BioLink : Jurnal Biologi Lingkungan, Industri dan Kesehatan, Vol. 9 (1) Agust (2022)
ISSN: 2356- 458X (print) ISSN: 2597-5269 (online)
DOI: 10.31289/biolink.v9i1.6837

BioLink
Jurnal Biologi Lingkungan, Industri, Kesehatan

Available online http://ojs.uma.ac.id/index.php/biolink

THE REDUCING OF ORGANIC LOADING AND PHOSPHATE (PO_4) IN DOMESTIC WASTEWATER TREATMENT BY CONSTRUCTED WETLAND SYSTEM USING CANNA INDICA AND CYPERUS ALTERNIFOLIUS

Rendi Yopi Trifando, Haryati Bawole Sutanto*, & Guruh Prihatmo

Biology Study Program or Department, Faculty of Biotechnology, Universitas Kristen Duta Wacana, Yogyakarta, Indonesia

Submited : 05-04-2022; Reviewed : 07-07-2022; Accepted : 09-08-2022

**Corresponding author*: E-mail : haryati@staff.ukdw.ac.id

Abstract

The domestic wastewater is mostly produced in settlement areas and usually directly discharged into the environment. Its high organic matter and nutrients will pollute the environment. As an alternative, one of the good wastewater treatment systems is the Sub Surface Flow Constructed Wetland. This system has some advantages such as easy implementation, low cost, and doesn't need a large area. The aim of this study is to determine the efficiency of Canna indica and Cyperus alternifolius to reduce organic matter and phosphate. This study is an experimental study with two treatments (T1: SSF CW with Canna indica; T2: SSF CW with Cyperus alternifolius). The SSF CW system contains gravels those diameters are 3-5 cm, 1-3 cm, and <1 cm, as well as paddy soil as media with HRT of 3 days. The parameters measured included temperature, BOD, DO, PO4, and pH. Based on this study, it can be concluded that the higher removal efficiency of organic matter is shown by the CW SSF system with Cyperus alternifolius. It is 48,86% in T2 and 42,69% in T1. While the removal efficiency of phosphate in T1 and T2 are 65,70% and 67,21% respectively.

Keywords: *Canna indica; Constructed Wetland; Cyperus alternifolius; Domestic Wastewater; Phosphate*

How to Cite: *Trifando, R.Y., Sutanto, H.B., & Prihatmo, G. (2022). The Reducing of Organic Loading and Phosphate (PO4) in Domestic Wastewater Treatment by Constructed Wetland System Using Canna indica and Cyperus alternifolius, BioLink: Jurnal Biologi Lingkungan, Industri dan Kesehatan, Vol. 9 (1): Hal. 95-105*

INTRODUCTION

The increasing rate of population growth has caused the restricted area for settlement. These areas produce large amount of domestic waste generated from daily activities such as bathing, cooking, and toilet activities. The domestic waste is usually directly discharged into water bodies. Because of its high content of organic matter, nutrients, and pathogenic bacteria, it can cause environmental pollution (Sylla, 2020).

Therefore, before being discharged into the environment, a wastewater treatment is needed to reduce the amount of domestic waste.

In present, there is a wide range of wastewater treatment systems. However, most of these systems have major problems, including high manufacturing costs, requires large area, and difficult to operate (Tran *et el.,* 2019). As an alternative, Constructed Wetland (CW) is a low-cost, easy to implement, and highly efficient (Suswati & Wibisono, 2013). It uses physical, chemical, and biological processes as well as the role of plants to treat domestic wastewater. The CW can improve water quality by reducing pollutants in wastewater such as organic matter, suspended solids, heavy metals, pathogenic bacteria, and nutrients (Garcia-Avila *et el.,* 2019). It can treat wastewater by mimic the layout and functions of natural wetlands. There are several processes such as sedimentation, filtration, gas exchange, adsorption, precipitation, biological treatment by microorganism activity and plant absorption (Fildzah *et el.,* 2016). Constructed Wetlands are primarily composed of substrates, macrophytes, and microorganisms. The substrates commonly used is gravels, fibers, or sand. Biological action refers to the plant uptake, the coupling effects between microorganisms and plants, and the decomposition of microorganisms (Parde *et el.,* 2021).

