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Linking climate change to water provision: greywater treatment by constructed wetlands

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Abstract. Climate change has been felt to take place in Indonesia, causing the temperature to increase, additional drought with more moisture evaporates from rivers, lakes, and other bodies of water, and intense rainfall in a shorter rainy season. One of the major concerns is the risk of severe drought leading to water shortages. It will affect water supply and agriculture yields. As a country extremely vulnerable to the climate change, Indonesia must adapt to the serious environmental issues. This paper aims to offer an effort of water provision by recycling and reusing of greywater applying constructed wetland systems. The treated greywater is useful as water provision for non-consumptive uses. A recent experiment was conducted on a household yard using a single horizontal subsurface flow type of constructed wetland. The experiments demonstrated that the constructed wetland systems reduced effectively the pollutants of TSS, BOD, COD, and detergent to the level that are compliant with regulatory standards. The constructed wetland has been established for almost two years however the system still works properly.

1. Introduction

Due to the rise of the greenhouse gas emissions in Indonesia, the impacts of climate change will be heavily felt by this country [1]. The impacts have been characterized by an increase of temperature, change of precipitation, a rise in sea level, and a threat to food security. One of the potential impacts of climate change would be the decrease in water availability [2]. As outlined clearly in the report of World Bank [3], the effect of climate change will come through the water cycle and are already visible.

Despite the abundance of water resources, in the dry season, water shortages are common in some parts of Indonesia due to varying climatic and geographic conditions [4]. Therefore, it is reasonable if this country receives a lot of attention as a vulnerable country in the face of climate change [1]. The most pressing area of concern at climate change is that of water security. The climate change hazards for water supply shortages had been studied based on the six indicators of vulnerability to water supply i.e., population density, land cover, water demand, confined aquifer and aquifer potential, water infrastructures, and water quality. The study found that the risk level of water supply shortage in Java-Bali is the highest among all regions in Indonesia. It was due to its dense population, built up areas domination, highest water demand for population and industrial growth [2].



The vulnerability of water supply shortage for irrigation will reduce the production of agriculture which in turn could pose a threat to food security in Indonesia [1]. The poor communities who rely on agriculture will greatly be affected by the impacts of climate change associated with the drought or water shortage [3]. The food and drinking water for daily needs will be expensive and inaccessible to the poor.

Environmental stresses like severe drought are most likely to continue. Therefore, adaptation to climate change through reducing the vulnerability of water supply shortage needs to be prepared. One of the possible efforts would be recycling and reusing of wastewater, and the cost-effective method of wastewater treatment is constructed wetland systems [5]. Water recycling and applicable technologies are key aspects to adapt to the impacts of climate change [6]. In addition, concern over water shortage issue is not only limited to the amount available to meet demand but also the quality of water. Hence, this paper aims to promote the constructed wetlands by providing a water supply for non-potable purposes as an effort to adapt to climate change and present the result of the constructed wetlands study.

1.1. Constructed wetlands

Constructed wetland systems are engineered systems which are designed and constructed to utilize the natural processes in treating wastewater [5]. These systems comprised of aquatic vegetation, substrates, water, micro-organisms and utilized complex processes involving physical, chemical, and biological mechanisms to improve water quality or remove such pollutants [7]. They have advantages such as low cost of construction and maintenance, low energy requirement compared to conventional technical wastewater treatment systems, and provide green aesthetic views [6].

Classifications of wetlands based on wetland hydrology are surface flow and sub-surface flow. Figures 1 and Figure 2 present the scheme of the types of the constructed wetlands.

