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The study for greywater treatment by local materials for reuse in scarcity areas

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ABSTRACT

Water scarcity is becoming increasingly severe and significantly impacts the lives of many individuals in rural areas. To improve water quality for reuse and reduce environmental impacts, the study has been conducted on the application of locally available, low-cost materials in simple operational processes for greywater treatment. The treatment model utilizes filter materials arranged in layers, consisting of coconut fiber (10 cm), manually crushed waste concrete (50 cm), and coconut shell activated carbon (30 cm). The results indicate that the treatment system achieves an efficiency of approximately 75% for COD and BOD_5 removal, with a hydraulic loading rate of 1.58 m^3/m^2 per day. In addition, the removal efficiency of TSS exceeded 80% at a hydraulic loading rate of 1.58 m^3/m^2 per day, while the removal efficiency for TKN was higher than 40%. The results indicate that at the lower water loading rate of 0.84 m^3/m^2 per day, the research model removed 48–50% of total phosphorus from greywater. Meanwhile, pH and EC showed minimal differences between the input and output of the research models across various loading rates, ranging from 0.84 to 3.2 m^3/m^2 per day. The system operated intermittently and continuously, with no significant differences in the pollution removal efficiency observed in the treatment of greywater. However, the water supplying for intermittently with 3 hours of water loading followed by 1 hour of rest, which aligns with the typical frequency of intermittent greywater discharge in households. The quality of the treated water indicates its potential for storage for reuse in crop irrigation, particularly in areas facing water scarcity.

Keywords: greywater, reuse, coconut fiber, activated carbon, crushed waste concrete.

INTRODUCTION

Water is an important part of life and one of the essential resources for all human activities. However, water resources are becoming increasingly scarce due to declining quality and quantity, primarily caused by population growth, global climate change, urbanization, and so on. The state of water scarcity emerged several decades ago and has since continued to spread across many territories around the world.

According to forecasts on 2050, the world population reach to 10.2 billion people. Many developing countries in Asia and Africa will face clean water scarcity for this population growth (Boretti and Rosa, 2019). In fact, this issue is becoming increasingly severe and is currently spreading across all continents around the globe, not only countries with limited water reserves and resources. Particularly complex developments related to water scarcity have emerged in recent years, driven by drought and reduced rainfall, which are closely tied to regional precipitation patterns (Gross et al., 2015). According to a report by Mekonenn and Hoestra, two-thirds of the global population (mainly in India and China) live under conditions of water scarcity for at least one month per year and more than half a billion people face water scarcity throughout the entire year (Mekonenn and Hoestra, 2016).

In Vietnam, especially in the Mekong Delta, water scarcity has occurred frequently in recent years during the dry season due to saline intrusion and a decline in upstream water levels of the Mekong River caused by hydroelectric. This increasingly severe water shortage recurs annually in provinces such as Tra Vinh, Vinh Long, Hau Giang, Kien Giang, Ben Tre, Ca Mau, Bac Lieu, and other places affecting both the quality of irrigation water and even the tap water supply in urban areas, where salinity levels often exceed the allowable limits for domestic use (Nguyen Thanh Hung, 2020).

Greywater is increasingly recognized as a valuable resource that can alleviate water scarcity. It offers significant potential for treatment and reuse, as it typically contains lower levels of pollutants, yet constitutes a large proportion of total household wastewater. The components of greywater mainly originate from household activities and products used by humans, such as soap, toothpaste, shampoo, hair, skin cells, fabric particles, and so on. According to Anh et al., the amount of produced greywater in households depends on the current living standard of the country (Anh et al. 2024). In developed countries, daily water used ranges from 100 to 200 liters.person^{-1}.day^{-1}, of which 60–70% of this tap water becomes greywater. In contrast, in developing countries, the amount of greywater is produced about 20–30 liters.person^{-1}.day^{-1} (Maimonn et al., 2018).

A result of study in Greece indicate that average daily greywater production was equal to liters.person^{-1}.day^{-1} and accounts for approximately 70–75% of the total household wastewater production (135 L per person per day) (Noutsopolous et al., 2018). Furthermore, the "Guidelines for residential properties" in Canberra state that the average amount of greywater from bathing and washing can reach approximately 300 liters.person^{-1}.day^{-1}. According to Gross et al., treating household greywater for toilet flushing could save between 40 and 60 liters of freshwater per day (Gross et al., 2015). Several studies have explored the treatment reuse of water using different materials to help save water and address the global water scarcity challenge. The treatment of greywater typically involves a combination of physical, chemical, and biological processes. Among these, the filtration is considered one of the simplest methods to ensure the safety of greywater for non-potable applications (Kusumawardhana et al., 2021).

