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The Potential of Water Hyacinth (*Eichhornia crassipes*) for the Phytoremediation of Curug Sigay Domestic Wastewater Using a Retention Pond

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ABSTRACT

The water hyacinth plant (*Eichhornia crassipes*) is often used for the phytoremediation process. This is because water hyacinth is a plant that is easy to find, besides that water hyacinth is able to grow in polluted waters and is able to produce biomass. This study aims to analyze changes in pH, TDS, temperature and DO levels in domestic wastewater at the Sigay waterfall which was treated with *Eichhornia crassipes* (water hyacinth) plants with the addition of palm fiber and gravel over a treatment period of 3, 6 and 9 days in retention ponds, as well to determine the optimum time for phytoremediation of Eichhornia crassipes in retention ponds. crassipes (Water hyacinth) during the experiment. The experimental reactor consisted of 3 treatments, namely water hyacinth fiber palm+gravel for 3 days (T-H3), 6 days (T-H6) and 9 days (T-H9) with reactor without treatment as the control. Each reactor is filled with 3L of leachate. The reactor is left in the open and exposed to sunlight. Data were processed using the ANOVA test. The results show a value of P= 0.027 for pH, P=0.026 for temperature, P=0.003 for TDS and 0.066 for the DO test with a value of α=0.05, which indicates that if P<0.05 there is a significant difference between each treatment.

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1. INTRODUCTION

The Sigay Waterfall, with an approximate height of 15 meters, is located in Babakan Nagawir RT 04 RW 06, Gegerkalong Girang, Bandung City, precisely behind the campus of Universitas Pendidikan Indonesia. The waterfall's proximity to residential areas and its position within the flow of the Cibeureum River, which has been polluted by domestic wastewater from the surrounding environmentsignificantly affects the ecosystem's natural capacity to neutralize contaminants (Haryoto, 1999; DISLHK, 2018).

According to data from the Central Statistics Agency (BPS, 2023) in the *Bandung in Figures* 2023 report on river water quality, all rivers in Bandung City remain polluted, with water quality status categorized as mildly to moderately contaminated. Goel (2006) defines water pollution as any change in water quality or composition, whether natural or human-induced, that reduces its suitability for drinking, domestic use, agriculture, industry, recreation, wildlife, and other purposes.

Given the severity of river pollution, effective water management is crucial. One promising approach is the use of aquatic plants to reduce pollutant loads in water bodies, known as phytoremediation. This technique is environmentally friendly and relatively easy to implement (Moosavi & Mohamd, 2013; Mirwan, M. & Puspita, I, 2021). A highly potential plant for this process is water hyacinth (*Eichhornia crassipes*). This plant is readily available, capable of growing in polluted waters, and produces substantial biomass (Rai & Singh, 2016). It also has a significant ability to absorb nutrients, organic compounds, and various chemicals from wastewater (Dewi, 2012). Based on this background, this study aims to analyze changes in pH, temperature, TDS (Total Dissolved Solids), and DO (Dissolved Oxygen) levels in domestic wastewater from the Sigay Waterfall treated with water hyacinth in a system enhanced with coconut fiber (*ijuk*) and gravel over periods of 3, 6, and 9 days. Furthermore, this research seeks to determine the optimum duration for the phytoremediation process using water hyacinth in a constructed retention pond.

2. METHODS

2.1 Sample Collection and Processing Method

The water samples used in this study were domestic wastewater collected from the flow of the Curug Sigay River. Sampling was conducted using the grab sampling method at points representing the pollution source before significant dilution occurred. To ensure consistency, the samples were then homogenized and stored in sterile containers according to standard wastewater sample preservation protocols prior to treatment.

2.2 Treatment System Design (Artificial Retention Pond)

The retention pond system was designed experimentally using specific-sized containers or tanks filled with a layered filter medium. The medium configuration was designed to simulate filtration and phytoremediation processes, consisting of a gravel layer at the bottom as a support and coarse filter, followed by a coconut fiber (*ijuk*) layer which functioned as a biological filtration medium to trap fine particles and provide attachment surfaces for decomposing microorganisms. Above these media layers, water hyacinth (*Eichhornia crassipes*) plants were added, selected for their proven capability to absorb heavy metals and nutrients (such as phosphate and nitrate) through their dense root systems. Each treatment unit (including the control) was designed with specific volume and plant-to-media ratios to ensure data comparability (Kalsum, 2014).

