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The performance of vertical flow constructed wetland for grey water treatment as the efforts in preserving water resources

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ABSTRACT

The problems of urbanization give an impact on environmental degradation due to the amount of untreated domestic wastewater, particularly grey water which pollutes the rivers. This study aims to determine the performance of the constructed wetland in treating grey water. The research was experimental research using vertical flow constructed wetland with *Cyperus papyrus* and *Phragmites australi*s. The results showed that the vertical flow constructed wetland using *Cyperus papyrus* was able to lower the pH onto 21.95%, TSS onto 59.62%, COD onto 81.25%, BOD onto 82.67%, Nitrogen onto 75%, and the Phosphate onto 65% as well as filled up the effluent standard. Different results were shown by the vertical flow constructed wetland using *Phragmites australis* which was able to lower the pH onto 19.51%, TSS onto 50%, COD onto 78.52%, BOD onto 69.33%, Nitrogen onto 55%, and phosphate onto 54% and still was not able to fill up the effluent standard.

Key words : *Environmental degradation, Grey water, Wastewater, Vertical flow constructed wetland*

Introduction

Water is one of the keys for health, human development and ecosystems; becomes the basis in creating fundamental component of the nation; and has important role in eradicting poverty and promoting gender equality; as well as contributes to food and energy security (Cisneros, 2015). However, billions of people in the world have serious problems of water resources, such as scarcity, pollution, sanitation, floods, droughts, ecosystems extinction, and irreversible loss of ecosystem services. Scientific estimation showed that four out of five or 80% of the earth population directly or indirectly facing threats to water security (Vörösmarty, 2010).

Considering to those definition and conditions, water scarcity was defined as a threat for the existence of the nation. Therefore, water as one of the major capital in national development should be preserved both amount and quality (water security). One of the key elements of water security was to collect and to treat wastewater in order to protect human life and the environment from pollution (UN WATER, 2013).

Collecting and treating wastewater are issues that are very crucial at the present time relating to the potential of future water scarcity. Rapid population growth combined with the increasing urbanization naturally exacerbates this phenomenon. UN WATER (2014) in the UN World Water Development Report 2014 reported that the global water demand would likely increase by 55% in 2050. By that time, more than 40% of world's population will live in water crisis area. The conditions of water scarcity are inversely to the fact that 70% of the earth's surface covered by water. Despite the salt water, only 2.5% is clean water. It showed that water scarcity will definitely occur worldwide. The possibility of water scarcity will mainly occur in the world's major cities. Scientists argued that more than 50% of the global population has been already in the cities (UN, 2012; UNFPA, 2007) with the highest growth occurred in Asia and the rapid growing urban demands more sanitation systems. In South Asia, nearly 1 billion people have no access to adequate sanitation services (World Bank, 2012).

Generally, in the big cities in Indonesia, there are two major problems; one is the high population due to rapid urbanization and two is population growth. Those problems affect to urban sanitation conditions which are inadequatly both in quality and quantity; cause environmental degradation; and decline public welfare. Those conditions were showed by the increasing pollution of air, soil, water and groundwater as direct impact of domestic, industry, and transportation activities. Therefore, those domestic polutions are significantly affecting the quality of the environment in the city.

Domestic wastewater is a wastewater generated from domestic disposal area, usually in the form of feces or urine (*black water*), as well as wastewater from kitchen and bathroom (*grey water*). Characteristics of domestic wastewater generally contain various substrates such as: TS (Total Solids) 350-1200 mg/L, TDS (Total Dissolved Solid) 200-850 mg/L, TSS (Total Suspended Solid) 100-350 mg/L, BOD (Biological Oxygen Demand) 40-400 mg/L, COD (Chemical Oxygen Demand) 250 -1000 mg/L, total nitrogen 20-85 mg/L, total phosphorus 4-15 mg/L, and fat 50-150 mg/L (Eawag, 2005).

Based on Article 33 of the Constitution of the Republic of Indonesia, the law firmly protects the availability and sustainability of water resources (water security). Water security is one of the pillars of sustainable development, as if the two sides of a coin, water security can also be implemented in sustainable development. Therefore, it needs continuous, simple, cost-effective, secure and user-friendly processing system to improve health and environmental conditions. To make it more sustainable, the system should be not only economically viable, socially acceptable, as well as technically and institutionally appropriate, but also environmental and natural resources secured. Constructed wetland is one of the technologies which meet those requirements.