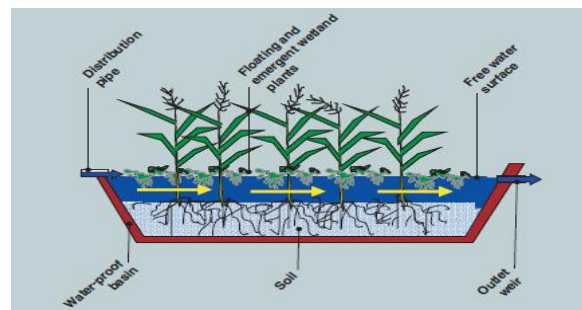


Figure 1. Surface flow [8]

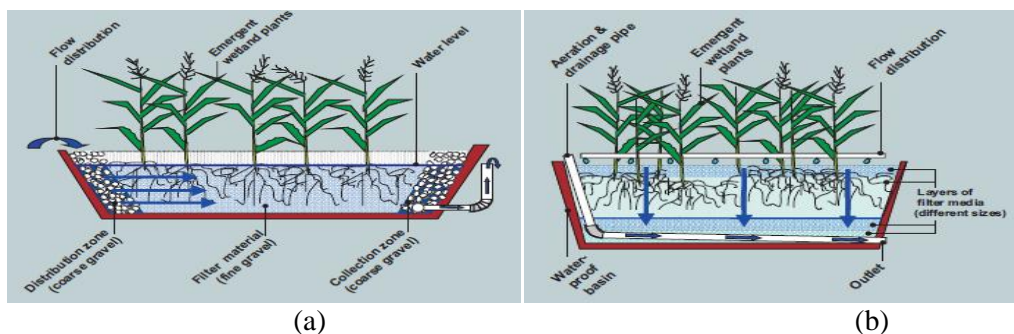


Figure 2. (a) Horizontal sub-surface flow; (b) Vertical sub-surface flow [8]

The free surface flow systems are similar to natural wetlands in which shallow flow of wastewater over saturated substrates. Based on the water flow direction, the subsurface flow wetlands are classified into horizontal and vertical sub-surface flow systems. The horizontal systems allow

wastewater to flow horizontally from inlet to outlet. The vertical systems facilitate wastewater to move down vertically to the bed. To achieve maximum removal efficiency of pollutants, horizontal and vertical-flow wetlands are combined as a single stage known as hybrid systems [9]. Constructed wetlands for wastewater treatment are potentially a good solution for treating domestic and industrial wastewater due to the simple operation and low implementation cost, and they are flexible systems which can be used for single households or for communities [6].

1.2. Aquatic plants

Aquatic plants commonly used in constructed wetlands are emergent plants, floating-leaved plants, submerged plants, and free-floating plants. Among the mentioned plants, emergent plants are the main aquatic plants used for wastewater treatments in constructed wetlands [10]. The functions of aquatic plants are to release oxygen from their root, to provide microorganisms with a source of carbon, to allow solids to settle out of the water column, to assimilate nutrients, to provide a substrate for microorganisms who are the most important processors of wastewater contaminants. Hence, plants play an important role in wastewater treatment wetland [11,12]. Large aquatic plants growing in wetlands, called macrophytes, have an additional site-specific value by making wastewater treatment systems aesthetically pleasing [6,10].

1.3. Substrates

Substrates also play an important role in constructed wetland systems. They provide a suitable growing medium for plants, allow the movement of wastewater flow, support biochemical and chemical transformation, and provide sites of removed pollutants [9]. Types of substrates commonly used for constructed wetlands wastewater treatment are natural materials such as sand, gravel, clay, limestone, zeolite, etc. Recently, an industrial by-product of substrates like fly ash, coal cinder, alum sludge, oil palm shell, etc. and artificial products like activated carbon, lightweight aggregates, compost, calcium silicate hydrate, and ceramic were also used [7].

1.4. Micro-organisms

There are various micro-organism communities in a wetland, both in aerobic and un-aerobic conditions, comprising many types of bacteria, fungi, algae, and protozoa, including pathogenic viruses. They live in the natural conditions of water, substrate, and the roots of aqua plants. They consume organic and nutrient loads in the wastewater, so that the pollutant existing in the wastewater could be reduced, destroyed, or even removed [13,14]. Among the micro-organisms, *Escheria coli* is commonly used as an indicator of faecal contamination [15]. Removal of pathogen indicated by coliform bacteria (fecal coliform and total coliform) is to be the priority in wastewater treatment in developing countries [16]. In addition, removal of coliform bacteria more than 99% would be a target of constructed wetland design criteria [9].