2.3 Water Quality Parameter Measurement

The observed water quality parameters covered basic physicochemical properties: acidity (pH), temperature, Total Dissolved Solids (TDS), and Dissolved Oxygen (DO). Measurements of pH, temperature, and TDS were conducted in-situ and/or in the laboratory using a pre-calibrated Water Quality Tester. Meanwhile, the DO parameter was specifically measured using a DO Meter for higher accuracy. Measurements were performed periodically to monitor the dynamics of water quality changes during the research period.

2.4 Statistical Data Analysis

The measurement data were analyzed statistically to test the significance of differences between treatments. Considering that water quality data are often not normally distributed or homogeneous, preliminary tests for normality using the Shapiro-Wilk test and homogeneity of variance using Levene's test were conducted first. Based on the results of these prerequisite tests, the appropriate inferential statistical analysis method was selected. If the data did not meet parametric assumptions, the Kruskal-Wallis Test was used as a non-parametric alternative to test median differences among more than two groups. If the data met the assumptions of normality and homogeneity, a One-Way ANOVA Test was employed to test the significance of mean differences among groups. If the ANOVA results indicated significant differences, post-hoc tests such as Tukey HSD or Duncan were conducted to identify which specific treatments differed. All statistical analyses were performed with a 95% confidence level ($\alpha = 0.05$) using statistical software such as SPSS or R Studio.

3. RESULTS AND DISCUSSION

3.1. Water Quality of Curug Sigay River Prior to Phytoremediation

The Curug Sigay River has been contaminated by domestic wastewater originating from the surrounding residential areas. This condition has impaired the natural self-purification capacity of the environment. The initial baseline measurement revealed that the river water had a pH of 6.89 and a temperature of 22.5 °C, classifying it as a water body impacted by domestic effluent (BPK, 2004). These initial physicochemical conditions provide a critical reference point for assessing the effectiveness of the subsequent phytoremediation intervention.

3.2 pH Parameter

Statistical analysis using SPSS indicated a significance value (p-value) of 0.027, which is below the 0.05 threshold. This result leads to the rejection of the null hypothesis (H_0), confirming a statistically significant difference in pH levels across the observation period from day 0 (H_0) to day 9 (H_9). Therefore, the phytoremediation process significantly altered the pH of the domestic wastewater. The data demonstrate a significant decrease in pH across all treatment units containing aquatic plants (water hyacinth), with the differences also being significant between each sampling interval (e.g., day 3 vs. day 6 vs. day 9). This consistent decline suggests an active role of the plant and microbial community in the system. The progressive acidification could be attributed to several biological processes: (1) the release of root exudates and organic acids by *Eichhornia crassipes* during metabolism, (2) the production of carbon dioxide (CO_2) from intensified microbial respiration on the root surface (rhizosphere) and within the filter media, and (3) the nitrification process, where ammonium is converted to nitrate, releasing hydrogen ions. The trend of pH reduction is illustrated in the **Figure 1**.

