Phytoremediation model of greywater treatment in the Purwodadi Botanic Garden

R Irawanto1,2

1 Environment Studies, Brawijaya University, Malang, Indonesia
2 Purwodadi Botanic Garden, Pasuruan, Indonesia Corresponding author: rony001@lipi.go.id

Abstract. Water treatment of domestic wastewater/greywater to be reused and safe for environment are needed. In addition, bearing in mind that the need for water sources for the community is getting scarce, especially in dry season. Greywater treatment can be done naturally by using plants or known as phytoremediation. With this natural process, the operational costs for treating greywater is cheap. The potential of plants diversity in the Purwodadi Botanic Garden as a wastewater treatment in wetland model can be used as an education tool for visitors and has aesthetic value. The aim of this study was to provide a phytoremediation model for greywater treatment in the Purwodadi Botanic Garden. The method used was descriptive (quantitative and qualitative). Data collection was done through obtaining documents, conducting interviews, sampling and laboratory analyses of wastewater quality with parameters stated in Permen LHK 68/2016. The pond as a phytoremediation model in constructed wetland / floating wetland (CW / FW) functions as a propagation of aquatic plants, surface water and greywater treatment, educational facilities, and also recreation facilities. The developed pond is divided into three segments: Zone 1 pre-processing (inlet), Zone 2 processing (CW / FW) and Zone 3 post processing (outlet). The development of zone 3 can enhance the beauty of the landscape while ensuring the diversity of the biological community, as well as other tertiary treatment processing systems.

1. Introduction
The environment is a space occupied by living things together with non-living objects in them [1]. According to regulation in UU 32/2009, the environment is a unity of space with all objects, power, conditions, and living things, including humans and their behavior, which affect nature itself, the survival of life, and the welfare of humans and other living things. The environment can suffer damage that can cause pollution, one of which is water pollution. Water pollution can be caused by human activities, producing both domestic and industrial waste.

Domestic wastewater treatment (greywater) management is expected to be safe for the environment and also can be reused according to regulation Permen PUPR 04/2017, considering the source of water for the community needs has begun to be scarce. Greywater treatment can be done naturally using plants, or known as phytoremediation techniques.

Phytoremediation is a technology for cleaning, removing or reducing pollutants in soil or water using plants. Aquatic plants can act as wastewater treatment [2]. So that with the existence of aquatic plants, water pollution can be resolved and water quality can be restored. Plants can change pollutants
/ wastewater into reduced levels, or become harmless, or even become materials that are re-used by plants [3].

Purwodadi Botanic Garden, has a duty and responsibility to conserve plants, especially in the lowlands area. Plants that have been planted and used as collections in Purwodadi Botanic Garden will be utilized, and will be used for data on conservation, research and education activities [4]. Based on regulation Perpres 93/2011, the definition of a botanic garden is an ex-situ plant conservation area that has a collection plants of documented arranged according to taxonomic, bioregion, thematic classification patterns or a combination of these patterns for the purpose of conservation, research, education, tourism, and environmental services. Where the main characteristics of a botanic garden is the availability of a living plants collection documented, and supporting collection of seeds and herbariums [2].

The existence of aquatic plants as agents of domestic wastewater (greywater) treatment in an aesthetic garden setting can give an impression and beautiful views [5]. With this natural process, operational costs for greywater processing are not too high. This is also supported by the potential for plant biodiversity in the Purwodadi Botanic Garden, where there are many species of aquatic plants spreaded in several ponds. Besides functioning as a greywater treatment, this model can be used as an educational tool for visitors.

This study aimed to provide a plan of a phytoremediation model for greywater treatment in one of the ponds in Purwodadi Botanic Garden. It is expected that with this treatment model, the treated greywater can be reused. Besides it can function as technically, it can also function as environmental education for visitors of Purwodadi Botanic Garden.

2. Materials and Method

This research was conducted during December 2019 - July 2020. The study used a qualitative descriptive approach. The research activities were divided into two stages: Stage 1 conducting data collection and laboratory testing of wastewater characteristics at Purwodadi Botanic Gardens LIPI, and Stage 2 conducting a field survey and technically applicable requirements by Settlements Research Center (Puslitbang PUPR). The laboratory test was done in the Environmental Agency (DLH) of East Java Province and Perum Jasa Tirta I Malang.

Parameters tested during the field survey were temperature, COD, Permanganat (KMnO4), Ammonia, TDS, and Conductivity. While for testing in the laboratory, the domestic wastewater (greywater) quality parameters according to regulation Permen LHK 68/2016, were pH, TSS, BOD, COD, oils and fats, are added with detergents / surfactants.