Constructed wetland is an ecosystem consisting of engineered plants and microorganisms that live in the rizosphere in infrastructure to remove pollutants in the wastewater. Reed grasses, Cattails, Bulrushes, *Cyperus papyrus*, *Canna indica*, *Phragmites australis*, *Typha spp, Scirpus spp* are plants which are commonly used in the constructed wetland (Greg *et al.,* 1998; Ahmed and Arora, 2012; ElZein *et al.*, 2016). The ecosystem mimics the natural wetland construction by utilizing the biogeochemical cycles typically used to treat wastewater (Rousseau *et al.*, 2008; Soulwene *et al.,* 2009). Constructed wetland was designed as an alternative system for conventional wastewater treatment which easily operates and has low operating costs (Brix, 1994; Hoffmann *et al.,* 2011; Padma *et al.,* 2011; Dadan *et al.,* 2016). Constructed wetland can be implemented both in tropic and subtropic areas; accordingly the technology is perfect to be used in developing countries such as Indonesia (Dallas *et al.,* 2004; Denny, 1997; Haberl 1999; Kivaisi, 2001).

One of constructed wetland types is a vertical flow system. Vertical flow constructed wetland is one type of constructed wetland which can practically be implemented in urban areas and slums because it does not require big area and has low ecological impact (Roberts, 2011). Vertical flow system is more effective in removing organic contaminants than horizontal flow (Kivaisi, 2001; UN-HABITAT, 2008). This is because the vertical flow systems, wetland media is continuously fed in batches to cover the entire surface and there is a interlude between the waterings which allow the media dries and allow the air to fill the wetland media (Cooper *et al.*, 1996a; Korkusuz *et al.,* 2004), hence the mechanisms provides oxygen transfer in the system (Korkusuz *et al.,* 2004).

The problems of untreated grey water have occured in urban areas where the situation leaves the potential cause to environmental problems. On the other hands, there are technologies that successfully remove pollutants nitrogen in the water, as well as reclamate and reuse the wastewater (Kadlec and Wallace, 2009; USEPA, 1993; Vymazal, 2011). This study aims to determine the performance of the constructed wetland for the grey water treatment in domestic wastewater.

Materials and Method

The Characteritic of Grey Water

The raw materials of grey water samples were collected from domestic wastewater using manual sampling methods. The wastewater is analyzed and characterized according to standard methods. The content of wastewater, the method used, and the analysis results are seen in Table 1.

The Design of Constructed Wetland

A vertical flow constructed wetland system had dimensions of 1.25m (length) x 0.65m (width) x 100 cm (depth) designed based on the rate of flow and organic loading rate (UN HABITAT, 2008). This research prepared 70 cm depth of and 30 cm freeboard, or with total depth of 100 cm considering the sufficient nitrification process in addition to the allow the persistent organic pollutants (Patel and Dhariya, 2013). The flow rate was maintained at 10 liters/day. Sewerage vertically flew downward through the filter medium and the treated water was collected through the outlet at the bottom. The base of the sloped was 1% heading into the outlet in order to maintain the similarity of water depth across the bed constructed wetland as well as to simplify the maintenance. There was no previous study or research to determine the optimal slope, yet it was recommended on 0.5 to 1% for simplifying construction and proper drying (Patel and Dharaiya, 2013). Detention times used in this study were 5, 10, 15, and 20 days.

The Wetland Vegetation and Filterbed Construction

There are various species of plants used in constructed wetland vegetation. Generally, the vegetations used are local species which are easily available and grow in the local climate. Some of them are decorative plants. Despite their functions in wetland construction, they also have an aesthetic value (Vymazal, 2011).

Vegetations used in this research were *Cyperus papyrus* and *Phragmites australis* planted at a density of 10 shoots/m^2 taken from natural wetland. According to Cooper *et al.*, (1996), *Cyperus papyrus* and *Phragmites australis* grow in a substrate with 70 cm depth consisting of 15 cm of fine sand, 15 cm small gravel, 40 cm big gravel, and 30 cm freeboard. The plants had been watered daily for a month to grow the formation called the acclimatization period. Then the plants were carefully observed the growth and the health. Therefore the constructed wetland is showed in Fig. 1.

