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***THE REMOVAL EFFICIENCY OF ORGANIC LOADING,
PHOSPHATES AND DETERGENTS IN WASTEWATER OF CAR
WASH SERVICE BY CONSTRUCTED WETLAND SYSTEM***

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Abstract

*The car wash wastewater has a proportion of detergent and it can cause considerable impacts to pollute the environment and health if they are not processed in well. SSVF CW is one of an alternative wastewater treatment, because it has the advantage such as wastewater flowing below the surface of the media so it reduces the smell of wastewater. The objective of this study was to determine the removal efficiency of reducing pollutants in the wastewater of treated car wash by Constructed Wetland and the influence of *Chrysopogon zizanioides* rhizosphere depth in supplying DO distribution. This experimental laboratory scale study used 2 PVC for reactor. Each pipe has 4 sampling points. The DO was measured from different depth, while the other parameters were from the effluent. The ratio of the media used was 1:3:2:4 from the top to the bottom. The SSVF CW system had high TSS removal efficiency of 94.74%, while the removal efficiency of COD, Detergent, and Phosphate was 76.21%, 54.54%, 30.65%, respectively. DO distribution at a depth of 84 cm in both pipes increased even though the root zone was only 26.5 cm.*

Keywords: *Chrysopogon Zizanioides; Detergent; Dissolved Oxygen; Subsurface Vertical Flow, Wastewater of Car Washing Service*

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INTRODUCTION

The increasing number of cars provides business opportunities such as car washing services in various places, especially in big cities. When viewed from an environmental perspective, car washing without realizing it can be one of the causes of reduced environmental quality through the waste produced, because in general there are still many car washing services that directly drain the resulting waste into the environment or water bodies without being treated first. From one car washing place, the waste discharged can reach 150 L - 350 L per day, and has parameters Chemical Oxygen Demand (COD) 302.33 mg/L, Total Suspended Solids (TSS) 172.67 mg/L, phosphate (PO₄) 5.20 mg/L, 35.95 mg/L detergent and alkaline pH (Hashim & Zayadi, 2016). In addition, if observed directly, car washing waste also has some characteristics such as cloudy, smelly and foamy.

In general, detergents in washing wastewater are composed of phosphate compounds and surfactants. Surfactants are used as basic ingredients for washing activities because they contain compounds that can lower the surface tension of water so that it can cause foam. These compounds will later be harmful to water

bodies if they are disposed of directly without prior processing, one of the effects is that it will cause a layer on the surface of the water body, namely foam produced from detergent so that it can block the process of transferring oxygen from the air into the water. Then the waste produced will also experience an increase in the nutrient content derived from organic matter and phosphate in wastewater (Kowsalya *et al.*, 2020; Azteria & Gani, 2020). The higher phosphate content will be very dangerous for the environment, because phosphate will cause eutrophication in water bodies due to uncontrolled algae growth, oxygen transfer inhibition occurs and then reduces dissolved oxygen (DO) content in water bodies and will be harmful to biota or animals. microorganisms that live in water bodies (Hammer & Mark, 2014).

In the field, there are still many car washing services that are still constrained to implement a waste treatment system due to several things, one of which is the cost and the land required is quite large. It has led to the emergence of innovations about alternative waste treatment systems that are cheap and easy to implement, namely waste treatment using an artificial wetland system or Constructed Wetland (CW) is one system that can be used for

natural waste treatment processes so that it does not require high costs. large enough. In this system many activities occur, both sedimentation and filtration (physical), adsorption and oxidation (chemical),

One type of CW that is usually used is the Subsurface Constructed Wetland (SSF CW) system in which the treated wastewater is below the surface of the media. Then in terms of flow direction, the right one to apply to densely populated settlements is vertical flow (VF) because it uses only a small amount of land, vertical flow constructed wetlands have several other advantages, including being more aerobic and also very capable of removing organic loads and TSS. To be applied in a densely populated environment, the Subsurface Constructed Wetland has advantages such as being safe from mosquito larvae and reducing odors from waste (safe for the community's perspective), besides being able to reduce waste water levels by 60-80% both BOD, COD, TSS, and nutrients from wastewater (Fildzah *et al.*, 2016).