Standard methods guidelines used are: SNI 06-6989.23-2005, Test methods for temperature using a thermometer. SNI 06-6989.11-2004, Test method for the degree of acidity (pH) using a pH meter. SNI 6989.72-2009, Test method for biochemical oxygen demand. SNI 06-6989.10-2011, Test method for vegetable oil and mineral oil by gravimetry. SNI 06-6989.30-2005, Test method for ammonia levels with a spectrophotometer in phenate. SNI 06-6989.51-2005, Test method for anionic surfactant content using a methylene blue spectrophotometer. APHA 2540-D.Ed 23.2017, Total Suspended Solid. APHA 5220-C.Ed23.2017, Chemical Oxygen Demand.

The laboratory testing results data are processed and analyzed based on the standard technical assumptions and applicable technical requirements, until an appropriate greywater waste management technical model is obtained. The model is presented in a picture with descriptive that explain in results and discussion

3. Results and Discussion

3.1. Purwodadi Botanic Garden and Pond Plant

Purwodadi Botanic Garden which is also known by the name of “Hortus Ilkim Kering Purwodadi” is one of the Indonesian Botanic Garden which has the task and function of collecting plants that live in
the dry lowlands area. Purwodadi Botanic Garden is a Plant Conservation under the Research Center for Plant Conservation and Botanic Garden, Deputy for Life Sciences - LIPI.

Purwodadi Botanic Garden has an area of around 85 ha, located in Pasuruan Regency, East Java Province, at an altitude of 300 m above sea level with flat to hilly topography. Average annual rainfall is 2366 mm with wet months between November and March with temperatures ranging from 22 °C - 32 °C. There are 32 ponds in Purwodadi Botanic Garden which are habitats of various aquatic plants. This aquatic plant has many economic and ecological benefits, one of which plays a role in phytoremediation.

The existence of ponds in Purwodadi Botanic Garden to collect water from irrigation and drainage canals, thatwater mixed with greywater population. The water that has been collected in a pond is then channeled back into the drainage canals outside the botanic garden. Even though the pond is planted with aquatic plants, there has not been much testing done for water quality from canals and ponds, whether or not it meets the wastewater quality standards. For this reason, Purwodadi Botanic Garden took initiative to make one of the ponds as a greywater treatment from domestic wastewater.

Greywater treatment can be done naturally by utilizing plants and microorganisms. The treatment process can be done in a pond called wetland. Pollutants are set aside through a combination of physical, chemical and biological processes which include sedimentation, precipitation, adsorption into soil particles, assimilation by plant membranes, and microbial transformation. Microorganisms that attach to the roots of plants and that are found around the roots of plants have a major role in the process of degradation of organic compounds. With this natural process, operational costs for greywater treatment are not too expensive.

For that greywater treatment ponds in Purwodadi Botanic Garden are planned to use wetland system. This is also supported by the existing potential in diversity of aquatic plants. Besides functioning as a wastewater processor, ponds-shaped wetland can function aesthetically as an education for visitors.

3.2 Water Quality in Ponds Canals
One of the ponds planned as a phytoremediation model for greywater wastewater treatment is located behind the main office of Purwodadi Botanic Garden - Plant Conservation Center. The source of raw water (inlet) from this pond has a quantity of water that depends on the season. While water quality is affected by surface water from irrigation canals and greywater from office managers, prayer rooms and guesthouses in botanic garden. The existing condition and location of the pond of phytoremediation model of greywater wastewater treatment in the Purwodadi Botanic Gardens can be seen in Figure 1.

![Figure 1. Pond of Phytoremediation, Conditions and Location in Purwodadi Botanic Garden](image-url)
To find out the water quality mix with greywater (inlet/before entering the pond), tests were carried out both, in field and in laboratory. Test results in field can be seen in Table 1. While laboratory results for water quality mix with greywater can be seen in Table 2.

**Table 1. Water Quality mix with Greywater (before entering the pond)**

| No  | Parameters | Unit | Test Result |
|-----|------------|------|-------------|
| 1.  | Temperature | °C   | 28.9        |
| 2.  | CODK\(\text{MnO}_4\) | mg/L | 10          |
| 3.  | Ammonia    | mg/L | 0.5         |
| 4.  | TDS        | mg/L | 24.9        |
| 5.  | Conductivity | mS | 0.372       |