The main kinds of Constructed Wetlands are Free Water Surface (FWS) and Sub Surface Flow (SSF), in which, Sub Surface Flow Constructed Wetlands are further classified into Horizontal flow, Vertical Flow, Hybrid, and Floating Treatment Wetland (Parde *et el.,* 2021). In horizontal flow, wastewater flows horizontally from primary to secondary treatment. According to Raphael *et al*., (2019) it can reduce BOD, COD, total suspended solid, and phosphate. In vertical flow the water flow will transport from top to bottom vertically and absorbed by the substrate or wetland. It can reduce BOD, COD, and Nitrate. The difference between vertical and horizontal flow is flow direction and the presence of aerobic conditions in the system. In horizontal flow, oxygen transfer to saturated media is limited because the system always fully filled. While in vertical flow emerge tidal conditions, thus the oxygen can increase significantly (Sylla, 2020).

Canna indica is also known as ornamental plant, and it has rhizomes, upright stems, and often grow 2 – 3,5 m. The rhizomes are branched horizontally as tuber and the flowers has various colors such as red, yellow, and orange. It has higher growth rate with significantly high biomass production which is related to nutrient uptake, and tolerance to water stress. BOD and PO4 (phosphate) removal rates were 87,3% and 82,6% for *Canna indica* (Haritash *et al.*, 2015). *Cyperus alternifolius* or umbrella plant as macrophytes in wetlands is a year-round plant that can be grown in semi-shady conditions and humid soil. It has strong underground root, grow up to 2 m, and erect aerial stem which doesn't have any branches (Yong *et el.,* 2010). *Cyperus alternifolius* can accumulate heavy metal and pathogens, also BOD and PO4 (phosphate) removal rates were 73% and 70% (Shahi *et al.*, 2013). The aim of this study is to determine the efficiency of *Canna indica* and *Cyperus alternifolius* to reduce organic matter and phosphate in domestic wastewater using Sub Surface Flow Constructed Wetland. Hence, this study results can be used as a reference in the selection of macrophytes and as an alternative system in wastewater treatment.

MATERIALS AND METHODS

This study was conducted from February to July 2021. Wastewater reactor and analysis of temperature, pH, Biological Oxygen Demand (BOD), and Dissolve Oxygen (DO) were carried out at the Environmental Laboratory of the Faculty of Biotechnology, Duta Wacana Christian University. The analysis of PO4 (phosphate) was carried out at the Center for Environmental Health and Disease Control Engineering (BBTKLPP) Bantul, Yogyakarta. This study using the Sub Surface Flow Constructed Wetland (SSF-CW) in the laboratory scale. Two treatments were used, using ornamental plant *Canna indica* (T1) and natural wetland plant *Cyperus alternifolius* (T2). The reactor design has a distance between sampling points of 14.5 cm to determine the distribution of dissolved oxygen (DO) based on the depth. In both reactors, the same media arrangement was carried out containing from top to the bottom, the first layer of paddy fields, small gravel with diameter < 1 cm, small gravel with diameter 1-3 cm, and gravel with diameter 3-5 cm. Based on Wijaya (2018) the ratio of the media is 1: 2: 3: 2 (Figure 1).

