The Use of Greywater for Hydroponics Plant in Griya Katulampa Bogor City

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Abstract. The daily activities of the community in Griya Katulampa which are washing clothes, cooking, and activities in the bathroom produce greywater. Greywater from the activity directly flows to the Ciliwung River. This has the potential to cause pollution in river water bodies. The purpose of this paper was to publish the results of research on the impact of the use of filtered greywater for hydroponic plants. This study used experimental methods in the field to build bioretention demonstration plot that is used to filter greywater for hydroponic media of various types of leaf vegetable plants. Based on the results of the study, the use of individual greywater was 171.2 litres/person/day. From the results of the observations, it was shown that hydroponic growth at 4 weeks (harvesting time) of the highest productivity were water spinach (96.9%), lettuce (75.0%), and spinach (51.5%). Water spinach as a potential plant at 4 weeks had an average growth rate of 31 cm high, 2 stems, 30 leaves. Filter media used to produce the highest productivity of water spinach on the leaf part was the combination media of active charcoal-cyperus. Leaf is a part of water spinach plant that is commonly consumed by the community.

1. Introduction

Background

Bogor City has been declared as a Water Sensitive City involving various parties, including the government, academic, business, community, and media. Water Sensitive City is a holistic vision in integrated water resource management that has purpose to protect and maintain the health of sources and waterways, reduce flooding, and recycle wastewater. The purpose of Water Sensitive City is to integrate water resource management and urban planning that provide broader benefits such as increasing biodiversity, improving the function of public spaces, healthy waterways and empowering communities [1]. In the concept of Water Sensitive City there are several steps that must be taken, one of which is "Sewerage City". Sewerage City is a city that leads to a system of developing waste disposal far from housing on the right channel. The purpose of Sewerage City is to create a clean and protected environment from diseases caused by greywater. Greywater is the water collected separately from sewage flow that originates from clothes washers, bathtubs, showers and sinks, but does not include...
waste water from kitchen sinks, dishwashers, and toilet [2]. The characteristics of greywater depend firstly on the quality of the water supply, secondly on the type of distribution both drinking water and the grey waste water (from piping, chemical, and biological processes in the biofilm on the piping walls), and thirdly from the activities in the household [3]. The greywater in urban, rural, and dormitory have concentration of TSS, BOD, COD, and pathogens before storage and reuse [4].

Griya Katulampa is an organized settlement in the Ciliwung River riparian and has a variety of water sources from PDAMs and springs. The Griya Katulampa community has independently managed springs used for non-consumption activities. However, Griya Katumpa has not had greywater management, so that greywater flows directly to the drainage canal and the Ciliwung River. The greywater has a dangerous effect that is increasing in salinity, boron, and surfactants that can damage the properties of plants and pollute groundwater and the spread of pathogens in improving health. Greywater is also very dangerous to human health because there are several bacterial contaminants including *Escherichia Coli* and *Salmonella* [3]. So that the need to manage greywater is to reduce environmental pollution from the pollution of greywater to minimize the impact on human health in densely populated residential areas. Management of greywater requires an easy, inexpensive, and effective way so that it can be used by the community sustainably. Bioretention is a technology to manage greywater by absorbing and diverted by vegetation followed by vertical filtration by using soil as a medium of absorption. Greywater that comes from the bioretention process will be used for the hydroponics of spinach, water spinach and lettuce which can be consumed by the community.

Hydroponics is a method of farming without land which has many benefits for society and environment. Hydroponics can produce vegetables and fruits to support food and nutrition security for families and society at large scale. Hydroponics can produce economic value because hydroponic products are more qualified and can be marketed at the right price. The benefits of hydroponics for the environment can provide greenery and beauty. The purpose of the paper was to determine the quantity and quality of domestic greywater at Griya Katulampa and to know the impact of filtered greywater for hydroponic plants.

2. Research Methods

Location and Times

This research was conducted in 3 months from March to June 2018 in organized settlement in Griya Katulampa, Kelurahan Katulampa, Bogor City (Figure 1).