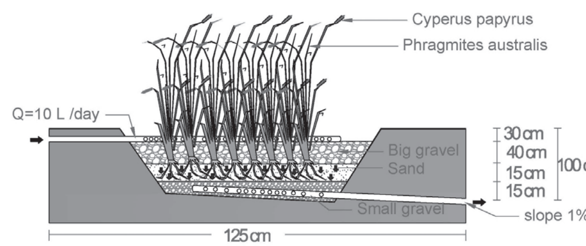

Fig. 1. Sub surface flow constructed wetland

Results

The results of the grey water treatment constructed wetland using *Cyperus papyrus* are seen in Table 2. Collecting samples of grey water was done before processing and during processing at day 5, 10, 15, and 20. Those samples were analyzed using several parameters and compared to the guide standard of effluent output.

The observation during the treatment using a constructed wetland on day 5, 10, 15 and 20 as seen

Table 1. The physical-chemical characteristics of grey water

No	Parameter	Unit	Analysis Result	Domestic Wastewater Quality Standard (East Java Governor Decree No. 72Year 2013)	Analysis Method
1	pH	-	6,60	6-9	pH meter
2	TSS	mg/L	104	50	Gravimetry
3	COD	mg/L O_2	256	50	Reflux/Titrimetri
4	BOD	mg/L O_2	150	30	Winkler
5	Nitrogen	mg/L NH_3-N	20	-	Kjeldahl
6	Phosphat	mg/L PO_4-P	10	-	Spectrophotometry

in Table 2 showed that the pH varies from 6.4 to 8.2. Values were favorable for the occurrence of biological processes as required in the constructed wetland. In addition, variations in the pH according to the guidelines for the re-use of wastewater were safe for agriculture/plantation (WHO, 2006; Kengne *et al.*, 2014).

The pH influent of grey water was 8.2 during the treatment on day 5, 10, 15, and 20 by removal efficiency of 21.95% gradually. At the end of the observation, on the day 20, pH obtained was 6.4 which was allowed by the East Java Governor Decree No. 72 Year 2013 about the standard qualities of industrial wastewater and /or other business activities. Conditions were slightly different on removing process of pH in Table 3.

Although the results in the pH of the effluent filled up the required stated by government from 6-9, removal efficiency using *Phragmites australis* had no value as high as *Cyperus papyrus* or by 19.51% as shown in Figure 2.

Table 1, 2 and Figure 3 showed the ability of Total Suspended Solids (TSS) using the constructed wetland. The wetland whether using Cyperus papyrus or Phragmittes australis was able to remove the TSS effluent in order to fill up standards. The ability in removing the TSS using the constructed wetland with *Cyperus papyrus* was 59.62% more than with