The substrate or media affects the constructed wetland system, this is because the media such as soil, gravel and plants become one unit in the preparation of the constructed wetland. The level of media capability affects the residence time of wastewater and will result in contact

between microorganisms with wastewater and plants also affects the spread of oxygen into the CW system produced by plant roots (Vymazal, 2010). TPlants also have an important role in the degradation of pollutants. Plants will absorb certain compounds in the waste that are needed as nutrients for plants, then plants are also associated with microorganisms in adsorption of particles and metal ions contained in wastewater by supplying oxygen (Dewi *et al.*, 2019).

One of the plants that can be used to treat car washing waste is *Chrysopogon zizanioides* or its local name is called vetiver / larasetu / usar is a plant that can grow in various types of soil because it has a fibrous root system and dense root growth capable of growing up to 3 m, this plant is easily found in various parts of Indonesia. *Chrysopogon zizanioides*. Plan able to reduce the percentage of COD parameters as much as 80.65% and TSS as much as 98.34%. In addition, the plant *Chrysopogon zizanioides* also able to reduce the parameters of ammonia and phosphate (Dewi *et al.*, 2019). The plant that also has economic value, namely at the roots it can be used as an essential oil (CABI, 2021).

Therefore, this study was conducted to determine the effectiveness of reducing organic, phosphate, and detergent loads

in car washing service waste using *Chrysopogon zizanioides* on the Subsurface Vertical Flow Constructed Wetland (SSVF) system, in addition to knowing the effect of the growth of the root zone of *Chrysopogon zizanioides* plant at the distribution of DO in the system Subsurface Vertical Flow Constructed Wetland.

MATERIALS AND METHODS

This research was a type of laboratory-scale experimental research. The waste treatment system used was SSVF CW. The reactor consisted of 2 PVC pipes, each pipe had a height of 100 cm and a diameter of 11.5 cm. The preparation of the substrate media consisted of paddy soil, gravel measuring <5 mm, gravel measuring 5-15 mm, and gravel measuring 20-30 mm, with a media arrangement ratio of 1:3:2:4 from top to bottom. Each pipe had 4 points for DO sampling, for the sampling points with a depth of 21 cm, 42 cm, 63 cm, and 84 cm from the top of the media surface. The *Chrysopogon zizanioides* plants used were neither too young nor too old. The two PVC pipes had the same HRT

(Hydraulic Retention Time), which was 1.5 days, so the entire HRT reactor was 3 days with a wastewater discharge (Q) of 1.89 mL/minute. The reactor was fed continuously from the inlet tub to the first loop to the second loop (pipe 1 to pipe 2) and then to the outlet tub. The car washing waste used for this study was taken from one of the car washing services.

The research process started from acclimatization for 4 weeks, the aim was for the adaptation process of plants to the new living environment and the growth process of microorganisms in the media. The steady state stage is achieved for 5 days by monitoring the DO value at the outlet point. After the steady state condition was reached, the physical parameters (temperature, TSS), chemical parameters (COD, phosphate, detergent, pH, and DO), and plant biology were measured (height, weight, root length, and number of leaves).

RESULTS AND DISCUSSION

Based on the results of research that has been done obtained the following data:

Table 1. The results of the average measurement of physical and chemical parameters, efficiency values, and car washing waste quality standards

Parameter	Unit	Treatment			Quality standards*	
		Inlet	Outlet	Efficiency (%)	Car wash	Motorcycle Wash
temperature	°C	26.14a	26.43a	-	±3 air temperature	
pH	-	8.38a	8.01a	-	6.0-9.0	
DO	mg/L (ppm)	2.39a	7.04b	-	-	-
COD	mg/L (ppm)	116.71a	27.76b	76.21	25	6.25
Phosphate	mg/L (ppm)	1.28a	0.89b	30.65	2^	
Detergent	mg/L (ppm)	0.33a	0.15b	54.54	1	0.25
TSS	mg/L (ppm)	100.38a	5.00b	94.74	400	100

Description:

Data that do not show a significant difference (not significant) are marked with the same letter, while data that shows a significant difference (significant) are marked with a different letter.