1.5. Application of constructed wetlands

Today, the application of constructed wetlands in various wastewater purification systems is popular all over the world, especially in developed countries [5,6,7]. In Denmark, the application of constructed wetlands for two decades of experience shows that the systems are generally efficient in removing TSS and BOD concentration to be less than 20 mg/L [17]. The use of surface water flow and subsurface flow constructed wetlands for various wastewater originated in a range of industries, aqua farms, agricultural, animal, and petrochemical wastes, highway runoff, etc were reviewed in [5]. Greywater treatment systems for households and neighborhoods in low and middle-income countries were discussed in detail by [13]. The application of constructed wetland system in developing countries is however still very limited [16] including In Indonesia.

2. Greywater Treatment

Greywater is the wastewater generated from domestic activities in bathrooms, laundry, and all washing in the kitchen in households and other buildings [15]. The wastewater generated from the toilet is considered blackwater which may not be reused due to the high concentration of harmful viruses and bacteria. The composition of greywater greatly depends on the quality and type of water supply and household activities [13,15]. Bathroom greywater contains soaps, shampoos, toothpaste, and other body care products, traces of urine and feces. Greywater from laundry contains chemicals from detergents. Kitchen greywater contains food residues, oil & fat, and dishwashing detergent. Greywater nonetheless contains micro-organisms as a result of its contact with human body. However, the concentrations of micro-organisms are substantially lower than that of blackwater and are therefore much safer to be recycled and reused. In addition, although greywater is generally less polluted than other wastewater, it may still contain pathogenic microorganisms, suspended solids, and other household substances or chemicals [13]. Even though greywater is less contaminated than blackwater, the large volume of greywater produced will contribute to the total pollution of domestic wastewater discharged into existing drainage systems. In Indonesia, domestic wastewater contributes to the amount of 60% pollution in the receiving natural water systems [18].

In general, households, apartments, and business areas in cities in Indonesia already separate greywater from blackwater. Due to one of the most serious impacts of climate change is drought or water shortages, recycling and reusing greywater for providing non-consumptive water source would be a significant effort to anticipate the drought. The advantage of recycling greywater is that it is a large source with a low organic content [6]. In addition, greywater is produced regularly, available throughout the year, and can be readily reused for domestic application. Therefore, the treatment of greywater would be an innovative water provision concerning water supply shortages impact for climate change.

3. Material and methods

The study was performed within a household yard located in the city of Surakarta, Central Java, Indonesia. The site is characterized by a humid tropical climate region. A single horizontal subsurface flow constructed wetland was used to investigate pollutant removal efficiency of greywater from a single house. The constructed wetland was made with a dimension of 1.7 m x 0.7 m x 0.7 m (L x W x D) and filled with river sand and gravel as its substrate. At the inlet and outlet zone of the constructed wetland, gravels with a diameter of 1-3 cm were filled to 50 cm deep and 20 cm long. In the plantation zone, river sands with its permeability of 5.48×10^{-5} cm/sec were set up for 130 cm long. The locally available macrophyte plant of *Cyperus* was used and planted in the plantation zone at 25 cm interval.

Before entering the constructed wetland, the greywater was mechanically pre-treated in a sedimentation tank. The plants need to be acclimatized by discharging the greywater in the constructed wetland with gradual concentration from 25 to 100% within four weeks. Greywater was distributed across the width of the system. The influent and effluent samples were collected at the inlet and outlet respectively through a Ø25 mm pipe. Water samples were collected in 1.5 liters of plastic bottles, stored at 4°C, and transported to the laboratory. Household greywater is produced daily and directly accumulated in the sedimentation tank, therefore this study applied hydraulic retention time of one day. The parameters to be monitored were total suspended solids (TSS), the power of hydrogen (pH), 5 days biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), detergent, and oil & grease. The first and the second study were carried out in November 2015 and August 2017 respectively.