Tools and materials

Tools and materials used for hydroponic installations were paralon pipes (33 cm long and 4 inch diameter), netpot (5 cm in diameter and 7 cm in height), rockwool, water spinach seeds, spinach seeds, and lettuce seeds. Tools and materials used for bioretention demonstration plots were plastic container boxes, filter media (palm fiber, burlap sacks, active charcoal, sawdust), and plant absorbent (cyperus, *melati air*, and kana), top soil, sand, gravel, nets, paralon, and knee. The tools and materials to test the quality of greywater were a sample volume bottle of 1.5 L and a water collected with a volume of 5 L.

Data Collection Methods

Hydroponic Plant Data Collection

Planting hydroponics began with a seedling in rock wool stored in plastic trays within 2 weeks. Seeds that grow from 3 - 5 cm were moved to the net pot. The hydroponics had 96 holes consisting of 32 water spinach plants, 32 lettuce plants, and 32 spinach plants (Figure 2). Data collection on plant height, amount of leaves, and amount of stems in hydroponic plants showed growth hydroponics plant.
Bioretention Demonstration Plot Data Collection

Location of water sampling the quality before process bioretention or existing greywater at one point in communal drainage. Taking water samples at the beginning of the construction of the bioretention demonstration plot based on water used assumptions for household activities. Taking water samples carried out at 06.00 - 10.00 (morning) based on maximum water usage time. The sampling of greywater was taking out using a 1500 ml bottle for all parameters.

Data Analysis Methods

Status of the quality of pollution greywater

Analysis of water quality status used the Nemerow Pollution Index method in accordance with the Decree of the State Minister of Environment No. 115 of 2003 Appendix II concerning Guidelines for Determining the Status of Water Quality. To find out the level of pollution of greywater, used the following formula:

$$P_{ij} = \sqrt{\left(\frac{Cl}{Lij}\right)^2 M^2 + \left(\frac{Cl}{Lij}\right)^2 R^2}$$

Information:
Lij = Concentration of water quality parameters stated in the quality standard
Ci = Concentration of water quality parameters in the field
Pij = Pollution index for designation
(Cl / Lij) M = maximum Cl / Lij value
(Cl / Lij) R = Cl / Lij value on average
After obtained PI value, determine the water quality status with the following conditions:

| PI Value | Water quality standard          |
|----------|--------------------------------|
| 0 ≤ Pi ≤ 1.0 | Meet quality standard, good condition |
| 1.0 ≤ Pi ≤ 5.0 | Small pollution          |
| 5.0 ≤ Pi ≤ 10 | Moderate pollution         |
| Pi ≥ 10     | Heavy pollution             |

**Hydroponic Plant Data Analysis**

Analysis of hydroponic plants was calculating the percentage of plant growth. The percentage of hydroponic plant growth was calculated by the following formula:

\[
\text{Percentage} = \frac{\text{Number of seeds plants growing}}{100\%}
\]

Analysis of average growth rates, growth of leaves, and growth of stems were calculated using the following formula:

\[
\text{Growthrate} = \frac{\text{Amount of growth planting}}{\text{Number of plants}}
\]

**Data Analysis of Bioretention Demonstration Plots**

The construction of the bioretention plots made from a plastic container box measuring 48 cm in length, 33 cm in width, and 33 cm in height (Figure 2). Bioretention is the technology of absorbing waste water diverted by vegetation with organic mulch absorbing media, such as sawdust, activated charcoal, burlap sacks, and palm fiber. The other bioretention filter media were sandy soil, top soil, and gravel. The composition of each filter media includes 50% sandy soil, top soil 20-30%, and mulch 20-30% (PGC 2009). In this study three vegetations were selected as absorbers of greywater in the bioretention box such as Kana (*Canna sp*), Melati Air (*Echinodorus palifolius*), Cyperus (*Cyperus papyrus*).

![Bioretention box design](image)

Figure 2 Bioretention box design

This process started from greywater flowing into the bioretention until the quality of greywater better. Water quality before the bioretention process was compared with the quality of water after the
bioretention process so that it will show how the impact after absorption of grey water parameters such as pH, BOD, COD, TSS, oil and grease, NH₃, and total coliform. Greywater came from the bioretention process that will be used for hydroponic plants.