*Field Test

**Table 2. Water Quality mix with Greywater (before entering the pond)**

| No. | Parameters   | Unit | Test Result* | Standard Quality |
|-----|--------------|------|--------------|------------------|
| 1.  | Suhu         | °C   | 25.8         |                  |
| 2.  | TSS          | mg/L | 24.2         | 30               |
| 3.  | pH           | -    | 7.44         | 6-9              |
| 4.  | BOD          | mg/L | 5.67         | 30               |
| 5.  | COD          | mg/L | 15.3         | 100              |
| 6.  | Oils and fats | mg/L | < 0.59      | 5                |
| 7.  | Ammonia      | mg/L | 0.179        | 10               |
| 8.  | Detergents (mean) | mg/L | 0.206       |                  |

*Laboratory Test

The results of both, field and laboratory tests show that in general, the quality of greywater (inlet) wastewater, which is a source waterof pond, is still below the domestic wastewater quality standard according to regulation Permen LHK 68/2016. However, looking at the conditions at the time of water sampling in the rainy season, and this water source is an open canal that is very affected by rain water, the results above only represent quality in the rainy season. In the dry season, the water quality in irrigation canals and ponds is predicted to be different because there is no rainwater dilution. While the existing condition of the pond is overgrown with several aquatic plants with arrangement, species variation and functions that have not been optimized, where the water discharge ranges from 0.0375 m³/sec - 0.0430 m³/sec.

**3.3 Model Wetland System (CW-FW)**

Wetland is transition areas between land and water, wetland or natural wetlands include, among: swamps, wet grasslands, land affected by tides, floodplains, and wetlands along river waterways (UN-HABITAT, 2008). Whereas Constructed Wetland (CW) is an artificial wetland, with the function of purifying wastewater using physical, chemical and biological methods in an eco-system, utilizing the processes of filtration, adsorption, sedimentation, ion exchange and microbial decomposition in natural processes of plants. CW plays a role in water treatment systems as well as green open space providers.

In general, CW is distinguished based on the pattern of water flow, on the surface (surface flow) and the bottom (subsurface flow) or a horizontal system and a vertical system or a combination of the two (hybrid). CW treatment traditionally involves the use of emergent aquatic plants rooted in sediments, either with subsurface flow or surface runoff. Whereas Floating Wetland (FW) is an innovative variant
of the system by developing the roots of emergent aquatic plants in the growing media in the container that floats on the surface of water, as in Figure 2.

![Figure 2. System Models: Constructed Wetland and Floating Wetland](image)

The FW system allows water treatment in bodies of water that are too deep for plants to grow. FW is a proven concept that is used successfully for surface water treatment, municipal wastewater, landfill leachate and mine tailings ponds. Plant roots spread through floating media and descend into the water creating a dense column of roots. Not only do plants take nutrients and contaminants, roots and floating media provide a large surface area for the formation of bacterial biofilms, and other microbes attached to the surface that play a role in the absorption and degradation of nutrients in the system [6].

3.4 Design of Phytoremediation Model Pond
The pond that will be developed as a wetland phyemedation model is intended as a means of developing aquatic plants collection, surface water and greywater treatment, as well as education and recreation facilities for visitor. Wetland pond development is planned to be as an effort:

- Formation of water quality treatment zones according to detention time, pollutant targets set aside and the function of each zone in the wetland pool.
- Enriching the diversity of aquatic plants and their ability to absorb water pollutants.
- Contribution in improving surface water quality so that it is safer to use for agricultural crops and residents around the botanic garden.
- Re-use and storage of clean water for fisheries and watering collection plants in botanic garden.

The wetland pond area will be developed into 3 segments / zones, namely: pre-processing zone, processing zone and pasca-processing zone, with a design as shown in Figure 3.
3.4.1 Pre-processing Zone

In this zone it is intended to hold trash and solids deposition suspended or pre-processed. Soil media formed in this zone will increase and can be utilized as a pollutant treatment media. In the pre-processing zone design, it is necessary to the following:

(1) Use of coarse screens of iron / wood bars is about 32-100 mm and the fine screen of the net is about <25 mm.
(2) Depth in this zone is suggested 0.3-0.6 m
(3) To increase depositional effectiveness, overflow flow is designed at 20-80 m / day. These criteria affect sedimentation, avoid turbulence, dead zones, short flow or depositional instability.
(4) Plants in this zone can be developed emergent aquatic macrophyta. Some collection plants such as Sagittaria, Echinodorus, and Acanthus can be selected.
(5) Maintenance of this zone is necessary because if the water flows quickly on the surfacecausing short retention times and subsequent processing capabilities.

3.4.2 Processing Zone

On the water test results Table 2. shows the TSS content of 24.2 mg/L, BOD 5.67 mg/L, COD 15.3 mg/L, and Ammonia 0.179 mg/L. The content of these organic substances can come from household / domestic wastewater pollutants, because the source of water that flows into the drainage comes from domestic activities around the office. The nitrate content in raw water is still below the value of natural waters <5mg/L, indicating that the source of raw water has not been polluted by human or agricultural activity waste [7].