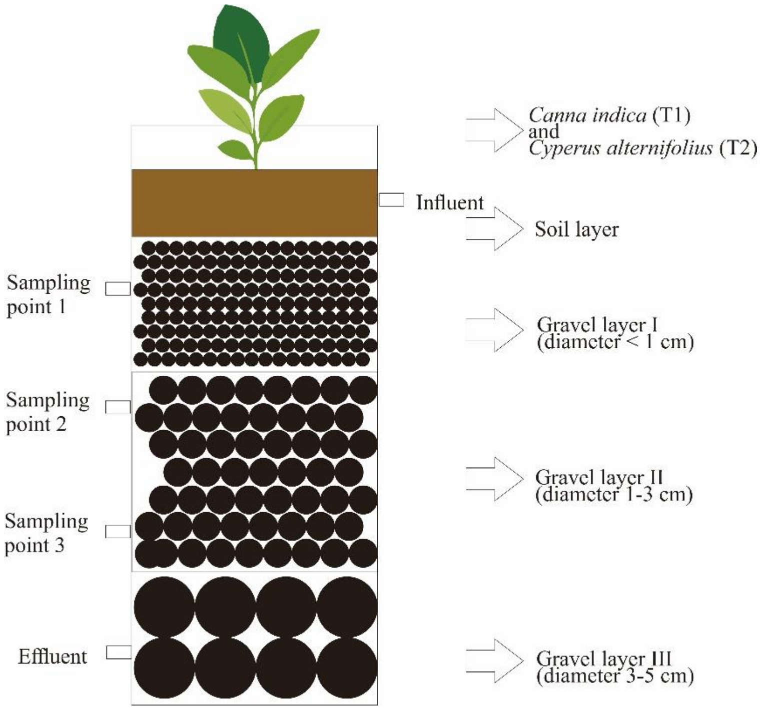

Figure 1. Design of Sub Surface Flow Constructed with *Canna indica* and *Cyperus alternifolius*

Domestic wastewater will be flowed to T1 and T2 reactors with the same discharge using vertical down flow with HRT of 3 days. The DO parameter was measured from different depth of 23 cm (TS 1), 36,5 cm (TS 2), 51 cm (TS 3), and 65,5 cm (TS 4/effluent). The reactor volume is 120 L and can accommodate 48 L influent. The flow used in this study was the sub surface flow. T1 and T2 respectively have 4 sampling points. T1 was filled with *Canna indica* plants, while in T2 with *Cyperus alternifolius* plants.

Domestik wastewater was obtained from Duta Wacana Christian University, Yogyakarta, Indonesia. This wastewater was analyzed for initial contents of BOD, Phosphate, and DO. Each parameter of temperature, pH, DO, BOD, and PO4 (phosphate) was measured every 3 days for 24 days. The temperature was measured using thermometer. Dissolved Oxygen (DO) was measured by DO meter. Biological Oxygen Demand (BOD) was measured using the reference method of Winkler (SNI 6989.72:2009). pH was measured by pH meter. Phosphate (PO4) was carried out using the reference method of APHA 2017, section 4500 P-D.

The statistical tests were done using SPSS 22.0 software package. A significance level of ρ=0,05 was used for all statistical tests and values reported are the mean (average). When a significant difference was observed between treatments (T1 and T2) in the One-Way ANOVA procedure, it was followed by post hoc test. Post hoc test pair comparisons were also performed to test equal variations using Duncan honestly significant difference test.

RESULTS AND DISCUSSION

Based on the results shows that the treatment of domestic wastewater using constructed wetland system with *Canna indica and Cyperus alternifolius* can reduce wastewater pollutants with different efficiency rate. The results depend on the characteristic of each plant.

Table 1. Wastewater Test Results with SSF-CW systems T1 and T2

Parameter	Unit	*Influent*	*Effluent* T1	Efficiency (%)	*Effluent* T2	Efficiency (%)	Quality standards
Temperature	°C	25,29^{a}	25,19^{a}	-	25,38^{a}	-	Std. dev. ± 3 °C*
pH	-	7,87^{a}	7,99^{a}	-	7,91^{a}	-	6 – 9*
BOD	mg/L	183,23^{b}	105^{a}	42,69	93,71^{a}	48.86	75*
Phosphate	mg/L	8,66^{b}	2,97^{a}	65,70	2,84^{a}	67.21	2**

Information:
Numbers followed by same letter indicate no significant difference in mean value, while numbers followed by different letter indicate significant difference in mean value.
*Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor P.68/MENLHK-SETJEN 2016 Tentang Baku Mutu Air Limbah untuk Kegiatan IPAL Domestik Komunal
**Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor P.68/MENLHK-SETJEN 2016 Tentang Baku Mutu Air Limbah untuk Kegiatan Industri Sabun

Table 1 above shows the results of wastewater test with Sub Surface Flow Constructed Wetland (SSF-CW) systems with *Canna indica* plant (T1) and *Cyperus alternifolius* plant (T2).

