These wetland models were arranged as Vertical Sub-surface Flow (VSSF) and Horizontal Sub-surface Flow (HSSF) systems to evaluate the performance of each type at the Hydraulic Retention Time (HRT) of 6 days. Samples were collected from influent and effluents of each system at two weeks interval over a two month period and Total Coliforms (TC), Fecal Coliforms (FC), Five-day Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids were measured. Results show that average removal efficiencies of TC, FC, BOD_5 & TSS were 91.3%, 99.99%, 70.58%, 75.03% and 94.24%, 98.3%, 66.08%, 79.4% in HSSF & VSSF systems respectively indicating high removal efficiencies in both systems.

KEYWORDS: small community, Fecal Coliform, constructed wetlands

1. INTRODUCTION

Most of the water resources around the globe are degrading rapidly due to human mistreatment at an increasing rate with the population growth, industrial and economic development, agricultural activities etc., declining the availability of good quality water resources for human consumption (Llorens et al., 2011). This may leads to various health problems, socio-economic and cultural conflicts among various groups of people in the society. It has been estimated that, about 80% of the diseases and over a one third of deaths in the developing world caused by ingestion of contaminated water (Amendola et al., 2003). Thus, proper wastewater management mechanisms will play an important role in reducing the further deterioration of precious water resources globally, as high quality effluents are crucial for reducing the damage caused by releasing wastewater into water bodies (Iasur-Kruth et al., 2010). However, unlike in developed countries, wastewater treatment is a challenging task for engineers in developing countries to face with. In these countries, even though there is a little concern on urban wastewater management, very low or no attention has given for wastewater management in semi-urban to rural areas due to financial constraints and managerial constraints connected with undertrained personal. Therefore, there is a great need for the development of simple, economical, efficient, robust and reliable wastewater treatment technologies to reduce the pollutant loads in river basins for water quality improvement and beneficial use of water.

The constructed wetland technology for water pollution control treatment is an environmentally and socially pleasing treatment option that is widely used in many parts of the world (Kadlec and Wallace, 2009) and ideal for developing countries like Sri Lanka, particularly for small communities due to its simple operation, low capital cost, minimal maintenance requirement and low or no energy requirement (Weerakoon et al., 2010). It is a biological wastewater treatment technology designed to mimic processes found in natural ecosystems where plants, water and micro-organisms interact to improve the water quality. However, the treatment efficiencies of constructed wetlands depend on various factors such as influent pollutant characteristics, hydraulic loading rate, climatic variation and the required effluent characteristics (Tanaka et al., 2006). In addition, it has to be designed specifically to suit the local climatic conditions to take advantages of unique wetland properties to accomplish better results.

Constructed wetlands are of two basic types viz.; sub-surface flow (SSF) wetlands which maintain the water level below the filter media and free water surface (FWS) wetlands which exposes about 10 cm high water surface to atmosphere (US-EPA, 1993). SSF constructed wetlands can be further divided as horizontal SSF and vertical SSF wetlands according to the direction of the flow. Distinctive advantages of SSF wetlands over FWS wetlands include, lack of odour problem, lack of mosquito and other insect vector breeding sites and the minimal exposure of wastewater to contact with public (US-EPA, 1993).

There are many small communities such as cluster houses and line houses around small streams, in the natural settings of beautiful country side and in semi-urban areas in Sri Lanka, without paying more attention for proper wastewater disposal mechanisms. Due to the low income and lower education levels and traditional habits of the inhabitance these streams are highly susceptible for contamination with human excreta, creating serious health effects for downstream water users. Rajapaksha (2009) has been investigated the fecal pollution in few vulnerable small streams in Pussellawa Oya catchment after the severe Hepatitis A outbreak during May 2007 in Gampola, Sri Lanka (Annual Health Bulletin, 2007). According to Rajapaksha (2009), the average Fecal coliform levels in these streams (n=10) are ranges from 48 – 3462 FCU/100 mL (Fecal Coliform Units per 100 mL), with an average of 930 FCU/100 mL. Therefore, it is noted that the Fecal Coliform levels in most of these streams are exceeding from the Ambient Water Quality Standards for Inland Waters in Sri Lanka, which is 50 FCU/100 mL. Also, it is revealing the importance of controlling the fecal coliform levels in these streams for beneficial water use in the downstream.