In this study analyzed that grey water from each individual gave bioretention water requirements. The calculation steps were as follows:

a. The volume of greywater going to the bioretention box was calculated by the following formula:
   \[ V_{\text{inlet}} = V_{\text{individual\ greywater}} \times \text{the number of sampel people} \] ..........................(4)

b. The volume of greywater stored in the bioretention box was calculated as follows:
   \[ V_{\text{storage}} = (V_{\text{bioretention plot}} - V_{\text{media filter}}) \times \text{amount of bioretention} \] ............(5)

c. Evapotranspiration of pollutant absorbent plants was calculated using the following formula:
   \[ E_{\text{vapotranspiration}} = \text{plant evapotranspiration} \times \text{bioretention surface area} \] ...........(6)

d. The volume of hydroponic plant water needs was calculated by the following formula:
   \[ E_{\text{hydroponic requirements}} = \text{water consumption net pot} \times \text{amount of net pot} \] ...........(7)

e. The volume of water requirements such as bioretention as the volume of greywater absorbed was calculated as follows:
   \[ V_{\text{bioretention requirements}} = V_{\text{storage}} + E_{\text{vapotranspiration}} + E_{\text{hydroponic requirements}} \] ...........................................(8)

f. The volume of greywater flowing into drainage was calculated by the following formula:
   \[ V_{\text{greywater}} = V_{\text{greywater inlet}} - V_{\text{absorbed greywater}} \] ...................................(9)

g. Water requirement for bioretention box per m² was calculated using the following formula:
   \[ W_{\text{requirements}}/(m²) = \frac{V_{\text{bioretention box bioretention}}} {\text{bioretention surface area}} \] ...........................................(10)

h. Water requirement for each person for the bioretention tank can be calculated as follows:
   \[ W_{\text{requirements}} \left( \frac{\text{person}} {m²} \right) = \frac{V_{\text{of person daily greywater}}} {V_{\text{of net pot}}} \] ...........................................(11)

Information:
Volume inlet: liters / day
Volume storage: liters / day
Evapotranspiration: liters / day
Hydroponic requirements: liters / day
Volume bioretention requirements: liters / day
Volume greywater: liters / day
Bioretention surface area: m²
Netpot surface area: m²

Analysis of Greywater Quality
Analysis of greywater quality was done by comparing the quality standards. The purpose of this analysis was to determine the level of greywater pollution by comparing the measured parameters with water quality standard parameters in accordance with the Minister of Environment Regulation of the Republic of Indonesia (LH Regulation) No. 68 of 2016 concerning Domestic Wastewater Quality Standards and Decree of the Minister of Environment 115 of 2003 concerning Guidelines for Determining the Status of Water Quality.

3. Results and Discussion

The Quality and Quantity Greywater of Griya Katulampa
The quality of greywater before the bioretention process in Griya Katulampa had been measured by the index of no pollution (Table 1). TSS parameter of 31.50 mg/l was above the quality standard. TSS can be caused by population greywater such as food scraps, vegetables, meat, fibers, fruit, and dust particles that will become suspended material. TSS concentration will cause quite high turbidity in greywater. Especially hard-to-decompose waste fibers derived from clothing (polyester, nylon, and polyethylene), detergent and soap, and colloids that cause blockages in waterways [6].

| Parameter  | Unit   | Standard | Griya Katulampa |
|------------|--------|----------|-----------------|
| TSS        | mg/l   | 30       | 31.50*)         |
| pH         | -      | 6.0 – 9.0 | 6.55            |
| BOD        | mg/l   | 30       | 22.80           |
| COD        | mg/l   | 100      | 95,3996         |
| NH₃        | mg/l   | 10       | 0.04            |
| Oil and grease | mg/l | 5  | 1.50            |
| Coliform group | amount/100 ml | 3000 | 1500 |