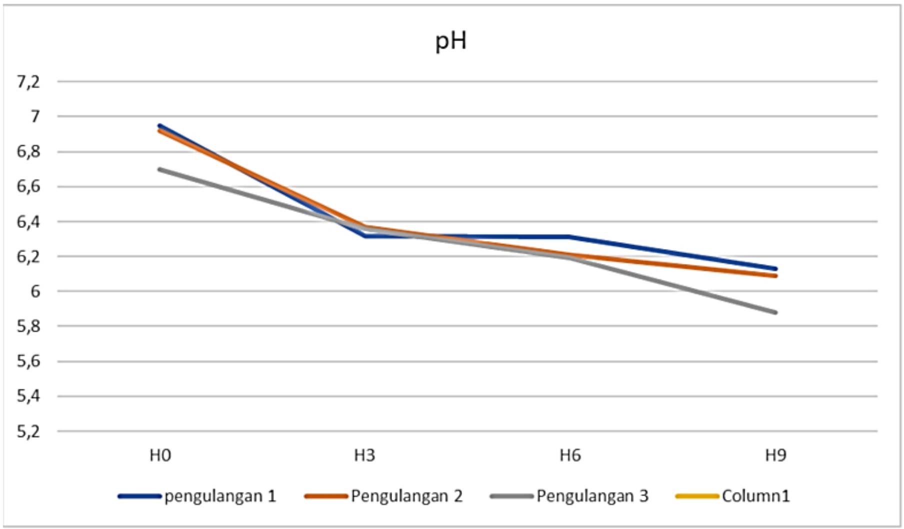

Figure 1. pH of domestic wastewater

Based on the graphical data, the percentage decrease in pH occurred as follows: from the initial condition (H0) to day 3 (H3): 8.6%, from H3 to H6: 0.8%, and from H6 to H9: 3.2%. The most substantial pH reduction was observed during the initial period (H0 to H3). This pronounced initial decrease is hypothesized to be primarily driven by the morphology and metabolism of the water hyacinth roots, which are known to excrete organic acids as metabolic byproducts. These organic acids subsequently dissociate in the water, releasing hydrogen ions (H^+) and directly contributing to the decline in pH. The accumulation of these acidic compounds in the rhizosphere during the early, rapid growth phase likely intensified this process.

Furthermore, aquatic plants significantly influence ionic equilibrium in water through root ion exchange. The active uptake of cations (e.g., NH_4^+, K^+, Ca^{2+}) by *Eichhornia crassipes* may be coupled with the release or displacement of H^+ ions into the surrounding water to maintain electrochemical balance, further driving acidification (Okonkwo, 1998). Another contributing factor is the release of carbon dioxide (CO_2) from root and microbial respiration within the system. Dissolved CO_2 reacts with water to form carbonic acid (H_2CO_3). In wastewater with an initially neutral to alkaline buffering capacity, carbonic acid dissociates, releasing additional H^+ ions and thereby lowering the pH (Utami, 2016). Platenik (2018) elaborates that these H^+ ions from carbonic acid can combine with hydroxide ions (OH), whose corresponding cations have been absorbed by the plant, to form neutral water (H_2O). This mechanism represents a crucial pathway for pH reduction in phytoremediation systems employing water hyacinth. The significant slowdown in the rate of pH decrease between H3 and H6 (only 0.8%) suggests a possible shift towards a new dynamic equilibrium or the depletion of readily available substrates for the acid-producing processes. The subsequent moderate decrease from H6 to H9 (3.2%) may indicate a continued, but slower, long-term acidification driven by sustained plant metabolism and microbial activity.

3.3 Temperature Parameter

Statistical analysis conducted using SPSS yielded a significance value (p) of 0.026, which is below the 0.05 threshold. This result indicates a statistically significant difference in temperature across the observation period from the initial condition (H0) to day 9 (H9), confirming that the phytoremediation process induced a measurable change in water temperature. As illustrated in the observation graph, the temperature exhibited a decreasing trend in the initial phases, declining by 4.3% from H0 to H3 and by a further 6.6% from H3 to H6. However, a notable reversal occurred during the H6 to H9 interval, with a substantial temperature increase of approximately 23%.

This pattern of initial cooling followed by a significant temperature rise is likely influenced by the experimental setup, particularly the relatively shallow depth of the treatment containers. The shallow water column facilitates rapid heat exchange with the ambient environment, leading to a more homogeneous temperature that is highly responsive to external fluctuations, such as diurnal variations in laboratory or ambient air temperature. The initial cooling may be attributed to evaporative cooling and the shading effect provided by the water hyacinth canopy. The subsequent sharp increase could correspond to a period of heightened microbial and plant metabolic activity (e.g., respiration), which generates heat, coupled with potential exposure to warmer environmental conditions during that specific measurement period. The graphical representation of temperature changes in the domestic wastewater from Curug Sigay is provided in the **Figure 2**.