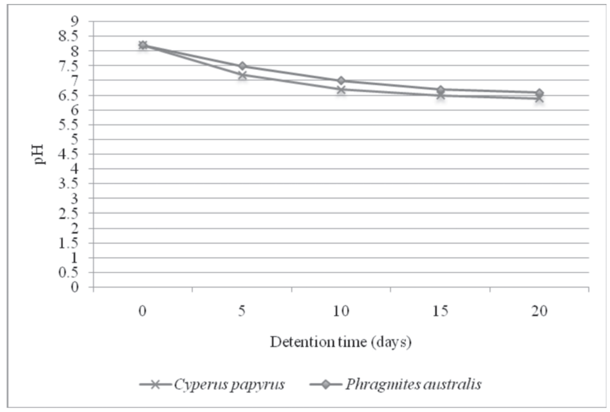

Fig. 2. pH allowance from constructed wetland using various plant species

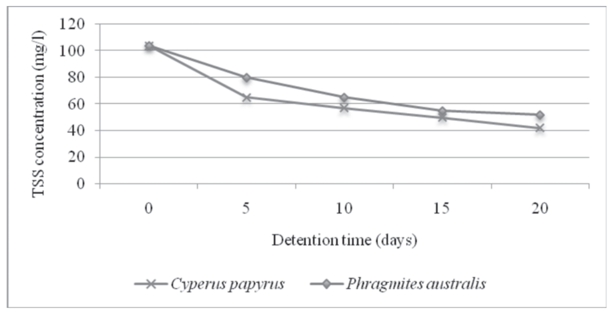

Fig. 3. TSS elimination in constructed wetland using various plant species

Table 2. Grey water treatment using *Cyperus papyrus*

Parameters	Unit	Guidelines for discharge of effluent	Detention Time (day)					Efficiency
			0	5	10	15	20	
pH	-	6-9	8.2	7.2	6.7	6.5	6.4	21.95
TSS	mg/L	50	104	65	57	50	42	59.62
COD	mg/L O_2	50	256	154	99	65	48	81.25
BOD	mg/L O_2	30	150	82	53	40	26	82.67
Nitrogen	mg/L NH_3-N	-	20	11	8	6	5	75.00
Phosphat	mg/L PO_4-P	-	10	5.3	4.5	3.8	3.5	65.00

Table 3. Grey water treatment using *Phragmites australis*

Parameter	Unit	Standard	Detention Times					Efficiency
			0	5	10	15	20	
pH	-	6-9	8.2	7.5	7	6.7	6.6	19.51
TSS	mg/L	50	104	80	65	55	52	50.00
COD	mg/L O_2	50	256	151	98	70	55	78.52
BOD	mg/L O_2	30	150	101	70	55	46	69.33
Nitrogen	mg/L NH_3-N	-	20	15	12	10	9	55.00
Phosphat	mg/L PO_4-P	-	10	9	6.8	5.4	4.6	54.00

Phragmites australlis which was only 50%, where the TSS refered to dissolved solids.

The organic contents of the output occured in wetland using *Cyperus papyrus* were shown in Table 1 and 2. The results showed that the COD removal in constructed wetland using *Cyperus papyrus* was 81.25% while the level of BOD was 82.67% (Fig. 4). It explained that the pH level for grey water treated using constructed wetland filled up the effluent standards output as the COD content was 48 mg/L from the standard of 50 mg/L; and the BOD content was 26 mg/L from the standard of 30 mg/L (Fig. 4).

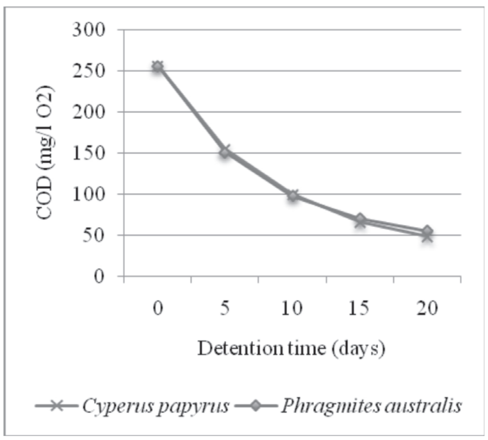

Fig. 4. The COD content in constructed wetland using various plant species

Different conditions showed in the constructed wetland using *Phragmites australis* where the the output was not able to fill up the effluent standards output, even though the efficiency reached 78.52% to 69.33% for both COD and BOD.

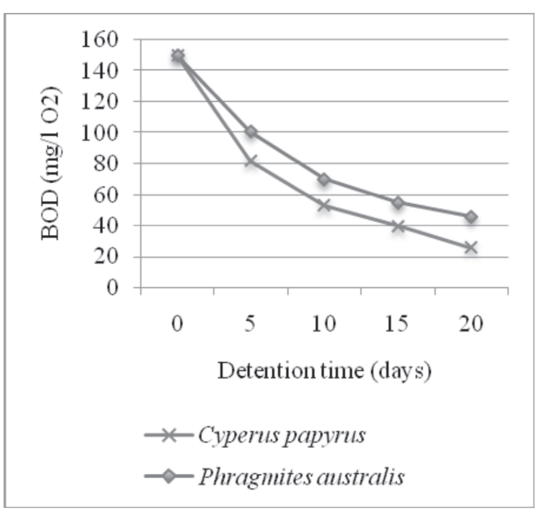

Fig. 5. The BOD content in constructed wetland using various plant species

The process of nutrient allowance in this research in terms of phosphorus and nitrogen was quite effective. This showed that the efficiency of constructed wetland using *Cyperus papyrus* was 75% for 20 days of operation (Table 2). While the nitrogen using constructed wetland with *Phragmites australis* was 55% (Table 3). Similar to previous process using different parameters, the nutrient resulted using *Cyperus papyrus* was higher than using *Phragmites australis* (Fig. 6 and Fig. 7).