The volume of greywater in Griya Katulampa from 4 houses consisting of 16 people. The total volume of daily greywater from 4 houses was 2.739 liters/day. The volume of individual greywater in Griya Katulampa was 171.2 liters/day. The potential pollution volume of greywater at Griya Katulampa was 386.398.4 liters/day. The volume of daily greywater comes from the use of water for daily activities such as bathing, cooking, washing clothes, washing dishes, washing hands, and ablution. The compounds contained in greywater varies from source to source depending on lifestyle, habits, equipment installation, and the use of chemicals in daily use [3].

| House | People | Activity | Greywater Volume (liter/day) |
|-------|--------|----------|------------------------------|
| GK 1  | 6      | Washing cloth, plate, and hands, bathing, cooking. | 1.173,9 |
| GK 2  | 4      | Washing cloth, plate, and hands, bathing, cooking, ablution | 804.8 |
| GK 3  | 2      | Washing cloth, plate, and hands, bathing, cooking | 332.8 |
| GK 4  | 4      | Washing cloth, plate, and hands, bathing, cooking | 427.8 |
| Total | 16     |          | 2.739.3                      |

Griya Katulampa was included in commercial housing with a population density of 159 inhabitants / ha. Griya Katulampa has an area of 14.2 ha with 2,257 residents and 460 houses. In managing water resources in Griya Katulampa, black water channel and greywater channel have been separated. Black water flows to septic tanks, while greywater uses pipelines to drainage which will flow to Ciliwung River. The social conditions of the community especially education and knowledge are very influential.
in managing water resources. The characteristics of the Griya Katulampa community were classified as educated and had middle to upper economic abilities [7].

The bioretention box has a volume of 52.27 liters with a size of 48 x 33 x 33 cm. The bioretention box made from plastic container boxes, plant absorbent, organic mulch, and filter media as absorption media. Greywater flowed continuously to bioretention box and hydroponic pipes. The water capacity retained in a bioretention box was 14.02 liters. The volume of water stored in the plot was 224 liters / day. The volume of daily greywater in the bioretention plot in Griya Katulampawas 2,739 liters / day from 16 people and 4 houses. In the bioretention unit, there was an evapotranspiration process which results in a reduced quantity of water in this unit, because plants need water for photosynthesis. Based on the results of the study [8] showed that pollutant absorbent plant evapotranspiration was 2.05 mm / day. The pollutant absorbent evapotranspiration in this study was 27.8 liters / day. The quantity of greywater will be reduced by evapotranspiration, hydroponic plant water requirements, and absorption in the bioretention box. Based on on the results of the study [9] showed that the rate of water consumption of hydroponic plant was 2.09 mm / day. Requirements water consumption of hydroponic plants in hydroponic pipes was 2 liters / day. The amount of water requirements such as bioretention includes water stored in bioretention box, evapotranspiration, and hydroponic water requirements. The amount of water stored in the bioretention box was 224 liters / day, evapotranspiration was 27.8 liters / day, and hydroponic needs was 2 liters / day. Bioretention process can be reduced 253.8 liters / day greywater volume. The volume of greywater flowed into the drainage channel was 2,485.2 liters / day. The volume of greywater absorbed by the bioretention process in Griya Katulampa was 9.2%, which came from 16 people and 4 houses. The amount of reduction in the volume of greywater individually obtained 15.86 liters / person / day. Base on this study, it was found that the volume of greywater from 1 person was able to provide water for 9.20 m² bioretention.

**Hydroponic Plant Growth**

Based on observations, the average percentage growth of hydroponic plants in Griya Katulampa was 72.80% (Table 2). The highest percentage occurred in observation 2 with a timerange of 3 weeks. Hydroponic plants that have the highest productivity was water spinach as much as 74.46% (Figure 3). Water spinach is a type of plant that has a long life and fast growth. Water spinach plant is suitable to be planted in the Bogor region with productivity of 56.66%. Water spinach is suitable for growing hydroponic plants because water spinach grows in low-lying areas up to an altitude of 1000 mdpl, at a temperature of 20-30 °C, sunshine identity around 10 hours with PH 5.5 - 6.5 [10].