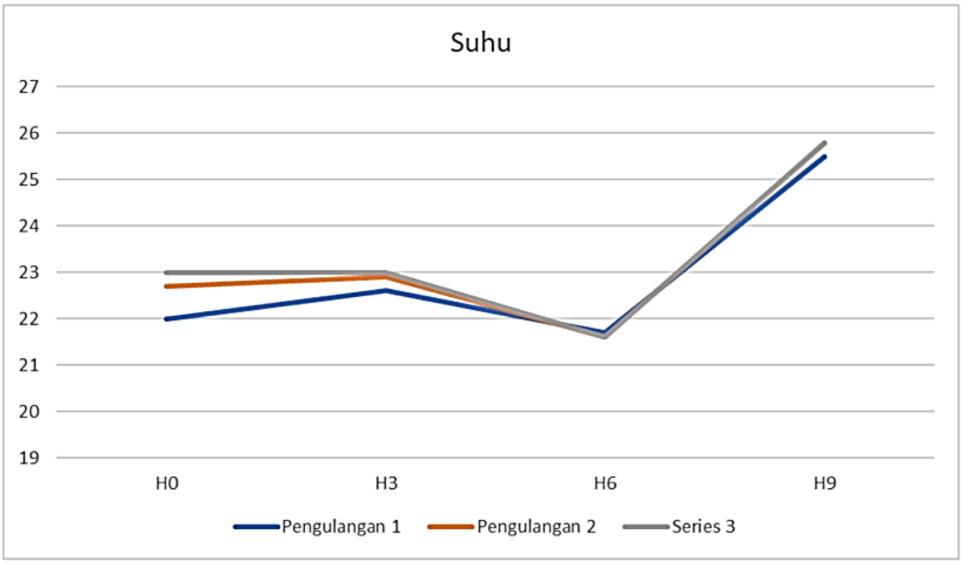

Figure 2. Temperature of domestic wastewater

The temperature increase observed at H9 can also be attributed to higher ambient light intensity during that particular sampling event, leading to greater solar heat absorption by the water in the treatment containers. Furthermore, the density of the water hyacinth canopy in each container significantly modulates light penetration into the water column. A denser leaf canopy reduces the amount of incident light reaching the water surface, resulting in lower wastewater temperatures. Throughout this study, the recorded wastewater temperature ranged from 21.6°C to 23.0°C.

This observed range aligns with the findings of Purwandari (2009), who stated that the optimal temperature for aquatic plant growth typically falls between 22°C and 30°C. The presence of aquatic plants also introduces a biologically-mediated cooling mechanism through transpiration. This process involves water uptake by the roots and its subsequent release into the atmosphere via stomata on the leaves. Transpiration has an evaporative cooling effect on both the plant itself and its immediate microenvironment, which can contribute to a localized decrease in water temperature within the treatment area. Moreover, dense vegetation acts as a physical barrier, reducing the intensity of direct solar radiation on the water surface. A closed leaf canopy creates a shading effect, diminishing sunlight exposure and consequently maintaining lower water temperatures compared to systems without vegetative cover.

Therefore, the temperature fluctuations recorded during the experiment represent a complex interplay of external environmental factors (e.g., ambient light and temperature) and internal system dynamics driven by plant physiology (e.g., canopy density and transpiration rate). The final measurement at H9 likely reflects a transient state dominated by external heating, temporarily overriding the cooling contributions of the phytoremediation system.

3.4 Total Dissolved Solid (TDS)

Statistical analysis performed with SPSS indicates that the TDS parameter following phytoremediation treatment with water hyacinth showed a statistically significant difference, with a significance value (p) of 0.003 ($p < 0.05$). This confirms that the treatment had a measurable impact on the concentration of dissolved solids in the wastewater. As presented in the accompanying graph, the TDS value exhibited a distinct trend over the observation period. A decrease was recorded from the initial condition (H0) to day 3 (H3). Subsequently, the TDS level remained relatively stable at day 6 (H6), resulting in an overall reduction of approximately 5% from H0 to H6. However, a notable reversal was observed at the final measurement point (H9), where the TDS value increased again. The graphical representation of TDS levels in the Curug Sigay wastewater is provided in the **Figure 3**.