1.1 **Objectives**

- To identify the possible causes of human excreta pollution in a contaminated stream which runs through a small community (cluster of houses).

- To carry out water quality examinations in the selected stream to identify the level of pollution
- To investigate the applicability of constructed wetland systems for treatment of stream water by diverting part of the stream water.
- To compare the performance of HSSF and VSSF constructed wetland systems

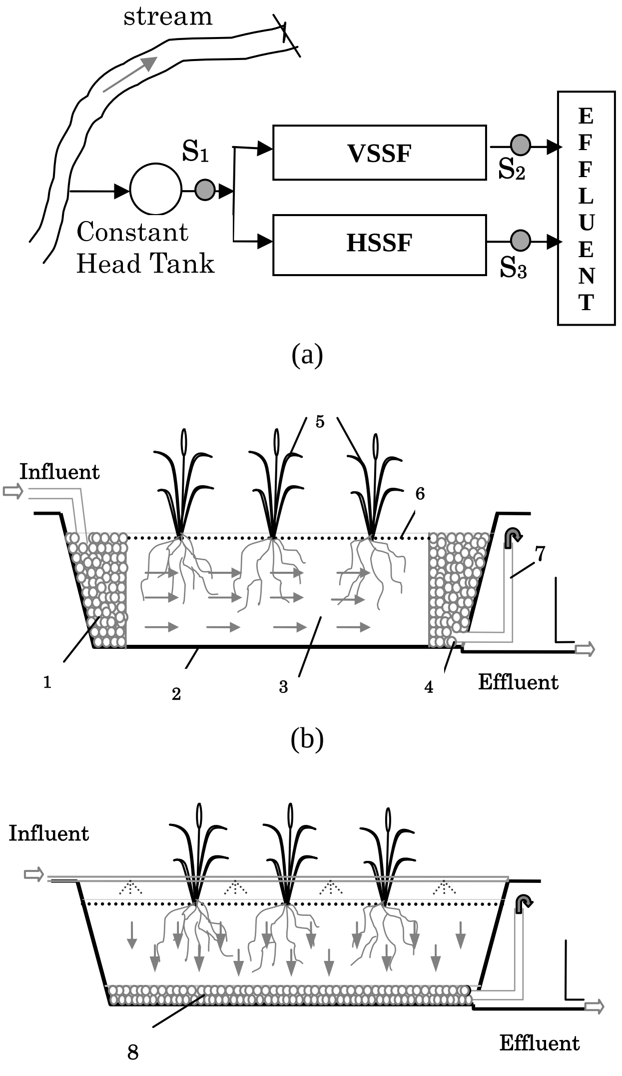
2. METHODOLOGY

2.1 Identification of sources of excreta pollution in the stream

Due to the reported severe hepatitis A outbreak in Gampola, Sri Lanka during May 2007 (Annual Health Bulletin, 2007), and the evidence of fecal pollution in small streams in Pussellawa Oya catchment investigated by Rajapaksha (2009), a vulnerable drainage stream for fecal contamination through a cluster of line houses in Melfort estate, Pussellawa was selected for this study. In order to verify the pollution levels in the drainage stream, water quality examinations especially Fecal Coliforn and Total Coliform levels, were carried out for a one month period. Then a questionnaire survey was conducted to identify the possible causes for stream pollution, for the households along the drainage stream. The data collected from the questionnaire survey include the family size with age groups, available sanitation facilities and distance from that to the drainage stream, personnel hygiene data, gray water disposal mechanisms, water consumption data, water borne disease history etc. Then these data were analyzed to find out the most possible pathways for stream pollution.

2.2 Use of constructed wetlands for stream water purification

To investigate the applicability and performance of sub-surface flow constructed wetland systems for stream water treatment, two wetland systems of size 8.0m x 1.0m x 0.6m (Length x width x height) were constructed using brick masonry and cement mortar closer to the selected drainage stream as illustrated in the Figure 1 (a), without disturbing to the natural landscape. One of them was prepared as a HSSF constructed wetland system (Figure 1 (b)) and the other one was prepared as a VSSF constructed wetland system (Figure 1 (c)). Gravel (10 – 20 mm) was used as the wetland media in this study.



(a)

(b)

(c)

Figure 1; (a). Wetland mesocosm arrangement [S_1, S_2 and S_3 are sampling points], (b). Schematic diagram of a HSSF wetland system, (c). Schematic diagram of a VSSF wetland system, 1. Inlet zone, 2. Impermeable barrier, 3. Wetland media, 4. Outlet zone, 5. Wetland Vegetation, 6. Water level, 7. Swivel pipe, 8. Drain field.