() Yogyakarta Special Region Regulation (DIY PERDA) Number 7 of 2016 concerning Wastewater Quality Standards for Car/Motorcycle Washing Businesses/activities*

(^) Yogyakarta Special Region Regulation (DIY PERDA) Number 7 of 2016 concerning Wastewater Quality Standards for Business/Industrial Activities Related to Soaps/Detergents*

(-) None (unit efficiency, and parameter quality standards)

Table 1 data shows the results of the measurement of existing parameters, namely the inlet and outlet treatment data of the sewage treatment system. Then there is also quality standard data obtained from local Regulation in DIY Number 7 of 2016 concerning Wastewater Quality Standards for Car/Motorcycle Washing Businesses/Activities, with this quality standard it can be seen that every parameter, both inlet and outlet treatment, has met the standard existing quality standards or not.

Temperature is one of the main factors in the process of chemical and biological reactions in microorganisms in decomposing organic matter in car washing wastewater treatment, if the temperature is too extreme it will result in a removal microorganism activity or can

even cause death, therefore temperature is needed stable in the wastewater treatment process. When viewed from the data obtained, the temperature parameter at the outlet has increased compared to the inlet, but it can still be stated to be stable because the value is not significant. With a stable temperature, the processes that occur in the sewage treatment system can run well, as evidenced by the decrease in several parameters in table 1. One of them is TSS, where the data outlet reaches 5 ppm compared to the data inlet which is quite high, reaching 100.38 ppm.

From the results of table 1. the drastic decrease in the TSS value in the constructed wetland system can be influenced by several factors. One of them was since in the constructed wetland system there was a filtration process, it can

be seen from the composition of the existing media, besides that plant roots and microorganisms that grew on the constructed wetland media also helped the process of decreasing the TSS value. In this process suspended solids with large size, particle, shape and specific gravity were filtered or deposited in the media, then smaller solids were adsorbed by microorganisms such as biofilms and were converted into biomass through the metabolic processes of microorganisms in the constructed wetland media. Another factor was the HRT of wastewater in the constructed wetland system. With the application of HRT for 3 days which resulted in the contact time of wastewater with the media in the constructed wetland system being quite long and the filtration and adsorption processes in decreasing TSS parameters went well. The in TSS parameters was also influenced by the absorption or degradation of organic compounds by microorganisms (biodegradation) aerobically in the constructed wetland system (Hammer & Mark, 2014). Then the presence of plants also affected the decrease in TSS, plants also affected the microorganism community where with good environmental conditions the waste degradation process and the sliding

process or the death of microorganisms that have the potential to increase the TSS load are reduced. It is also in accordance with the measurement results of several parameters obtained, where the TSS parameter was directly proportional to several parameters such as COD, detergent, and phosphate (Nivala *et al.*, 2012).

The COD parameter measurement described the amount of oxygen demand contained in wastewater in treating or degrading organic matter both biologically (biodegradable) and chemically (non-biodegradable). From the sewage treatment process with this constructed wetland system, there was a decrease in COD parameters from inlet to outlet, as evidenced by the data from table 1. which indicates the efficiency value of the decrease reaching 76.21%. In constructed wetlands, the removal in COD parameters can be caused by several factors. Microorganisms and plants used were interrelated and played a role in the reduction of organic compounds. The plants used had an aerenchymatic network whose main function was to play a role in transferring oxygen produced from the photosynthesis process to the roots (rhizomes). Then the oxygen produced from the plant roots was used for metabolic processes by microorganisms in

the media and root zone, this metabolic process later broke down complex organic compounds into simpler forms because microorganisms had enzymes that were used to break the hydrocarbon chains in the wastewater. After these organic compounds were changed or overhauled, these were absorbed by plants as nutrients in the form of ions and inorganic compounds (Maharjan & Pradhanang, 2017). The decrease in COD parameters can also describe a decrease in detergent and phosphate since the COD parameter was directly proportional to the detergent and phosphate parameters. The process of degradation of organic compounds by microorganisms also affected the pH value.

In the process of degradation of organic compounds by microorganisms produced CO_2 , then CO_2 reacted to water to form HCO_3^- so that it caused the pH to decrease based on the results of table 1. In the constructed wetland system, pH parameters greatly affected the activity of microorganisms to degrade organic compounds in wastewater. Broadly, microorganisms are able to work normally under optimal pH conditions, if the pH was too acidic or too alkaline, it would cause disturbances in the metabolic and respiratory systems of existing microorganisms.