High organic matter in environment can cause the depleting of dissolved oxygen and lead aquatic biotics and fish to suffocate (Raphael *et el.,* 2019). Sub Surface Flow Contructed Wetland (SSF-CW) with *Canna indica*(T1) and *Cyperus alternifolius* (T2) can reduce BOD until 105 mg/L and 93,71 mg/L (Table 1). T1 and T2 were having almost similar removal efficiency in removing BOD. The decrease of BOD is caused by the ability of SSF-CW to treat domestic wastewater. Several processes that play role in the processing of the reducing of organic matter shown by reducing the BOD are sedimentation, biodegradation by microorganisms in media and roots zone, and assimilation by plants.

According to Vymazal & Lenka (2008), in Constructed Wetland the important role of plants is a place to provide substrate (rhizomes) for growth of microorganisms, Radial Oxygen Loss (ROL) which functions to transfer oxygen into rhizosphere zone, and absorb nutrients. *Cyperus alternifolius* has better BOD reduction efficiency than *Canna indica*. It could be due to the different types of roots. *Cyperus alternifolius* has a strong, elongated rhizome type, small size, and has adventitious roots, while *Canna indica* has larger root type, but is more fragile. The root system plays important role in transferring oxygen from leaves to roots. Oxygen is obtained from air and photosynthesis, then it will transferred through aerenchyma in plants into roots and rhizosphere zone.

According to Stottmeister *et al*., (2003) and Visser *et al*., (2000) in Li *et al.,* (2013). Oxygen is utilized by microorganisms in the root zone of both plants for metabolism. Microorganisms will decompose or degrade organic matter into simpler forms and then the plants can absorb it as nutrients. They are able to degrade the organic matter because they have special enzymes during metabolism which can break it down into simpler forms. Microorganisms degrade organic matter to produce energy, synthesize cells, respiration, and motility (Hammer & Mark, 2014). *Cyperus alternifolius* roots can penetrate to SSF-CW system further into the media than *Canna indica*. It causes the oxygen supply to *Cyperus alternifolius* effectively because it can reach a wider area of media. Moreover, applying a vertical flow system can also increase diffusion of oxygen SSF-CW, and the activity of microorganisms that decompose organic matter will optimum (Nivala *et el.,* 2012).

The excessed phosphate in environment can cause several problems such as algae blooms, decreased dissolved oxygen, and mortality for aquatic biota. SSF-CW with *Canna indica* and *Cyperus alternifolius* was able to reduce phosphate by average of 2.97 mg/L and 2.84 mg/L (Table 1). Phosphorus (P) plays important role for organisms because it functions as storage media and transfer energy between cells and genetic system (Vymazal, 2010). Phosphorus in waters is available in form of phosphate which consists of particulate and dissolved phosphate. Dissolved phosphate is divided into organic and inorganic phosphate (polyphosphate and orthophosphate). Organic phosphate forms can be divided into those that are easily decomposed (such as nucleic acids, phospholipids, or sugar phosphates) and organic phosphates that slowly decompose (inositol phosphate or phytin) (Vymazal, 2010). The reducing process of phosphate in SSF-CW can occur through several processes, such as absorption by plants, assimilation by microorganisms, filtration, adsorption on media, and precipitation. Phosphate which is insoluble in water will be treated by filtration and precipitation on media. Moreover, it also can be adsorbed on media or colloid, thus phosphate can decrease. Phosphate degradation is also executed by microorganisms which degrade complex phosphates into simpler forms through assimilation and can be absorbed by plants (Vymazal, 2010). Furthermore, mineralization also plays important role in absorption and assimilation by plants (Vymazal, 2010).