4. Result and discussion

The efficient removal of the greywater treatment was checked by testing the influent and effluent water quality. The result of the effluent testing would be confirmed with the Regulation of Ministry of Environment, the Republic of Indonesia, number 5 the year 2014, about the standard of wastewater

quality, and the Regulation of Government, Republic of Indonesia, number 82 the year 2001, about management of water quality and controlling of water pollution.

The second experiment aims to get to know how the performance of the constructed wetland after two-year establishment. Results of the first and second experiments were presented in table 1.

The study in 2015 resulted in a high removal of suspended solids (TSS). Suspended solid is removed primarily through the mechanism of sedimentation and interception [6]. The solid removal efficiency ranged from 95.5% to 99.6% with an average reduction of 98.1%. TSS at the outlet varied between 2-10 mg/L. In 2017, the TSS removal still achieved a high rate of 95.4%. The level concentration of 39 mg/l at the outlet is due to the very high level of the TSS concentration at the inlet. However, based on the Environment Ministry standard, the TSS level is still much safer (< 100 mg/l) to the environment.

Table 1. The removal percentage of greywater treatment

Parameter		Year 2015									Year 2017		
		3/11 Inlet	4 /11 Outlet	%	15/11 Inlet	16/11 Outlet	%	26/11 Inlet	27/11 Outlet	%	22/8 Inlet	23/8 Outlet	%
TSS	mg/l	461.0	2.0	99.6	238.0	2.0	99.2	222.0	10.0	95.5	840.0	39	95.4
pH	-	5.2	6.9		6.1	6.5		5.3	6.8		7.1	5.6	
BOD	mg/l	496.0	9.5	98.1	850.2	17.2	97.9	528.7	2.2	99.6	1372.0	142.0	89.6
COD	mg/l	1254.0	26.6	97.8	1862.5	37.2	98.0	1252.0	6.1	99.5	4067.5	414.2	89.8
Detrgt	mg/l				76.4	0.1	99.9				9825.6	95.5	99.0
O&G	mg/l	2.2	3.6					4.8	2.6		-		

The pH of water at the inlet and outlet remains in the allowable level (5 – 9) of the regulatory standards. Both studies, in 2015 and 2017, demonstrated that the removal of BOD and COD are very high. The treatment efficiency of BOD and COD in 2015 varied between 97.9-99.6% and 97.8-99.5% respectively. In 2015, the outlet BOD concentrations were 9.5 mg/l, 17.2 mg/L, and 2.2 mg/l. All values are below the threshold of 100 mg/L as set by the Environment Ministry standard. The values of 9.5 and 2.2 mg/l, which are less than 12 mg/l, fulfill the requirement of irrigation water standard of the Government Regulation. However, the one of 17.2 mg/l is a little bit higher than that of 12 mg/l need. The outlet COD concentrations ranged between 6.1-37.2 mg/L. It fulfills the quality standard of class IV (< 100 mg/l) for irrigation; moreover, it is compliant with class III (< 50 mg/l) for irrigation, livestock, fish farm, and other outdoor uses as set by the Government Regulation. In 2017, the constructed wetland, which has been established for almost two years, removed efficiently both parameters of BOD and COD, achieving more than 89% of removal. The concentration levels of both parameters at the outlet, which are higher than 100 mg/l, are certainly due to the very high level of both BOD and COD concentrations of the household greywater to be treated at that time. However, the magnitude of 89% removal after two years establishment indicates the constructed wetlands still work properly.

Typically, household greywater contains high concentrations of detergent. The constructed wetlands removed the detergent successfully, resulting in a very high-efficiency percentage of 99.9% and 99% in the study of 2015 and 2017 respectively. Unfortunately, the removal of oil & grease in the study could not be well defined because their removal is not consistent. The Government Regulation did not set such conditions of detergent and oil & grease parameters for class IV (irrigation use) water quality, however, further studies should examine the removal of both parameters by which the quality standard of water for class III and II can be determined.