Detergents were generally composed of several chemical elements, including phosphate compounds (can be tripolyphosphate), then surface active substances or surfactants, and other additional elements with different presentations according to the type of detergent used. With high surfactant content in water bodies, it will be very dangerous for biota or organisms in the water such as algae, fish and crustaceans where surfactants can lyse biological cell surfaces because they are amphiphilic (Handayani, 2020). The removal in detergent content in the constructed wetland system was due to several processes, including biodegradation and adsorption processes. Surfactant biodegradation occurred due to the presence of microbes carrying out enzymatic breakdown under aerobic conditions, the process of detergent reform mechanism was to remodel or break down complex chemical compounds into simpler compounds by microorganisms, especially in the carbon cycle (Scott & Jones, 2000). Then in the detergent adsorption process, the mechanism that occurred is that the surfactants contained in the wastewater will stick to the existing media such as gravel and soil. It is due to the existing media also had the ability to adsorb the detergent contained in the wastewater. In

the detergent adsorption process several other parameters also affected such as pH and temperature.

After the detergent was broken down, there was an element of phosphate in the wastewater. The increase in phosphate parameters can occur due to several factors. One of them was caused by an overhaul of the detergent in the wastewater, in accordance with the results of research which stated that if there is an overhaul in the detergent it will increase phosphate levels (Prochaska & Zouboulis, 2006). The decrease in phosphate can occur due to several mechanisms, namely adsorption (sticking, filtration, sedimentation), biological absorption, and complexation. The process that has the most role in constructed wetlands for reducing phosphate content is the process of biological absorption and assimilation by plants and microorganisms. The process that occurred is the activity of rhizosphere microbes on plant roots to remodel complex phosphate compounds such as orthophosphates into simple phosphate compounds. This process was referred to as the mineralization process.

Chrysopogon zizanioides plant was also able to directly reduce phosphate parameters, where this plant was also able to directly absorb certain phosphate compounds that function as nutrients for plant growth. Then there were also microorganisms that played a role in reducing phosphate levels, one of them was the polyphosphate accumulating organisms (PAO) microorganisms that played a role in aerobic conditions. Phosphate absorption was aimed at cellular formation which plays a role in aerobic conditions, in addition PAO also plays a role in accumulating polyphosphate in cells by 5 to 7% of cell biomass. In addition, the decrease in phosphate also occurred due to an adsorption process such as what occurred in the process of decreasing suspended solids parameters or TSS, where this process was a process of decreasing phosphate levels in wastewater through the process of filtration and sedimentation of insoluble phosphate elements. able to be deposited into sediment pores and bound to clay colloids (Prochaska & Zouboulis, 2006).

Table 2. Results of Biological Parameters

Parameter	Treatment					
	Pre-Sampling			Post-Sampling		
	Plant 1	Plant 2	Average	Plant 1	Plant 2	Average
Plant Height (cm)	18	11	14.5	95	110	102.5
Root Length (cm)	14	20	17	28	25	26.5
Plant Weight (gr)	47	42	44.5	61	47	54
Many Leaves	14	10	3.5	24	16	7

Table 2 shows that *Chrysopogon zizanioides* plants in each pipe are able to adapt and absorb inorganic compounds in the waste such as phosphate and detergent that have been remodeled or broken down into simpler elements and eventually become nutrients for plants. In accordance with research which states that the plants used in the constructed wetland system have an important role in reducing the parameters in wastewater, namely by absorbing/absorbing inorganic compounds from the overhaul of microorganisms. Then the phosphate parameter played a very important role in increasing biomass in plants because the increase in biomass in plants that were in an environment with a high phosphate content was more than that of a low phosphate content.(Rames & DeLaune, 2008).

Plant height for each pipe from pre-sampling and post-sampling which experienced plant height growth from 14.5 cm to 102.5 cm, it can be seen that the average plant growth reached 88 cm. It

indicates that *Chrysopogon zizanioides* plants in each pipe were able to grow, adapt and absorb inorganic compounds in waste such as phosphates and detergents that have been overhauled or broken down into simpler elements and eventually become nutrients for plants.

The root growth of *Chrysopogon zizanioides* was able to grow through the soil layer and hold soil particles with its root fibers. Therefore, with this excellent root growth ability, it is also beneficial for plants to obtain their nutrient source needs. It is also an advantage for microorganisms that live on CW SSVF media and the root zone of plants, where their oxygen intake was increasingly fulfilled.