Plants play role in absorption and assimilation (Reddy & Ronald, 2008). Phosphate will be absorbed by plants as nutrient for growth and as support in metabolism and cell formation. It can be easily absorbed directly by plants as orthophosphate. More complex forms such as polyphosphate will be broken down first into simpler orthophosphates. It also can relate to pH, along with the release of organic acids (such as citric acid, lactic acid, etc) by microorganisms in the rhizosphere by carrying out metabolism, pH will decrease. *Canna indica* was able to reduce phosphate with removal efficiency of 65,7%, while *Cyperus alternifolius* was 67,21%. Both plants showed considerable removal efficiency, but *Cyperus alternifolius* was slightly better. The decrease in phosphate has correlation with increase in biomass of both plants (Figure 2). The fluctuating daily sources of phosphate, as well as the absorption ability of each plant can be one of the reasons for the still high concentration of phosphate found in the effluent.

Figure 2. Plants growth in SSF-CW with *Canna indica* (T1) and *Cyperus alternifolius* (T2)

Table 2. Dissolved Oxygen Results Based on The Depth

	Unit	***Influent***	**Sampling Point**			
			1	**2**	**3**	**4**
Canna indica (T1)	mg/L	$1{,}27^{a}$	$2{,}46^{b}$	$2{,}95^{bc}$	$4{,}02^{d}$	$4{,}99^{e}$
Cyperus alternifolius (T2)	mg/L	$1{,}27^{a}$	$3{,}16^{bcd}$	$3{,}43^{bcd}$	$3{,}75^{cd}$	$5{,}30^{e}$

Information:
Numbers followed by same letter indicate no significant difference in mean value, while numbers followed by different letter indicate significant difference in mean value.

Table 2 shows the results of Dissolved Oxygen levels based on the depth from both T1 and T2 systems.

The dissolved oxygen (DO) at four levels of different depth in T1 and T2 is significantly different (Figure 3). It is still found even at basic level. In SSF-CW source of dissolved oxygen comes from plants through photosynthesis in leaves and oxygen diffusion in atmosphere (Stefanakis & Tsihrintzis, 2012). It can be diffused because the media or substrate has pores as air channels to enter the reactor. When oxygen enters and meets water, it will diffuse and cause the dissolved oxygen levels increase. SSF-CW with *Cyperus alternifolius* showed higher mean DO value when compared to *Canna indica*. It has highest mean DO value of 5,3 ppm at the depth of 65,5 cm, and lowest mean DO value of 3,16 ppm at the depth of 22 cm. Meanwhile, SSF-CW with *Canna indica* has highest average DO value of 4,99 ppm at the depth of 65,5 cm, and lowest average DO value of 2,46 ppm at the depth of 22 cm. Both plants have highest and lowest mean DO values at the same depth level (Table 2).