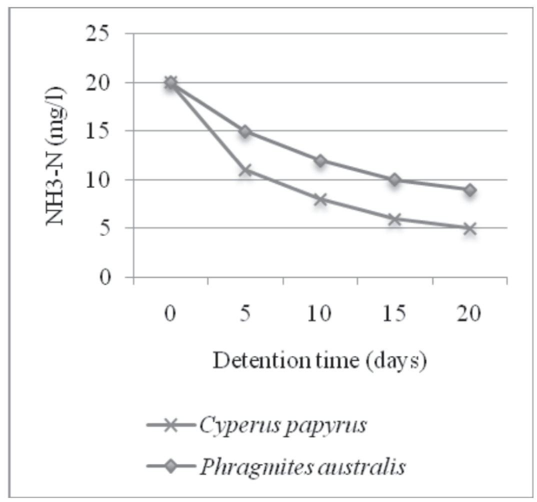

Fig. 6. NH3-N content in constructed wetland using various plant species

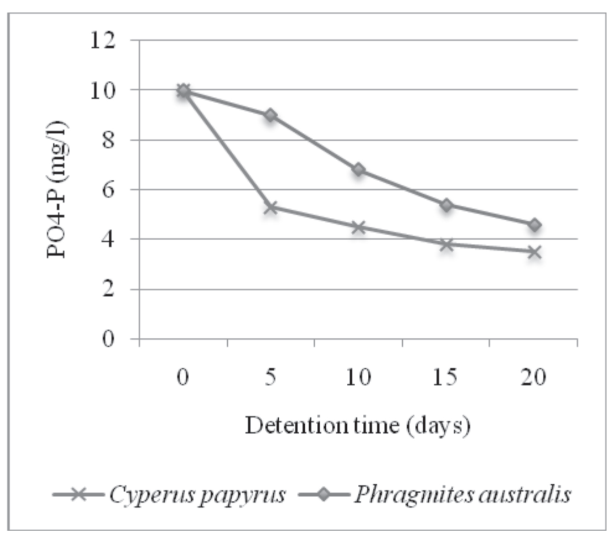

Fig. 7. PO4-P content in constructed wetland using various plant species

Discussion and Conclusion

Removing process of pH by constructed wetland in order to fill up the effluent standards either using *Cyperus papyrus* or *Phragmittes australis* was caused by the interaction of water with the substrate media of wetland and was not caused by microbial activities (Kadlec and Scott, 2009). Jensen explained that the composition of the media constructed wetland consisting of sand, gravel and soil caused the alkalinity substrate of wetland increased, so the buffer of constructed wetland was increased as well. The observation showed that samples taken at the effluent was colorless and odorless. The pH removal ability was similar to the report written by Vipat et al., (2008) who mentioned that there was a change in the pH of domestic wastewater using *Phragmites karka*. Another research showed that there was a downward trend in pH value of the lake water treatment using water plants (Dhote, 2009).

The removal ability for TSS was due to media arrangement of constructed wetland which was able to accumulate in the filter layer, especially on the sand as in the layering process which occured at pH results (Kadlec and Wallace, 2009; Kutne, 2014).

The removal process of both BOD and COD in constructed wetland occured because the process allowed bacterias to form colonies; developed and continued mineralization content of the mud; decomposed organic contents; and optimized the process of physical, chemical, and microbiological naturally (Hammer, 1989; Brix, 1994; Vipat *et al.*, 2008; Molle, 2003; Karathanasis *et al.*, 2003; Kengne, 2014). The appropriate area for bacteria in the wetland increased the activities of organisms on the root where the anaerobic and aerobic bacterias had active roles to remove both BOD and COD contents. Thereby the process prevented the contamination of grey water to water bodies and it became appropriate concept in wastewater management (Rao and Mamatha, 2004; Vymazal, 2009). Table 1, 2 and Figure 3 showed that the longer detention time gave, the more efficient the process would be. This is because the removal efficiency of organic materials had a function of Hydraulic Retention Time (HRT), where longer detention time would increase interaction in the constructed wetland system (Zirschky, 1986; Kanabkaew and Puetpaiboon, 2004).