Water for gardening or irrigation purposes (class IV or even class III) does not need such water qualities as high as the drinking water – class I. Therefore, the treated greywater resulted from the constructed wetland system could provide a water source for agriculture and other non-consumptive uses. In addition, the treated greywater will remain available as long as people use water for their activities during the period of climate change.

5. Conclusion

The separation of greywater and blackwater which is commonly applied in most households and business areas would be a big step toward water provision regarding water shortages. Using treated greywater is one of the methods which can be helpful in dealing with environmental climate change. By recycling greywater and reusing for irrigation/agriculture and other non-consumptive needs, saving a large amount of drinking water can be obtained.

The study of greywater treatment using constructed wetland system demonstrated that the system can effectively reduce contaminants of TSS, BOD, COD, and detergent to the levels that are compliant with regulatory standards for agriculture. After two years of its establishment, the constructed wetland system is still capable to remove the greywater pollutants in a significant amount of removal, hence, using the power of nature and not manmade chemical the constructed wetlands still work properly. The reuse of treated greywater considered as a new water resource will reduce water consumption and decrease water cost from water-piped supply services. Thus, constructed wetland systems are a viable option for removing contaminants from wastewater, simultaneously providing water resource for non-potable uses, and getting a green aesthetic environment.

The constructed wetland systems can be applied on the individual household yard or on a larger scale open space for communities. However, public awareness campaign should be carried out related to water shortage issues due to climate change impact. In addition, public campaigns on the application of constructed wetlands technology need to be deployed to cope with the water shortages.

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References

- [1] Mariah M 2010 *G. Majority E-J.* **1** 31-45
- [2] Djoko S A S, Oman A and Budhi S "Impacts of climate change on the sustainability of water supply in Indonesia" <http://www.researchgate.net> 2010 [online] available: <http://www.researchgate.net/publication/283056995> [Accessed: 10-04-2016]
- [3] World Bank "Indonesia: Climate Change" (Washington, DC: The World Bank) <http://www.go.worldbank.org> 2010 [online] Available: <http://go.worldbank.org/HQQFW5MV70> [Accessed: 20-11-2015]
- [4] Mohamad AF 2014 *Water* **6** 2000-2020
- [5] Jan V 2010 *Water* **2** 530-549
- [6] Heike H, Christopher P, Martina W and Elizabeth von M 2011 *Technology review of constructed wetlands* (Germany: Gesellschaft fur Internationale Zusammenarbeit/GIZ) pp 9-17
- [7] Haiming W, Jian Z, Huu H N, Wenshan G, Zhen H, Shuang L, Jin L F and Hai L 2015 *Biores. Tech.* **175** 594-601
- [8] Martin G 2008 *Constructed Wetland: A Promising Wastewater Treatment System for Small Localities* (Grafica Biblos, Peru) pp 7-8
- [9] Robert H K and Scott D W 2009 *Treatment Wetlands* second ed. (Boca Raton: Taylor and Francis Group CRC Press) p 65
- [10] Jan V 2011 *Hydrobiologia* **674** 133-156
- [11] Hans B 1994 *Water Sci. Tech.* **29** 71-8
- [12] Hans B 1997 *Water Sci. Tech.* **35** 11-7
- [13] Antoine M and Stefan D 2006 *Greywater Management in Low and Middle-Income Countries* Sandec Report No14/6 (Switzerland: Eawag) pp 1-7
- [14] Peter F R 2006 *J. Env. Bio.* **2** 78-89
- [15] Eva E, Karina A, Mogen H and Anna L 2002 *Urban Water* **4** 85-104
- [16] Amelia K 2001 *Ecol. Eng.* **16** 545-60

- [17] Hans B, Schierup H, and Arias C A 2007 *Water Sci. & Tech.* **56**. 63-8
- [18] Diana H, Sulistyoweni W, Setyo S M and Robertus W T 2013 *European Sci. J.* **9** 17 230-1