In all measurements of plant parameters *Chrysopogon zizanioides* showed the differences in growth between the two plants, where plants in pipe 2 measured plant weight gain, number of leaves, and root length which indicated that these plants did not experience too much growth compared to plants in pipe 1.

It can be due to several factors, one of which is the lack of nutrients obtained. Due to the continuous flow of wastewater from pipe 1 to pipe 2, it is possible that a lot of

nutrients have been absorbed by plant 1. With this reduction in nutrients obtained, it is what causes plants in pipe 2 to fall or some of their leaves turn yellow.

Table 3. Average of DO (Dissolved Oxygen) Parameter Results Per point

para- meters	Treatment								
	Inlet	P1 Point 1	P1 Point 2	P1 Point 3	P1 Point 4	P2 Point 1	P2 Point 2	P2 Point 3	P2 Point 4
DO (ppm)	2.39a	6.66bc	6.66bc	6.74bcd	7.00cd	6.75bcd	6.49b	6.71bcd	7.04d

Description:

Data that do not show a significant difference (not significant) are marked with the same letter, while data that show a significant difference (significant) are marked with a different letter.

The data generated in table 3. states that for each pipe at a depth of 84 cm (Point 4) the DO distribution is still quite good, even increasing. It may be due to several factors. The first factor occurred due to root growth which is long enough to exceed 10 cm, because this plant has aerenchyma tissue or air duct holes that function as a means of transferring oxygen from the atmosphere or from the results of the photosynthesis process that occurred in the leaves to the rhizosphere. From this process, the DO distribution was still high at a certain depth according to the depth of the growth of the root zone. Another factor can be caused by the diameter of the reactor used was quite small (11.5 cm). With this fairly small diameter, root growth in *Chrysopogon zizanioides* plants did not widen but deepens, so that the oxygen distribution was more even to a certain depth even up to point 4 in each

reactor. Then other factors can also be caused by the discovery of microorganisms which may be phytoplankton in the reactor to a depth of 84 cm (Point 4 Sampling DO) in each reactor with the presence of these phytoplankton, the photosynthesis process is still running even in low light conditions. With the results of the average data outlets which experienced an increase in DO, it also had an effect on decreasing the pollutant load contained in wastewater, which could be seen from the results of the parameter data for COD, TSS, phosphate, and detergents which decreased. Then other factors can also be caused by the discovery of microorganisms which may be phytoplankton in the reactor to a depth of 84 cm (Point 4 Sampling DO) in each reactor with the presence of these phytoplankton, the photosynthesis process was still running even in low light conditions. With the results of the average

data outlets which experienced an increase in DO, it also had an effect on decreasing the pollutant load contained in wastewater, which could be seen from the results of the parameter data for COD, TSS, phosphate, and detergents which decreased. Then other factors can also be caused by the discovery of microorganisms which may be phytoplankton in the reactor to a depth of 84 cm (Point 4 Sampling DO) in each reactor with the presence of these phytoplankton, the photosynthesis process was still running even in low light conditions. With the results of the average data outlets which experienced an increase in DO, it also had an effect on decreasing the pollutant load contained in wastewater, which could be seen from the results of the parameter data for COD, TSS, phosphate, and detergents which decreased.

The less oxygen contained in the water, the more dangerous it will be for the biota in it. Dissolved oxygen (DO) was one of the important factors in reducing pollutants in the SSVF CW system, because DO was the main factor affecting the activity of microorganisms. In a constructed wetland system, the distribution of dissolved oxygen (DO) can come from various sources, including atmospheric diffusion, plant-mediated oxygen transfer, through the application of

a system such as a reciprocal or tidal land system by creating fluctuating water levels in order to attract oxygen in the air for the purposes of microorganisms that were on the substrate. The higher the oxygen content in the constructed wetland, the better the organic compounds that can be processed or degraded (Liu *et al.*, 2016).