To facilitate easy distribution and collection of wastewaters in each system, the inlet and outlet zones of the HSSF wetland system and the drain field of the VSSF wetland system were filled with 30 – 50 mm size gravel. In addition, each wetland system comprises a surface layer of 10 cm deep soil (< 5 mm particle size) to support the vegetation. A nylon mesh is used between the soil and gravel layers to prevent sinking of soil into the gravel layer.

The two wetland systems were planted with *Typha angustifolia* (Narrow leaf Cattail) rhizomes of 30 cm high above ground containing at least two nodes, at 30 cm apart to achieve a plant density of 4 plants/m^2. Soon after planting, these wetland systems were kept at saturation condition for four weeks until they were grown properly. Then part of the stream water is diverted to a constant head tank, and applied to the two wetland systems at 3.5 cm/day HLR, to achieve 6 days HRT, through a control valve system. This arrangement of the wetland systems, just after planting are shown in the Figure 2. The flow was monitored daily to minimize errors.

Figure 2: Actual arrangement of wetland models in the field

Both influent and effluents samples were collected in 500 mL plastic bottles from each wetland model at two weeks interval and transferred into the environmental laboratory in the faculty of Engineering, University of Peradeniya, Sri Lanka for testing. wastewater quality parameters such as pH, BOD$_5$, FC, TC and TSS were measured in all samples according to Standard Methods of water and wastewater analysis. The removal efficiency (RE) of each parameter was calculated by using equation (1).

$$\mathrm{RE} = \frac{C_i - C_o}{C_i} \times 100\% \qquad (1)$$

Where, C_i and C_o are the concentrations of wastewater parameters at the influent and effluent, respectively. Using the removal efficiencies, a statistical analysis was carried out to test the significance treatment difference between the wetland systems.

3. Results and Discussion

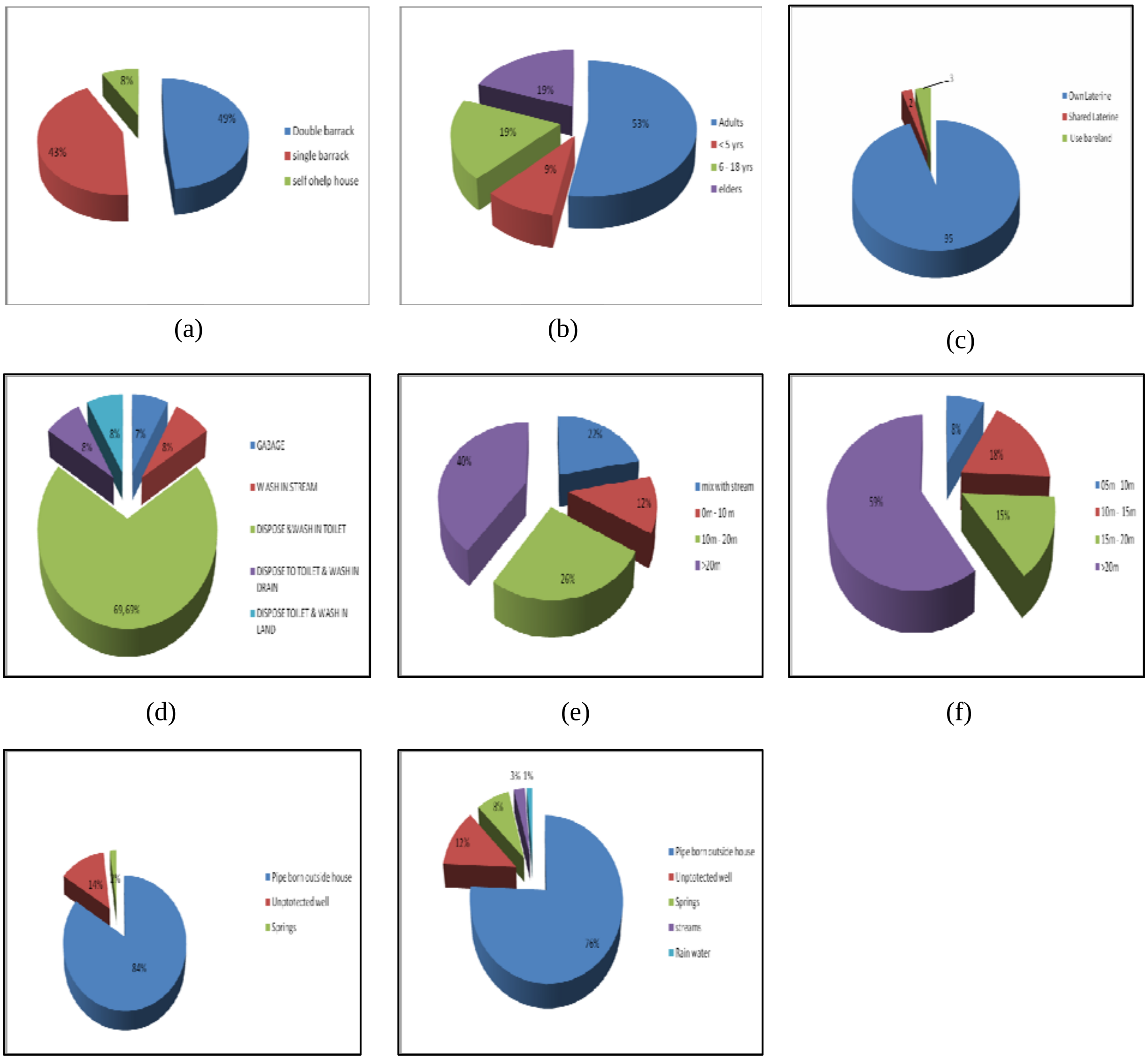
3.1 Characteristics of the small community along the selected drainage stream