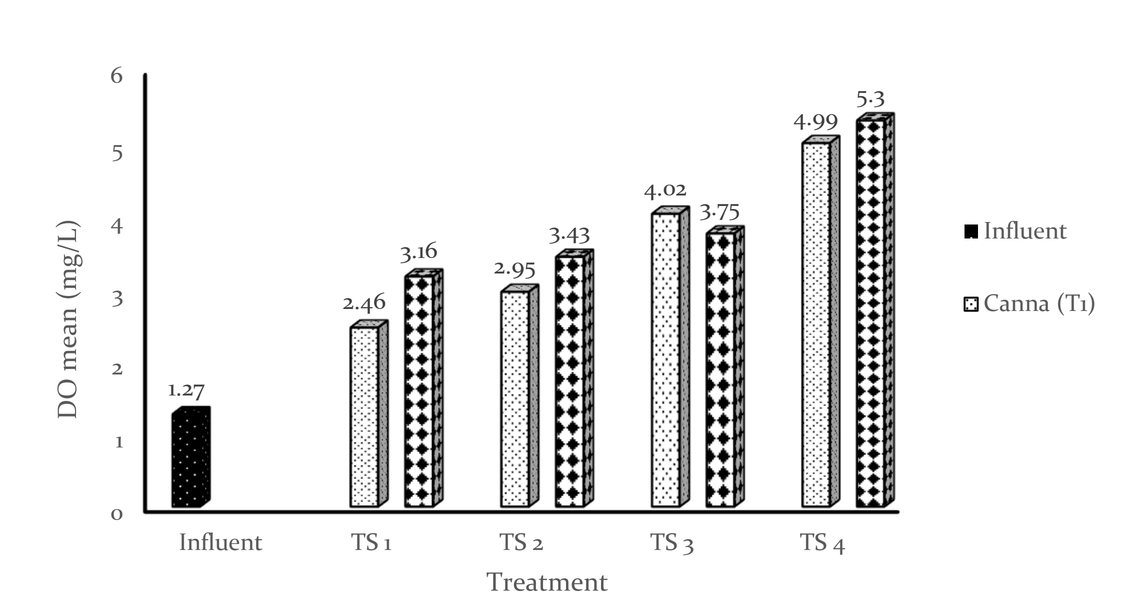

Figure 3. DO Distribution by The Depth

Both plants are able to transfer oxygen to lowest depth level. Those plants can supply oxygen because they have network / pores between cells called aerenchyma. According to Stottmeister *et el.,* (2003) and Visser *et al.*, (2000) in Li *et el.,* (2013) aerenchyma is intercellular space which functions to transfer oxygen from air through leaves, stems, and roots to be distributed into root zone/rhizosphere. In rhizosphere zone many decomposing microorganisms utilize dissolved oxygen to degrade or decompose organic matter. Photosynthesis also plays role in supplying oxygen from leaves to roots.

The SSF-CW with vertical flow direction also supports oxygen supply compared to SSF-CW with horizontal flow direction. It occurs because the vertical form makes water conditions unstable and fluctuating of water level, thus oxygen in the air will be oxygenated by microorganisms on substrate and media (Stefanakis & Tsihrintzis, 2012). With the increase in dissolved oxygen, the system turns more aerob, and it has influence on degradation or overhaul of organic matter by microorganisms both in roots zone or rhizosphere as well as in media. Sufficient oxygen supports microorganisms to degrade organic matter and carry out metabolism.

CONCLUSION

Sub Surface Flow Constructed Wetland with *Canna indica* and *Cyperus alternifolius* are a viable alternative for domestic wastewater treatment for organics and phosphate removal and can also increase dissolved oxygen in system. The removal efficiency of BOD with *Canna indica* and *Cyperus alternifolius* in SSF-CW was 42,69% and 48,86% respectively. Meanwhile, the highest removal efficiency of phosphate (PO4) was by using *Cyperus alternifolius* plants 67,21%, while with *Canna indica* plants reaches 65,70%. The ability of pollutant removal and aesthetic appearance of both plants make it easily accepted by the community for the construction of wetlands. As such it can provide an alternative solution for controlling environmental pollution problems in settlement areas as a low cost and less maintenance wastewater treatment system.

REFERENCES

Fildzah, A., Suryani, R., Dian, A., Fitriana, G., Nisa, A. C., & Samudro, G. (2016). Pengolahan Limbah Domestik Kawasan Pesisir Dengan Subsurface Constructed Wetland Menggunakan Tanaman Jatropha curcas L. *Jurnal Sains &Teknologi Lingkungan*, *8*(2), 80–88. https://doi.org/10.20885/jstl.vol8.iss2.art2

García-Ávila, F., Patiño-Chávez, J., Zhinín-Chimbo, F., Donoso-Moscoso, S., Flores del Pino, L., & Avilés-Añazco, A. (2019). Performance of Phragmites Australis and Cyperus Papyrus in the treatment of municipal wastewater by vertical flow subsurface constructed wetlands. *International Soil and Water Conservation Research*, *7*(3), 286–296.https://doi.org/10.1016/j.iswcr.2019.04.001

Hammer, Mark J., & Mark J. Hammer Jr. (2014). *Water and Wastewater Technology. Seventh Edition.* London: Pearson.