CONCLUSION

From the results of the research that has been carried out, it was found that the Subsurface Vertical Flow Constructed Wetland (SSVF CW) system using the *Chrysopogon zizanioides* (vetiver root) plant was quite effective in processing and reducing car washing waste parameters with a fairly high reduction efficiency value on the TSS parameter by 94.74%, for COD, Detergent, and Phosphate it was 76.21%, 54.54%, and 30.65%, respectively. In the Subsurface Vertical Flow Constructed Wetland system using *Chrysopogon zizanioides* (vetiver root) plants, it was found that DO distribution up to point 4 (84 cm depth) on both PVC pipes was still increasing up to 7 mg/L even though the growth of the root zone of *Chrysopogon zizanioides* (roots) plants was found. fragrant) on both PVC pipes grew to an average of 26.5 cm.

REFERENCES

- Azteria, V., & Gani, R. (2020). PENGELOLAAN LIMBAH MINYAK PELUMAS SEBAGAI UPAYA PENGENDALIAN PENCEMARAN LINGKUNGAN. *BIOLINK : Jurnal Biologi Lingkungan Industri Kesehatan*, 6(2), 178-185.
- CABI. *Chrysopogon zizanioides* (vetiver). (2021). <https://www.cabi.org/isc/datasheet/18528934> (Diakses 4 April 2021)
- Dewi, N. R., Hadisoebroto, R., & Fachrul, M. F. (2019). Removal of ammonia and phosphate parameters from greywater using *Vetiveria zizanioides* in subsurface-constructed wetland. *Journal of Physics: Conference Series*. 1402(3). <https://doi.org/10.1088/1742-6596/1402/3/033012>
- 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>
- Hammer, Mark J., & Mark J. Hammer Jr. (2014). *Water and Wastewater Technology: Seventh Edition*. London: Pearson
- Handayani, L. (2020). Pengaruh Kandungan Deterjen Pada Limbah Rumah Tangga Terhadap Kelangsungan Hidup Udang Galah (*Macrobrachium rosenbergii*). *Sebatik*. 24(1):75-80. <https://doi.org/10.46984/sebatik.v24i1.937>
- Hashim, N. H., & Zayadi, N. (2016). Pollutants characterization of car wash wastewater. *MATEC Web of Conferences*. 47: 4-9. <https://doi.org/10.1051/mateconf/20164705008>
- Kowsalya, E., Subhashini, S., Sharmila, S., & Rebecca, L. J. (2020). Treatment of Carwash Waste Water and Its Reuse to Manage Water Supply. *International Journal of Recent Technology and Engineering*. 8(5): 3605-3610. <https://doi.org/10.35940/ijrte.e6030.018520>
- Liu, H., Hu, Z., Zhang, J., et.al. (2016). Optimizations on supply and distribution of dissolved oxygen in constructed wetlands: A review. *Bioresource Technology*. 214: 797-805. <https://doi.org/10.1016/j.biortech.2016.05.003>
- Maharjan, A., & Pradhanang, S. (2017). Potential of Vetiver Grass for Wastewater Treatment. *Environment and Ecology Research*. 5(7): 489-494. <https://doi.org/10.13189/eer.2017.050704>
- Nivala, J., Wallace, S., Headley, T., Kassa, K., Brix, H., Afferden. M. V., Muller, R. (2012). Oxygen Transfer and Consumption in Subsurface flow Treatment Wetlands. *Ecological Engineering*
- Peraturan Daerah Daerah Istimewa Yogyakarta (PERDA DIY) Nomor 7 Tahun 2016 Tentang Baku Mutu Air Limbah Untuk Usaha/Kegiatan Cuci Mobil/Motor dan Untuk Usaha/Kegiatan Industri Berkaitan dengan Sabun/Detergen
- 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. <https://doi.org/10.1016/j.ecoleng.2005.10.009>
- Rames, R. K., & DeLaune, D. R. (2008). *Biogeochemistry of Wetlands*. Taylor & Francis Group.
- Reddy K. Ramesh, & Ronald D. Delaune. (2008). *Biogeochemistry of Wetlands: Science and Applications*. Florida: CRC Press
- Scott, M. J., & Jones, M. N. (2000). The biodegradation of surfactants in the environment. *Biochimica et Biophysica Acta - Biomembranes*. 1508(1-2): 235-251. [https://doi.org/10.1016/S0304-4157\(00\)00013-7](https://doi.org/10.1016/S0304-4157(00)00013-7)
- Vymazal, J. (2010). Constructed wetlands for wastewater treatment. *Water (Switzerland)*. 2(3): 530-549.