From the questionnaire survey conducted for the 74 households along the selected drainage stream in the Melfort Estate, Pussellawa, Sri Lanka, type of households, population data, sanitary facilities including excreta disposal mechanisms, gray water disposal mechanisms and water consumption patterns were collected.

From the data it was found that these households are comprised with private houses as well as single barrack and double barrack houses provided by the tea-estate and both nuclear families and extended families are living in these houses. It was observed that 49% of the houses are double barracks, 43% are single barracks and only 8% of private owned houses. The total population in this community is found to be 325, out of which 53% falls in the 18-50 years age group while 19% are 5-17 years, 9% are less than 5 years and 19% are more than 50 years of age. Out of 9% small children, there are 14 infants whose age is below 2 years.

When considering sanitary facilities in the households, 95% of houses are comprised with their own latrines, while 2% use neighbors' latrine. However, 3% use bare lands near the stream for defecation and use the stream water to wash after defecation. Also, it was found that there are six people with walking difficulties in this community; out of them excreta of 2 people directly or indirectly disposes into the stream. In addition, excreta of 31% of small children (less than 2 years old) are thrown in bare lands or wash into the stream. Moreover, almost all latrines in this community are pit latrines with cesspits and 26% of them are very close to the stream (< 18 m).

When considering gray water disposal, 22% of households direct their gray water into drains which finally flows into the stream and 38% disposes in longer drains (> 20m long) and 40% disposes safely. The other important investigation through the questionnaire survey was the water consumption pattern by the people in the community. It was found that 84% of households are supplied with pipe borne water at out-side the house for drinking, 14% use unprotected well while 2% use spring water.



(a) (b) (c)

(d) (e) (f)

(g) (h)

Figure 3: Characteristics of the small community along the selected drain (a) Category of houses, (b) Age groups, (c) Excreta disposal mechanism, (d) Children’s excreta disposal, (e) Distance to the stream from the cesspit, (f) Gray water disposal, (g) Drinking water source, (h) Water source for bathing and washing

Even though larger portion of the group are supplied pipe borne water for drinking, the water is not in good quality as sediments are freely appearing. However, the water borne disease history is considerably low in this community. Only one dysentery case within three months, one viral hepatitis case within one month and two diarrhea cases within one week is generally reported. Other than that fever, cold, stomach problems and thyroxin problems for small children are reported.

3.2 Possible causes for human excreta pollution in the stream water

Even though most of the houses are comprised with a latrine and few uses shared latrines, few of them still practices improper excreta disposal mechanisms including open defecation and use the stream water to wash after defecation. This could be due to their traditional habits or due to the lower education levels. In addition, people dispose the excreta of small children's and the people with walking difficulties to the stream directly or indirectly. These are the direct causes of excreta pollution of the stream water. On the other hand, it was noted that some of the cesspits of the latrines are very close to the stream. Therefore, there is a possibility to seep toilet wastes into the stream, indirectly polluting the stream water.