| Plant            | Observation 1 (%) | Observation 2 (%) | Observation 3 (%) | Average (%) |
|------------------|-------------------|-------------------|-------------------|-------------|
| Lettuce          | 50.00             | 90.60             | 84.30             | 75.00       |
| Spinach          | 43.70             | 59.30             | 59.30             | 51.50       |
| Water spinach    | 90.60             | 100               | 93.75             | 96.88       |
The growth of water spinach hydroponic plants was analyzed by measuring plant height, the number of leaves, and the number of stems (Figure 4). Water spinach hydroponic plants have the optimum height at the third observation in four weeks after planting the seeds on rockwool. The average height of water spinach in the third observation is 31.03 cm. Hydroponic plants with optimum height were found in a combination filter media burlap sack-melati air. The content of nutrients found in greywater filter media burlap sack-melati air which water quality was 3.85 mg/liter TSS, 13.82 mg/liter BOD, 62.12 mg/liter COD, and 0.19 mg/liter NH₃. The most stems in water spinach plants at the second observation in three weeks after planting the seeds on rockwool. The average amount of stems water spinach hydroponic plants in the second observation is 2.31. Water spinach hydroponic plants have the optimum amount of stems found in a combination of palm fiber-melati air. The content of nutrients found in greywater in combination filter palm fiber-melati air which was TSS 4.7 mg/liter, BOD 80.01 mg/liter, COD 26.01 mg/liter, and NH₃ 0.23 mg/liter. Water spinach hydroponic plants have the optimum amount of leaves on the second observation in three weeks after planting the seeds on rockwool. The average amount of leaves in the second observation were 40.65 strands. Water spinach hydroponic plant has optimum number of leaves was found in combination filter media activated charcoal-cyperus. The content of nutrients found in greywater 8.45 mg/liter TSS, 12.80 mg/liter BOD, 55.28 mg/liter COD, and 0.33 mg/liter NH₃. Leaves are part of the water spinach plant that is commonly consumed by the community.

The growth of spinach hydroponic plants was analyzed by measuring plant height, the number of leaves, and the number of stems (Figure 5). Spinach hydroponic plants have the optimum height at the third observation in four weeks after planting seeds on rockwool. The average height of spinach in the third observation was 1.56 cm. The most stems spinach at the second observation in three weeks after planting the seeds on rockwool. The average number of stems spinach hydroponic plants in the second observation was 0.62. Spinach hydroponic plants have the optimum amount of leaves on the second observation, three weeks after planting seeds on rockwool. The average number of leaves in the second observation reached 2.7 strands. Water spinach hydroponic plants have optimum height, number of stems, and amount of leaves are found in combination filter media palm fiber-kana. The content of nutrients found in greywater 8.45 mg/liter TSS, 12.80 mg/liter BOD, 55.28 mg/liter COD, and 0.33 mg/liter NH₃. Leaves are part of spinach plants that are commonly consumed by the community.
The growth of hydroponic lettuce plants was analyzed by measuring plant height and amount of leaves (Figure 6). Lettuce hydroponic plants have the optimum height at one observation in one week after planting seeds on rock wool. The average lettuce in the first observation was 1.75 cm. Hydroponic lettuce have the optimum height found in combination filter media burlap sack-melati air. The content of nutrients found in greywater were 38.8 mg/liter TSS, 13.12 mg/liter BOD, 62.12 mg/liter COD, and 0.19 mg/liter NH3 with filtering media burlap sack-melati air. Hydroponic lettuce has the optimum amount of leaves on the second observation in three weeks after planting seeds on rock wool. The average of leaves in the second observation is 2.7 strands. Hydroponic lettuce has the optimum amount of leaves found in combination media filter burlap sack-cyperus. The content of nutrients found in greywater were...
36.6 mg/liter TSS, 9.92 mg/liter BOD, 39.92 mg/liter COD, and 0.35 mg/liter NH3 with combination media filter burlap sack-cyperus filtering media. Leaves are part of the lettuce plant that is commonly consumed by the community.