Haritash, A. K., Sharma, A., & Bahel, K. (2015). The Potential of Canna lily for Wastewater Treatment Under Indian Conditions. *International Journal of Phytoremediation*, *17*(10), 999–1004. https://doi.org/10.1080/15226514.2014.1003790

Li, L., Yang, Y., Tam, N. F. Y., Yang, L., Mei, X. Q., & Yang, F. J. (2013). Growth characteristics of six wetland plants and their influences on domestic wastewater treatment efficiency. *Ecological Engineering*, *60*, 382–392. https://doi.org/10.1016/j.ecoleng.2013.09.044

Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia. (2016). Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor P.68/MENLHK-SETJEN 2016 Tentang Baku Mutu Air Limbah untuk "Kegiatan IPAL Domestik Komunal dan Kegiatan Industri Sabun".

Nivala, J., Wallace, S., Headley, T., Kassa, K., Brix, H., Afferden, M. Van, & Müller, R. (2012). Oxygen transfer and consumption in subsurface flow treatment wetlands. *Ecological Engineering*. https://doi.org/10.1016/j.ecoleng.2012.08.028

Parde, D., Patwa, A., Shukla, A., Vijay, R., Killedar, D. J., & Kumar, R. (2021). A review of constructed wetland on type, treatment and technology of wastewater. *Environmental Technology and Innovation*, *21*(xxxx), 101261. https://doi.org/10.1016/j.eti.2020.101261

Raphael, O. D., Ojo, S. I. A., Ogedengbe, K., Eghobamien, C., & Morakinyo, A. O. (2019). Comparison of the performance of horizontal and vertical flow constructed wetland planted with Rhynchospora corymbosa. *International Journal of Phytoremediation*, *21*(2), 152–159.https://doi.org/10.1080/15226514.2018.1488809

Reddy K. Ramesh, & Ronald D. DeLaune. (2008). *Biogeochemistry of Wetlands: Science and Applications.* Florida: CRC Press.

Shahi, D. H., Eslami, H., Ehrampoosh, M. H., Ebrahimi, A., Ghaneian, M. T., Ayatollah, S., & Mozayan, M. R. (2013). Comparing the efficiency of *Cyperus alternifolius* and Phragmites australis in municipal wastewater treatment by subsurface constructed wetland. *Pakistan Journal of Biological Sciences*, *16*(8), 379–384. https://doi.org/10.3923/pjbs.2013.379.384

Stefanakis, A. I., & Tsihrintzis, V. A. (2012). Effects of loading , resting period , temperature , porous media , vegetation and aeration on performance of pilot-scale vertical flow constructed wetlands. *Chemical Engineering Journal*, *181–182*, 416–430. https://doi.org/10.1016/j.cej.2011.11.108

Suswati, A. C. S. P., & Wibisono, G. (2013). Pengolahan Limbah Domestik dengan Teknologi Taman Tanaman Air (Constructed Wetlands). *Indonesian Green Technology Journal*, *2*(2), 70–77.

Sylla, A. (2020). Domestic wastewater treatment using vertical flow constructed wetlands planted with Arundo donax, and the intermittent sand filters impact. *Ecohydrology and Hydrobiology*, *20*(1), 48–58. https://doi.org/10.1016/j.ecohyd.2018.11.004

Vymazal, J., & Lenka Kröpfelová. (2008). *Environmental Pollution 14: Wastewater Treatment in Constructed Wetlands with Horizontal Sub-Surface Flow*. Berlin: Springer.

Vymazal, J. (2010). Review: Constructed Wetlands for Wastewater Treatment. *Water, 2, 530-549*. https://doi:10.3390/w2030530

Wijaya, D. H. (2018). Efisiensi Pengurangan Bahan Organik dan Fosfat dalam Limbah Domestik Menggunakan Tanaman *Heliconia psittarum* dan *Limnocharis flava* dengan Sistem *Subsurface-Flow Constructed Wetland*. Skripsi, Universitas Kristen Duta Wacana.

Yong, J., Tan, P. Y., Nor, H. H., & Tan, S. N. (2010). A Selection of Plants for Greening of Waterways and Waterbodies in the Tropics. Singapore: Chung Printing. 480 pp.