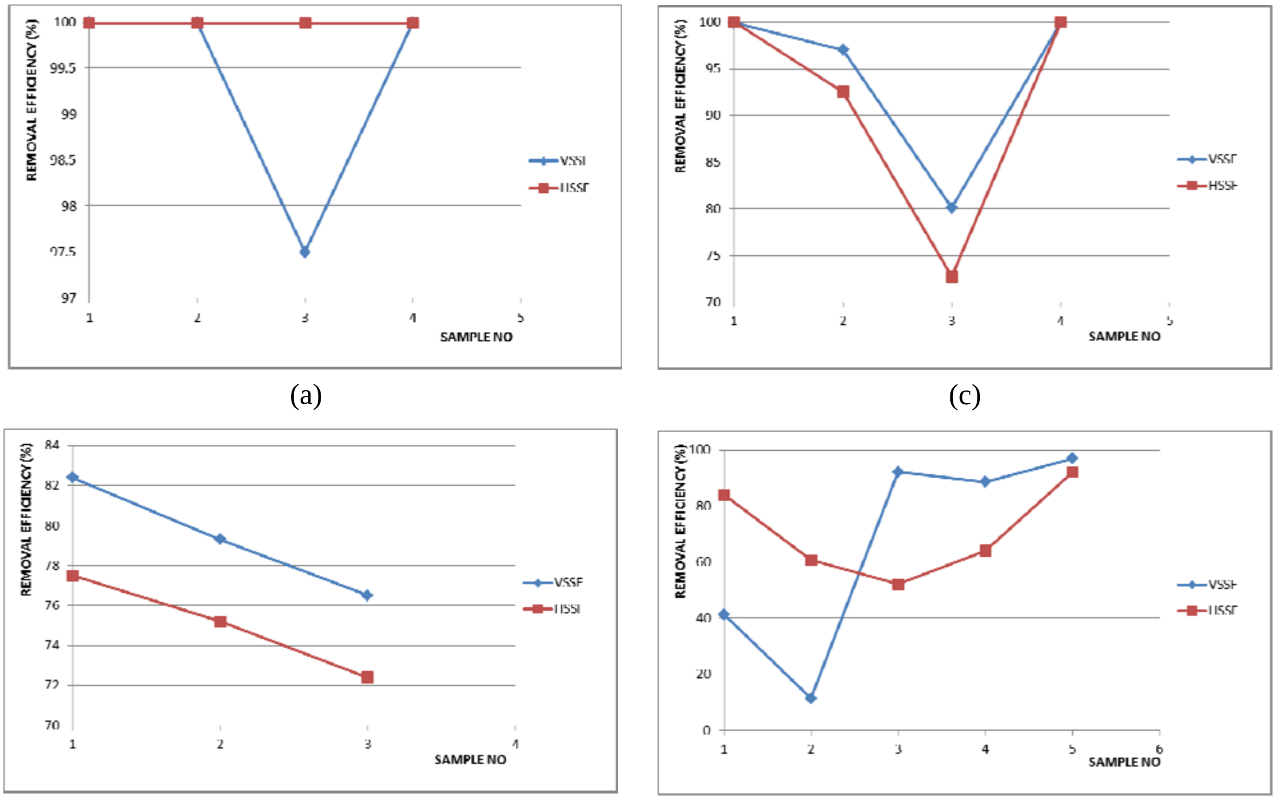
3.3 Use of constructed wetlands for stream water treatment

Average influent and effluent water quality for FC, TC and TSS with the percentage removal efficiencies are shown in the Table 1. It is noted that the influent water quality has been varied over time and could be due to the rainfall over the period which has not been monitored during the study.

Even though there are some differences in removal rates among the two systems, both HSSF and VSSF systems are capable in removing pollutants from wastewater. Amazingly it shows that FC removal in HSSF system is 99.99% throughout the study obtaining higher removal than VSSF system. On contrary, VSSF system shows better removal of TC. However the differences are very low. Both systems show satisfactory removal for both BOD_5 and TSS removal too. However, higher performance of BOD_5 and TSS are shown in the VSSF system. This could be due to the way of application of water into the system. When water is added to the system by sprinkling there is a higher possibility for water to contact with oxygen. This could be the reason for the higher BOD_5 removal in the VSSF system. Also VSSF system enables the filtering process successfully. as water flows top to bottom, thus it achieves higher TSS removal than HSSF system.