Nitrogen removal efficiency obtained was higher than previous researches conducted in Europe (≤ 40%) (Molle *et al.,* 2005; and Kadlec and Wallace, 2009). This condition was due to the tropical climate, the metabolic activities of plants, and microorganism that increased the transformation of nitrogen (Kutne *et al.,* 2014). Excellence constructed wetland for nitrogen allowance had also been written by several previous studies as Gerberg *et al.*, (1986), Wathugala *et al.*, (1987); Breen, (1990); Roger *et al.*, (1991); Clarke and Baldwin (2001); Kengne *et al.*, (2014).

The primary mechanism of ammonia-nitrogen allowance in constructed wetland occured from volatilizing NH_3 (Billore, *et al.,* 1999), nitrificating process (Kadlec and Scott, 2009) and denitrificing process (Gersberg *et al.,* 1989; Chang-gyun *et al.,* 2009; Vipat *et al.,* 2008). Decreasing ammonia occured when bacterias attacted on the surfaces of media wetland, such as *Nitrosomonas spp,* oxidize ammonia to nitrite with oxygen (Persson *et al.,* 2002; Senzia *et al.,* 2003) or occured due to plant absorption (Juren, 1999).

Removal process of phosphate was similar to the removal process of nitrogen, showing that using *Cyperus papyrus* was higher than using *Phragmites australis* (Figure 4). In Table 2, the removal process of phosphate using *Cyperus papyrus* showed efficiency as 65% while using *Phragmites australis* showed as 54% (Table 3), and similar conditions showed as well in removal process of nitrogen. Phosphate is one of the major nutrients required by the plant to grow better, but the availability of phosphate in receiving water bodies causes the negative effects of eutrophication (Kadlec and Wallace, 2009). Therefore, there have been many researches conducted to analyze this condition. The success in using constructed wetland in the phosphate allowance was reported by Prochaska and Zouboulis, 2006; Hoffmann *et al.,* 2011 and Bayansan, 2011. Phosphate was able to be removed by plants and microbes on constructed wetland through fragmentation, pulverization, mineralization, sedimentation, adsorption and precipitation process (Kadlec and Knight, 1996; Reddy and D'Angelo, 1997; Ayaz and Akca, 2001; Lin *et al.,* 2002; Kengne *et al.,* 2014). Lin *et al.* (2002) also described that the provision of phosphate on the constructed wetland was significantly higher than those recorded in non-wetland vegetations, as well as significantly corelated with the growth and productivity of crops in different systems.

The performance of vertical flow constructed wetland was showed by decreasing the effectiveness on the pollutants contained in the grey water. The results showed that the vertical flow constructed wetland using *Cyperus papyrus* was able to lower the pH onto 21.95%, TSS onto 59.62%, COD onto 81.25%, BOD onto 82.67%, Nitrogen onto 75% and phosphate onto 65%, as well as filled up the effluent standard output. Different results were shown by using *Phragmites australis* which was able to lower the pH onto 19.51%, TSS onto 50%, COD onto 78.52%, BOD onto 69.33%, Nitrogen onto 55% and phosphate onto 54%, yet it was not able to fill up the effluent standard output, especially for the parameters COD, BOD, Nitrogen and Phosphate. It was concluded that using *Cyperus papyrus* was more effective than using *Phragmites australis* in the grey water treatment.

References

Ahmed, M. and Arora, M. 2012. Suitability of grey water recycling as decentralized alternative water supply option for integrated urban water management. *IOSR Journal of Engineering.* 2(9): 31-35.

Ayaz, S.C. and Akca, L. 1999. Treatment of wastewater by natural systems. *Environmental International.* 2001; 26: 189-195.

Billore, S.K., Singh, N., Sharma, J.K., Dass, P. and Nelson, R.M. Horizontal subsurface flow gravel bed constructed wetland with *Phargmites karka* in central India. *Water Science Technology.* 40 (3) : 163-171.

Breen, P.F. 1990. A mass balance method for assessing the potential for artificial wetlands for wastewater treatment. *Water Resource.* 24 : 689-697.

Brix, H. 1994. Use of constructed wetlands in water pollution control: Historical development, present status and future perspectives. *Water Science and Technology.* 30(8): 209-223.