A case in point is a study conducted in Fahaheel, Salmiya, and Farwaniya of Kawait, using greywater collected from kitchen sinks, showers, and washing machines was treated through gravity-controlled filtration and disinfection techniques. The treatment system employed layers of activated carbon, sand, and gravel as filter media. Besides, the study also mentioned the possibility of replenishing groundwater with treated greywater (Samayamanthula, et al., 2019). In another study, Ahmad (2022) from Taylor University, Malaysia, investigated the use of Hibiscus Sabdariffa seeds as a biodegradable and non-toxic natural coagulant for greywater treatment, offering an environmentally friendly alternative to traditional chemical coagulants. In this study, activated carbon was explored as an adsorbent to research the productivity of particles and adsorbents according to different pH, coagulant, and adsorbent dosages (Ahmad et al., 2022).

Devikar et al., applied an electric coagulation filtration (ECF) system to treat greywater under different conditions. The statistical data was analyzed to evaluate experimental conditions to create models including COD, TDS, turbidity, and chloride removal efficiency with energy consumption using the response surface method (RSM) and ANOVA test. This study also characterized the sludge through scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), and FTIR spectroscopy to evaluate organic matter removal in ECF (Devikar et al., 2022).

In addition, a study used biochar and moriga oleifera seed protein in rural areas including Kwale and Siaya districts of Kenya using two treatment methods, complete agitation and batch filtration to treat greywater at the household scale. The research results of both methods achieved significant reductions including color, turbidity and surfactant level. While total organic carbon and total dissolved solids (TDS) increased, the treament was effective in reducing phosphate, nitrate, and iron (Ndinda et al., 2024).

At the Nature Tourism site in Malang, Indonesia, the performance of a circular-shape constructed wetlands (CCW) system in greywater treatment was studied. The CCW in this study were arranged circularly following the soil contour with three types of aquatic plants (Canna, Heliconia psittacorum, and Equisetum hyemale). The results demonstrated that the CCW system is effective in reducing organic pollutants while the water pH changes from acidic to neutral (Yulistyorini et al., 2023). Another study employed a greywater treatment system with a combination of activated carbon, coconut fiber, and Anaerobic Baffle Reactor (ABR) system. Water parameters including pH, turbidity, TSS, BOD, and COD, were analyzed to evaluate greywater quality and allow reuse (Sabara et al., 2022).

It can be seen that biological filtration treatment methods with filter materials combined with activated carbon materials have the potential to treat greywater for reuse purposes, especially for irrigation applications.

Using locally available materials to treat greywater for reuse is advantageous and feasible. This study utilizes coconut fiber (coconut is commonly grown in water-scarce areas in the Mekong Delta) and crushed waste concrete (waste concrete) as filter materials to treat greywater for reuse in irrigation, contributing to efforts to solve water scarcity in the Mekong Delta.

METHODOLOGY

Research materials

Filter materials

Coconut fiber was first washed with clean water, then soaked in water for 48 hours, followed by immersion in a 0.1% HCl acid solution to remove organic components adhering to the coconut fiber. The coconut fiber used in the greywater treatment research model is an inert and fibrous material.

The activated carbon installed in the experimental model is derived from coconut shell, and it was thoroughly cleaned by repeated rinsing with clean water. Activated carbon is in flake form, with a particle size of 1.5–5.0 mm. The density of coconut shell activated carbon used for the treatment model is 450 g/L (Figure 1).

The debris material used in the greywater treatment model consists of discarded concrete, primarily composed of sand and cement, originally used for construction purposes. This concrete was manually crushed into smaller particles, washed thoroughly, and soaked in clean water for 24 hours. It was then immersed in a 0.1% HCl solution to remove residual organic matter. Before being installed in the treatment model, the crushed waste concrete was rinsed again and dried. The density of crushed waste concrete is 1350 g/L (Table 1).