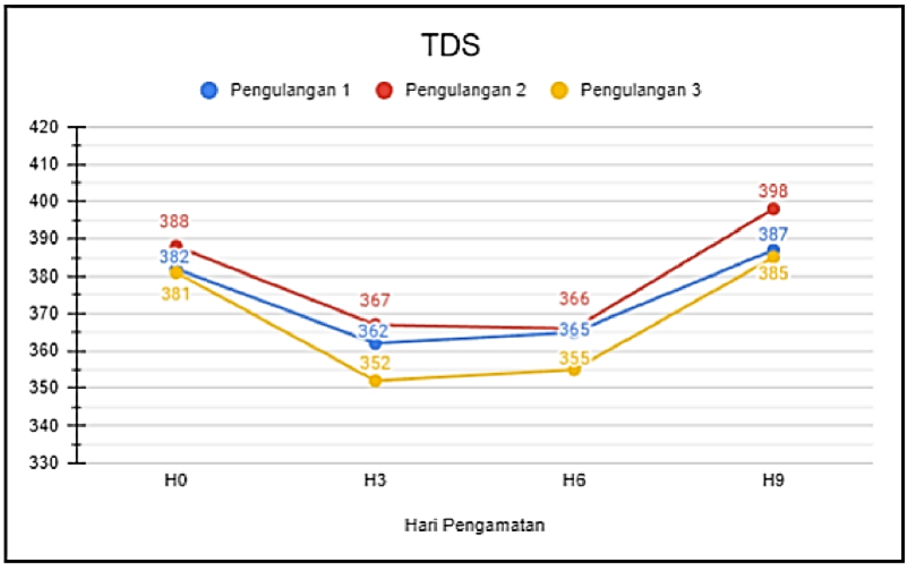

Figure 3. TDS of water sample from Curug Sigay

Total Dissolved Solids (TDS) represents a measure of the combined content of all inorganic and organic substances dissolved in water, typically expressed in parts per million (ppm). The observed reduction in TDS is intrinsically linked to bioremediation processes facilitated by living organisms within the phytoremediation system. *Eichhornia crassipes* plays a direct role by absorbing and assimilating dissolved ions and nutrients, thereby reducing their concentration in the water column. This aligns with the findings of Deffy *et al*. (2020), who reported that biological activity can degrade organic matter, consequently lowering the total dissolved solids in water. Furthermore, the decline in TDS is significantly enhanced by the activity of associated microorganisms that degrade complex organic compounds into simpler forms. The efficacy of this process is highly dependent on the population density and activity of these organisms in the environment, particularly in the rhizosphere (Retnosarri, 2013).

The subsequent increase in TDS at H9 is hypothesized to result from a decline in the bioremediative capacity of the water hyacinth system. This could be due to nutrient saturation within the plant tissues, a shift in plant metabolism, or the onset of senescence, where the rate of ion release from decomposing plant matter begins to exceed the rate of uptake. Based on the data from this study, the optimum point for TDS reduction was identified at day 6 (H6). Therefore, to sustain effective remediation beyond this period, a practical recommendation would be to transfer the treated wastewater to a fresh system containing new, actively growing water hyacinth. This sequential batch approach would ensure that the phytoremediation process continues efficiently by maintaining a high bio-absorption capacity within the treatment units.

3.5 Dissolved Oxygen (DO)

Statistical analysis revealed that DO levels from H0 to H6 showed a significant difference ($p < 0.05$), indicating an improvement in the water quality of Curug Sigay during this phytoremediation phase. However, when data from H9 was included in the analysis, the significance value changed to 0.066 ($p > 0.05$), rendering the overall difference in DO concentration from H0 to H9 statistically non-significant. The graphical trend of DO in the treated water samples is presented in **Figure 4**.