The surface water is based on observations, is still feasible to be used to irrigate plants/crops, and/or other uses such as freshwater fish farming, animal husbandry, according regulation to water class III (PP 82/2001). However, to get a good overview of water quality, periodic observations and testing of other chemical / biological parameters are needed. Mainwhile as use of recreation (water class II), prevention of pollution and increasing water hygiene are needed, through:

(1) Processing zones with the CW-FW principle, have design criteria [8]: Hydraulic detency time: 4-15 days. Water depth of 0.1-0.6 m. Load rate BOD5: <112 kg / ha / day. Hydraulic load rate: 0.01 - 0.05 m³ / m².day. Width : Length = 1: 2-10. In the existing condition the BOD5 load rate is very small and the hydraulic residence time is very fast, based on the results of the measurement of discharge 0.0375 m³ / sec - 0.0430 m³ / sec, and a void ratio of about 0.65, it takes time: 0.04 days (or can be interpreted 57.6 minutes).

(2) To increase the hydraulic detency time, the effectiveness of the pre-treatment zone must be considered and in this treatment zone it is necessary to restrict the flow of water so that the flow is plug flow, so that the organic and nutrient removal process can be more efficient and effective. Flow restrictions can use perforated plates, such as PVC plates and PVC pipes. In the current conditions, many aquatic plants macrophyta are floating. This spesies can be more intensified in this zone.
(3) The processing zone can also apply floating wetland, which is in the form of a floating garden using media consisting of pipes, nets, fibers, coconut coir. Organic compounds are degraded aerobic and also anaerobic by bacteria that attach to the bottom of plants (roots) and the surface of the media. Oxygen is needed for degradation aerobics is given through the air by diffusion or introduction of oxygen from the roots in rhizosphere. For example floating wetland with an area of 7 m², has a total mass of 12 kg, with a safety factor assumed to be 10%, so that the total floats are 13.2 kg, the volume of water displaced is around 0.0132 m³ with three layers of growing media applied, can be in the coconut coir, shell charcoal, and foam.

(4) Plants that can be used varies, preferably local plants which have potential as ornamental plants. According to several studies can set aside organic and nutrients such as Cyperus, Canna, Thalia, and Thypa.

3.4.3 Post-Processing Zone
In this zone it can function as an advanced processing unit, or shelter / container, and for various purposes, such as:
- Utilization as a means of water recreation. According to regulation PP 82/2001, the use of water for water recreation, it is necessary to fill up water class II requirements, including BOD <3 mg / L, COD <25 mg / L, nitrate <10 mg / L.
- Utilization for agricultural irrigation or watering the surrounding plants, can refer to water class III, including BOD <12 mg / L, COD <100 mg / L, nitrate <20 mg / L.
- Utilization of raw water sources for drinking water, can be done by increasing this zone functions as further processing, including by developing filtration gravel and carbon and disinfection. Water quality targets can be according to water class I at various seasons, including meeting BOD <2 mg / L, COD <10 mg / L, nitrate <10 mg / L.

Plant diversity can be prioritized in this zone, so as to enhance the beauty of the landscape and ecological functions can be improved as well as advanced processing also guarantee the diversity of biological communities are save. In this zone, functions can be increased, including:
(1) Development zones as advanced processing of CW-FW systems with emergent or floating macrophyta plants, to anticipate detergent pollution. On the test results <0.4 mg / L, it still meets the water quality of water class I <200 microg / L. But to anticipate the dry season or domestic activity disposal of wastewater or laundry, the ABS surfactant compounds and phosphate in detergents can currently increase pollution or eutrophication.

(2) Development of some zones with constructed wetland SF / SSF system with gravel media (5-32 mm) is better used, which has the potential for removal of heavy metals and other solutes that are not treated in the processing zone. Minimum hydraulic conductivity of \(10^3\) to \(10^4\) /second is needed to prevent surface runoff and canal formation, so media selection must be correct.

(3) Plants that can be used are more varied and colorful, such as Pontaderia, Nympha, and Nelumbo.

4. Conclusion
Development of phytoremediation model at Purwodadi Botanic Garden as a domestic wastewater (greywater) treatment with constructed wetland - floating wetland (CW-FW) system, intended for the development of aquatic plant collections, surface water treatment, educational, and recreation facilities. The pool area to be developed is divided into 3 segments: pre-processing zone, processing zone and post-processing zone. The development of plant diversity can be considered in all three zones, so as to enhance the beauty of the landscape and its ecological functions to ensure the diversity of biological communities in the aquatic ecosystem is maintained.

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