Grinding stones used for water filtration have a particle size range of 1–2.5 mm. These water filter millstones, purchased from water industry supply stores, were washed with clean water before being installed in the experimental model.

Drainage gravel, specifically egg gravel used for drainage, was purchased from water supply stores.

Figure 1. (a) coconut fiber; (b) coconut shell activated carbon; (c) crushed concrete; (d) grinding stone filters water; (e) drainage gravel

Table 1. The partical size distribution of crushed concrete

Grain size (d, mm)	Composition (%)
d < 0.5	75
0.5 < d < 3.15	15
d > 3.15	10

Greywater composition

To ensure the stability in greywater quality, the experiment evaluated the treatment efficiency of the model. This greywater was prepared by mixing clean water with various components and pollutants that simulate the characteristics of real household greywater, as detailed in Table 2.

Pollution components in experimental greywater included: pH (7.2–7.5); EC – electrical conductivity (550–720 µS/cm); TSS – total dissolved solids (120–150 mg/L); COD – chemical oxygen demand (240–320 mg/L); BOD_5 – biochemical oxygen demand (120–170 mg/L); TKN – total kjeldahl nito (3.5–8.5 mg/L); and total phosphorus (2–6.2 mg/L).

Research models

Model structure

The greywater treatment model operates by filtering through layers of filter material composed of coconut fiber layer (10 cm), crushed waste concrete layer (50 cm), coconut shell activated carbon layer (30 cm), drainage gravel layer (5 cm) installed in a 110 mm diameter, and 1.1 m high PVC filter tube (Figure 2).

Two filtration models were built in parallel to evaluate the filtration efficiency of crushed waste concrete materials: one model with a crushed waste concrete layer (50 cm) and one model with a grinding stone layer (50 cm). Both models had the same structure of filter materials but different conditions of water inflow (continuous and discontinuous inflow) to evaluate the treatment effectiveness of greywater.

Operating models

Artificial greywater was prepared in batches of 90 liters per time for the experimental model. A dosing pump was employed to control the water flow rate for the treatment research model. Preliminary tests were conducted to evaluate the treatment efficiency across different treatment models, with the aim of selecting a suitable model to study the application of greywater treatment for reuse in plants.

The experimental model was tested and evaluated with different experimental modes in terms of flow rate for the model (loading water) and water supply mode. Different flow settings were used to evaluate the model's processing efficiency. The model was set up and adjusted to switch between different loading modes as needed for the experimental conditions (Table 3).

Discontinuous feed flow was performed, specifically including 3 hours of charging flow with continuous water supply to the model and 1 hour of rest (Figure 3).

Sampling

Samples were taken to evaluate the processing efficiency of the model when the operating mode was in stable experimental conditions. Each experimental condition was sampled for evaluation at least 3 times, with samples taken from both the input and output water of the research model.

Table 2. Mixing ingredients of artificial greywater for experimental modeling

Number	Chemicals	Dosage
1	H_3BO_3	1.4 mg/L
2	$C_6H_{12}O_6$	28 mg/L
3	Na_2HPO_4	39 mg/L
4	Na_2SO_4	35 mg/L
5	$NaHCO_3$	25 mg/L
6	Wastewater from the laundry	20 ml/L
7	Fine clay	50 mg/L
8	Shampoo	200 mg/L
9	Toothpaste	10 mg/L
10	Output wastewater from the wastewater treatment factory	20 ml/L