Chang-gyun, L., Tim, D. and Fletcher, Guangzhi, S. 2009. Review: Nitrogen removal in constructed wetland systems. Wiley-VCH Verlag GmbH & Co. KGaA, *Weinheim Engineering Life Science.* 9 (10): 11–22.

Cisneros, B.J. 2015. Responding to the Challenges of Water Security: The Eight Phase of The International Hydrological Programme, 2014-2021, 2015. Hydrological Sciences and Water Security: Past, Present and Future. *Proceedings of the 11th Kovacs Colloquium, Paris, France.* IAHS Publ. 366.

Clarke, E. and Baldwin, A.H. 2001. Responses of wetland plants to ammonia and water level. *Ecological Engineering.* 18 : 257-264.

Cooper, P.F., Job, G.D., Green, M.B. and Shutes, R.B.E. 1996. Reed Beds and Constructed Wetland for Wastewater Treatment. WRc Swindon, UK.

Dadan, S.W., Taufiq, H., Dadan, S., T.B. Benito, K. and Denny, K. 2016. A review on sub surface flow constructed wetlands in tropical and sub tropica countries. *Open Science Journal* June.

Dallas, S., Scheffe, B. and Ho, G. 2004. Reedbeds for greywater treatment- case study in Santa Elena-Monteverde, Costa Rica, Central America. *Ecological Engineering*. 23 (1) : 55-61.

Denny, P. 1997. Implementation of constructed wetlands in developing countries. *Water Science Technology.* 35 (5): 27-34.

Dhote, S. and Dixit, S. 2009. Water Quality Improvement through Macrophytes: A Review. *Environmental Monitoring Assessment.* 152 : 149–153.

EAWAG, 2005. Greywater Treatment on Household Level in Developing Countries: A State of The Art Review. Swiss Federal Institute of Technology Zurich.

ElZein, Z., Abdou, A. and Abd ElGawad, I. 2016. Constructed Wetlands As A Sustainable Wastewater Treatment Methods in Communities. *Procedia Environmental Sciences.* 34 : 605-617.

Gersberg, R.M., Elkins, B.V. and Goldman, C.R. 1983. Nitrogen removal in artificial wetland. *Water Resource.* 17(9) : 1009-1014.

Greg, W., Young, R. and Brown, M. 1998. *Constructed Wetlands Manual,* Vol. 1. Department of Land and Water Conservation. University of New South Wales. Australia.

Haberl, P. 1999. Constructed wetlands: A Chance to Solve Wastewater Problems in Developing Countries. *Water Science Technology.* 40 (3) : 11-17.

Hammer, D.A. 1989. *Constructed Wetlands for Wastewater Treatment Municipal, Industrial and Agricultural.* Lewis publ. Boca-Raton FL.

Hoffmann, H., Winker, M., Christoph, P. and Elizabeth, V. 2011. Technology review of constructed wetlands: Subsurface flow CW for greywater and domestic waste water treatment", Sustainable sanitation-Ecosan program, www.gtz.de/ecosan.

Kadlec, R.H. and Wallace, S.D. 2009. *Treatment Wetlands.* Second ed. Taylor & Francis Group, Boca Raton, FL.

Kanabkaew, T. and Puetpaiboon, U. 2004. Aquatic plants for domestic wastewater treatment: Lotus (*Nelumbo nucifera*) and Hydrilla (*Hydrilla verticillata*) systems. *Journal of Technology.* 749 – 756.

Karathanasis, A.D., Potter, C.L. and Coyne, M.S. 2003. Vegetation effects on fecal bacteria, BOD, and suspended solid removal in constructed wetlands treating domestic wastewater. *Ecological Engineering.* (20): 157-169.

Kengne, E.S., Kengne, I.M., Nzouebet, W.A.L., Akoa, A., Viet, H.N. and Strande, L. 2014. Performance of vertical flow constructed wetlands for faecal sludge drying bed leachate: Effect of hydraulic loading. *Ecological Engineering.* (71): 384-393.

Kivaisi, A.K. 2001. The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. *Ecological Engineering.* 16(4): 545-560.