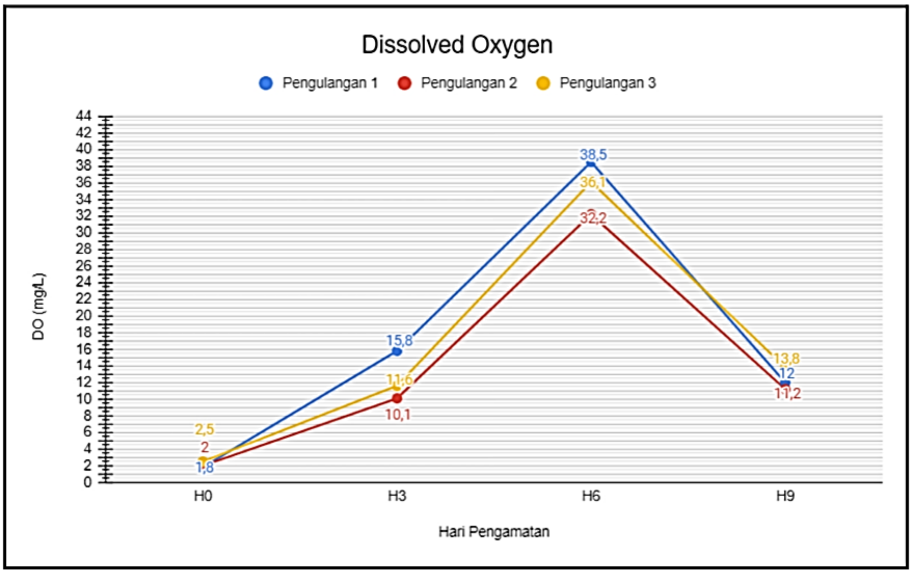

Figure 4. DO of water sample from Curug Sigay

The observation graph indicates a clear increase in DO concentration from H0 to H6. The most substantial rise was observed in the first replicate, where DO increased from 1.8 mg/L to 38.5 mg/L, representing an approximate 90% enhancement. This increase is strongly correlated with intensified bioremediation activity, where aerobic microorganisms degrade pollutants, a process that can be stimulated by root exudates and improved water conditions. Conversely, a sharp decline in DO of about 68% was recorded at H9, suggesting a cessation or reversal of the water quality improvement trend.

Dissolved Oxygen (DO) refers to the concentration of molecular oxygen in water, originating primarily from photosynthetic activity of aquatic plants and diffusion from the atmosphere (EPA, 2023). DO is a critical parameter for aquatic life respiration, microbial metabolism, and the aerobic oxidation of organic and inorganic compounds, which is the cornerstone of many bioremediation mechanisms. Higher DO levels generally signify better water quality. Conversely, high concentrations of organic pollutants can deplete DO, as the microbial oxidation of organic matter consumes substantial oxygen (e.g., the oxidation of 3 mg/L of carbon can require up to 9 ppm of DO) (Haddad, *et al*., 2021).

The coincident decrease in DO and increase in TDS at H9 are interrelated. A higher load of dissolved substances can increase water viscosity and reduce the oxygen transfer coefficient, thereby impeding oxygen diffusion from the atmosphere and leading to lower DO levels. Based on these integrated results, the optimum period for effective bioremediation using water hyacinth in this system was identified at day 6. To maintain treatment efficacy beyond this point, a sequential batch operation is recommended, transferring the wastewater to a fresh unit containing new, actively growing water hyacinth.

3.6 Condition of Water Hyacinth and Overall Water Quality Post-Phytoremediation

The physiological condition of the water hyacinth after the phytoremediation process showed visible changes, including leaf chlorosis (yellowing) and paling. These symptoms are likely attributed to the combined stress of nutrient depletion in the wastewater and exposure to residual toxic substances. According to Audiyanti, *et al*. (2019), yellowing of leaves can be triggered by organic pollution. Furthermore, the initial health of the plants, including pre-existing leaf damage, may have compromised their bioremediative capacity from the outset.

The water quality test results demonstrate that phytoremediation provided measurable improvement in the condition of Curug Sigay water up to day 6, characterized by decreasing TDS and increasing DO. However, a decline in quality was observed again by day 9. This pattern indicates that the remediation capacity of the water hyacinth reached its optimum around day 6, beyond which its effectiveness diminished. Therefore, to continue the remediation process efficiently, a system overhaul—transferring the effluent to a new batch with fresh plants—is necessary. Consequently, the optimum phytoremediation duration identified in this study is six days.

4. CONCLUSION

Based on the research findings, it can be concluded that the use of water hyacinth (*Eichhornia crassipes*) as a phytoremediation agent significantly improves the quality of domestic wastewater from the Curug Sigay River. The treatment effectively reduced Total Dissolved Solids (TDS) and increased Dissolved Oxygen (DO) levels, while pH changes tended to stabilize and shift toward a neutral condition. The phytoremediation process reached its optimal efficiency on the sixth day of treatment, marked by the most significant changes in water quality parameters.

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