Table 1: Influent and Effluent water quality parameters with removal efficiencies of the consecutive weekly samples (6 days HRT) collected after one month of maturation

Parameter	Influent Con.	Effluent			
		VSSF		HSSF	
		Con.	RE%	Con.	RE%
FC (FCU/ 100 mL)	8000	0	99.99	0	99.99
	526	0	99.99	0	99.99
	320	8	97.5	0	99.99
	236	0	99.99	0	99.99
TC (TCU/ 100 mL)	$8*10^6$	512	99.9	152	99.99
	2800	84	97	210	92.5
	572	114	80.1	156	72.73
	760	0	99.99	0	99.99
TSS (mg/L)	102	18	82.4	23	77.5
	121	25	79.3	30	75.2
	98	23	76.5	27	72.4
BOD_5 (mg/L)	1.38	0.81	41.30	0.22	84.1
	2.19	1.94	11.40	0.86	60.70
	3.82	0.30	92.10	1.83	52.10
	2.11	0.24	88.60	0.76	64.00
	3.37	0.10	97.00	0.27	92.00



(a) (c)

(b) (d)

Figure 4: Removal efficiencies of the consecutive weekly samples (6 days HRT) collected after one month of maturation (a)Fecal coliform (b) Suspended solid(c)Total coliform(d)Five-day Biochemical Oxygen Demand

4. Conclusions

Due to the lower income and the lower level of education, people do not care about proper excreta disposal mechanisms and it is a major pathway for human excreta pollution in streams. Therefore, awareness programmes could be conducted at these places to reduce the damage.

Experimental results reveal that both VSSF and HSSF systems are viable in removing pollutants from stream water effectively at 6 days retention time at tropical conditions. However, long term results are needed for the selection of the best system.

Acknowledgements

The authors like to acknowledge the CB project in Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka, for providing funds to carry out this study

REFERENCES

Amendola, M., Souza, A.L.de and Roston, D. M. 2003. Numerical Simulation of Fecal Coliform Reduction at a Constructed Wetland, *Revista Brasilleira de Engenharia Agricola e Anbiental*, 7(3): 533-538.

Annual Health Bulletin, 2007, Ministry of Health, Sri Lanka.

APHA, *Standard Methods for the Examination of Water and Wastewater*, 1998, 20th Edition, American Public Health Association, Washington DC, USA.

Isaur-Kruth, L., Hadar, Y., Milstein, D., Gasith, A. and Minz, D., 2010, Microbial Population and Activity in Wetland Microcosms Constructed for Improving Treated Municipal Wastewater, *Microbial Ecology*, 59 (4): 700-709.

Kadlec, R. H. and Wallace, S. D., 2009, *Treatment Wetlands*, Second edition, CRC Press, Taylor and Francis Group.

Llorens, M., Perez-Marin, A. B., Aguilar, M. I., Saez, J., Ortuno J. F. and Meseguer V. F., 2011, Nitrogen Transformation in Two Subsurface Infiltration Systems at Pilot Scale, *Ecological Engineering,* 37: 736-743.

Rajapaksha I. H., 2009, Investigation of water quality variation in Pussella oya catchment, *Mphil Thesis,* IWRM Programme, Postgraduate Institute in Agriculture, University of Peradeniya.

Tanaka, N., Jinadasa, K. B. S. N., Werallagama, D. R. I. B., Mowjood, M. I. M., and Ng, W. J., 2006, Constructed Tropical Wetlands with Submergent-Emergent Plants for Water Quality improvement, *Journal of Environmental Science and Health Part A,* 4: 2221-2236.

Weerakoon, G. M. P. R., Mowjood, M. I. M., Herath, G. B. B. and Jinadasa, K. B. S. N., Performance Comparison of Subsurface Flow and Surface Flow Constructed Wetlands in Tropics, *Proceedings of the 13th Asian Congress of Fluid Mechanics,* 17th-21st December 2010, Dhaka, Bagladesh.

US-EPA, 1993, *Subsurface Flow Constructed Wetlands for Wastewater Treatment A, Technological Assesments*, Environmental Protection Agency, US-EPA., Washington Dc., 832R-83-008.