Korkusuz, E.A., Beklioglu, M. and Demirer, G.N. 2004. Treatment Effeciencies of the Vertical Flow Pilot-Scale Constructed Wetlands for Moestic Wastewater Treatment. *Turkish Journal Engineering Environmental Science.* 28(1): 333-344.

Lin, Y.F., Jing, S.R. and Lee, D.Y. 2002. Nutrient removal from aquaculture wastewater using a constructed wetlands system. *Aquaculture.* 209 : 169-184.

Molle, P., Liénard, 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 Technology.* 51(9): 11–21.

Padma, V., Paul, G., Allen, W., Alka, T. and Mamta, T. 2011. Localised domestic waste water treatment part 1- Constructed Wetlands. *Journal of Scientific and Industrial Research.* (70) : 583-594.

Patel, P.A., Dharaiya, N.A. 2013. Manmade wetland for wastewater treatment with special emphasis on design criteria. *Scientific Reviews and Chemical Communications.* 3(3): 150-160.

Prochaska, C.A., Zouboulis, A.I. 2006. Removal of phosphates by pilot vertical-flow constructed wetlands using a mixture of sand and dolomite as substrate. *Ecological Engineering.* 26(3): 293-303.

Rao, S.M. and Mamatha, P. 2004. Water quality in sustainable water management. *Current Science.* 87 (7) : 942-947.

Reddy, K.R., D'Angelo, E.M. 1997. Biogeochemical indicators to evaluate pollution removal efficiency in constructed wetlands. *Water Science Technology* 35(5): 1-10.

Roberts, B.M. 2011. *Development of portable recycled vertical flow constructed wetlands for the sustainable treatment of domestic greywater and dairy wastewater.* Thesis. Colorado State University.

Rogers, K.H., Breen, P.F. and Chick, A.J. 1991. Nitrogen removal in experimental wetlands treatment systems: evidence for role of aquatic plants. *Resources Journal Water Pollution* (63): 934-941.

Rousseau, D.P.L., Lessage, E., Story, P.A., Vanrolleghem, D.P. 2008. Constructed wetlands for water reclamation. *Desalination.* (218): 181-189.

Soulwène, K., Fadhel, M., Neila, S., Samir, B., Abdennaceur, H. 2009. Performances of A Constructed Wetland Treating Domestic Wastewaters during A Macrophytes Life Cycle. *Desalination.* (246): 452–467.

UN WATER, 2013. Water Security and Global Water Agenda: A UN-WATER Analytical Brief. United Nations University Institute for Water, Environment & Health (UNU-INWEH), Canada.

UN WATER, 2014. The United Nations World Water Development Report: Water and Energy. UNESCO, Paris.

UN, 2012. World Urbanization Prospects: The 2011 Revision. ST/ESA/SER.A/322.

UNFPA, 2007. State of World Population: unleashing the potential of urban growth.

UN-HABITAT, 2008. Constructed Wetlands Manual. United Nations Human Settlements Programme (UN-HABITAT),

USEPA, 1993. Subsurface flow constructed wetlands for wastewater treatment - A Technology Assessment. EPA 832-R-93-008.

Vipat, V., Singh, U.R., Billore, S.K. 2008. Efficiency of Root zone Technology for treatment of Domestic wastewater: Field scale study of a Pilot Project in Bhopal. (MP), India. Proc. of Taal-2007. The 12th World Lake Conf. 995-1003.

Vörösmarty, C.J. 2010. Global threats to human water security and river biodiversity. *Nature.* (467): 555–561.

Vymazal, J. 2009. Constructed Wetlands for Wastewater Treatment: Five Decades of Experience. *Environmental Science and Technology.* 45 (1): 61-69.

Vymazal, J. 2011. Plants used in constructed wetlands with horizontal subsurface flow: a review. *Hydrobiologia.* (674) : 133-156.

Wathugala, A.G., Suzuki, T. and Kurihari, Y. 1987. Removal of nitrogen phosphorus and COD form wastewater using sand filtration system with Phragmites australis. *Water Resources.* (21): 1217-1224.

World Bank, 2012. Bangladesh: Towards Accelerated, Inclusive and Sustainable Growth— Opportunities and Challenges."

Zirschky, J. 1986. Basic design Rationale for Artificial Wetlands. Contract Report 68-01- 7108, USEPA, Office of Muni. Poll. Cont. Washington, DC.