![Figure 6 Hydroponic growth of lettuce plants](image)

**Greywater as a Hydroponic Plant Growth Media**

Bioretention has several advantages which can be arranged with flexible designs, small sites, and are very useful for improving the landscape and improving environmental aesthetics [10]. Greywater came from the bioreorientation process will be used for watering of water spinach, spinach and lettuce hydroponic plants for benefit to the surrounding community. Prototype bioretention system was tested to observe its efficiency in reducing greywater pollutants for potential greywater reuse in gardening and potable water. Bioretention system is one of the popular water sensitive urban design for source control urban runoff, which usually fits with urban landscape. Bioretention can serve multi-functional objectives greywater treatment and reuse, water conservation, value addition to the urban landscape and biodiversity [11].

Based on this study, existing TSS parameter have the highest descend of 87% in the combination media filter burlap sack-melati air (figure 7). Burlap sack is an organic fiber that has the ability to increase microbial support and has a high specific surface area. Organic fiber supports the development of biofilms so as to increase the rate of biodegradation. The advantages of natural fibers are low density, relatively low cost, and good biodegradability [12]. Existing BOD parameter have the highest descend of 56% in the combination of kana and palm fiber media filter. Greywater flowed to palm fiber media have functions to filter particles that escape from the sand layer and even the flow of water. Palm fiber media can be used as a medium for growth of aerobic bacteria so that it can reduce BOD parameter in the Rotating Biological Contractors (RBC) method [13]. Existing COD parameter have the highest descend of 72% in the combination of kana and palm fiber media filter.
Hydroponic growth have nutrients derived from the content of compost in top soil as a growth medium for absorbing pollutant plants. Organic material of greywater can contribute nutrients to hydroponics as nutrients that important function in physiology, so that plant growth gets better. The nitrification process occurs when bacteria oxidize ammonia and ammonium ions to form nitrates ($\text{NO}_3^-$) which are soluble and ready to be used by plants. Plants tend to use nitrate ($\text{NO}_3^-$) as a source of nitrogen for protein synthesis because nitrates have higher mobility in the soil and are easily bound to plant roots. In the Susnawati et al. 2015 study showed that greywater can be used as hydroponic medium water because the comparable pollutant levels still meet the standards for agriculture. Domestic wastewater that contains macro nutrients such as nitrogen as much as 0.0110%, phosphor as much as 0.0124%, and potassium as much as 0.0002% [14].

N, P, K elements contained in liquid waste are needed by plants for physiological and metabolic processes to increase the rate of growth of hydroponics. The N element has function for the formation of chlorophyll, the higher N is absorbed by plants, the more chlorophyll formed will increase. Chlorophyll functions as an absorbent light from the sun and can increase the rate of photosynthesis, so that the photosynthesize produced can be used to increase high growth. P element has function the formation of Adenosine Triphosphate (ATP). ATP is energy that requires plants in each cell activity including cell enlargement and cell extension including on the stem which can increase plant growth. K element as an activator of various essential enzymes in photosynthetic and respiration reactions as well as enzymes that can function the synthesis of starch and protein [15].

4. Conclusions and Recommendations

**Conclusion**

The bioretention plot can reduce the volume of Griya Katulampa greywater to have a pollution status without pollution index (still meeting quality standard). The volume of greywater in GriyaKatulampawas171.20 liters / person / day. The amount of reduction in the volume of greywater individually was 15.86 liters / person / day. From the results of the observations, it was shown that hydroponic growth at 4 weeks (harvest time) of the highest productivity were water spinach (96.9%), lettuce (75.0%), and spinach (51.5%). Water spinach as a potential plant at 4 weeks has an average growth rate of 31 cm high, 2 stems, 30 leaves. Filter media used to produce the highest productivity of
water spinach on the leaf part was the combination of active charcoal-cyperus media. Leaf is part of the water spinach plant that is commonly consumed by the community.

**Suggestion**

Suggestions for this research are:

1. In reducing the volume of greywater, Griya Katulampa requires 24,363 box of bioretention to reduce the volume of greywater 386,398 liters/day.
2. The most productive types of hydroponic plants are water spinach that can be harvested within one month.

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