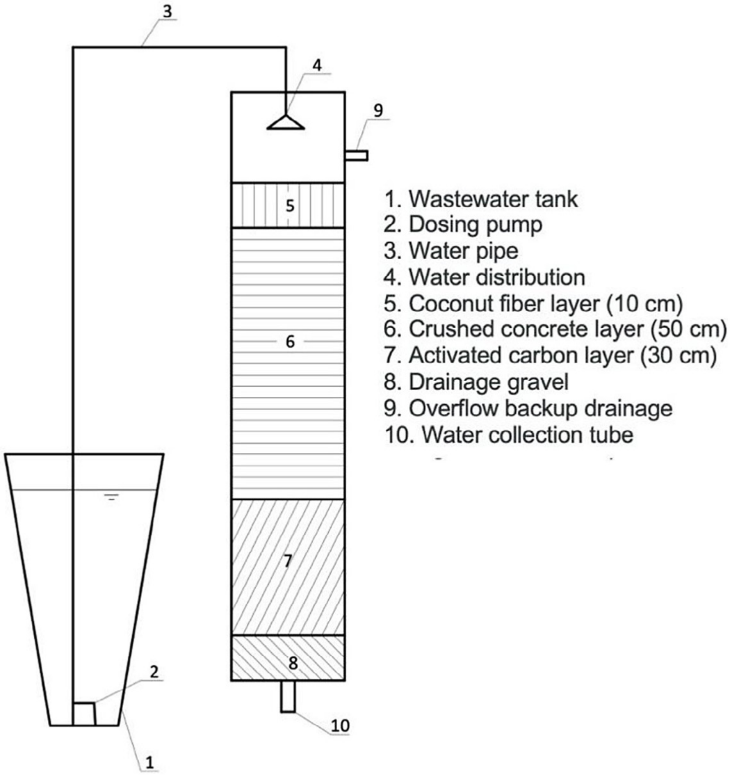

Figure 2. Diagram of the experimental model

Table 3. Operating conditions of a model during the research process

Periods	Days			Flow (Liter/day); Loading water (m^3/m^2.day)	Notes
	Start	Finish	Time		
I (model adaptation)	0	32	32	12 L/day; 1.26	Two models work in parallel (with filter material being grinding stone and crushed waste concrete material)
II	33	54	21	8; 0.84	Continuous water inflow
II’	55	68	13	8; 0.84	Discontinuous water inflow
III	69	95	26	10; 1.05	Continuous water inflow
III’	96	111	15	10; 1.05	Discontinuous water inflow
IV	112	140	28	15; 1.58	Continuous water inflow
IV’	141	152	11	15; 1.58	Discontinuous water inflow
V	153	169	16	30; 3.2	Continuous water inflow
V’	170	183	13	30; 3.2	Discontinuous water inflow

DATA ANALYSIS AND PROCESSING METHODS

Data analysis method

Input and output greywater analysis criteria of the experiment were conducted according to Standard Methods for the Examination of Water and Wastewater (2017). The effectiveness of treatment and the evaluation of greywater treatment research models were analyzed. Data processing and calculation methods were performed using statistical software. The analysis and interpretation of data from research experiments are presented in scientific reports with data, tables, and graphs of research results.

Experimental analysis and evaluation methods

Experimental results were collected with 3 repetitions for carrying out the research. Analysis

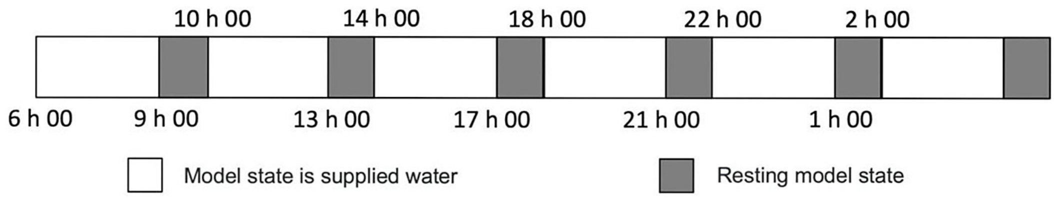

Figure 3. Working time chart of a model with discontinuous water inflo

was performed using the R program, with t-test and ANOVA applied to evaluate the results of the research conditions.

RESULT AND DISCUSSION

Grey water treatment efficiency of crushed waste concrete and grinding stone for water filtration

The study compared the treatment efficiency of two models with a different material layer in the two models to evaluate the effectiveness. The two structural models were completely identical, except for the 50 cm high filter layer made of crushed waste concrete (MH1) and Grinding stone filters water (MH2). The models were also run for 20 days with the same water load (1.26 m^3/m^2.day). The treatment efficiency of two material types, arranged in two models, was evaluated using the treatment efficiency parameters COD, BOD_5, TSS.

Research results (Figure 4) show that the model with a layer of crushed waste concrete filter material performs better than the model with a layer of grinding stone filters water. Besides, crushed waste concrete filter material supports for the development of microbial membranes than crushed stone, therefore making it better suited for handling organic components in wastewater.

Regarding COD and BOD treatment, for crushed waste concrete filter material, the treatment efficiency was 61.4 ± 3% and 57.9 ± 1.6%, respectively. In contrast, for crushed stone filter material, the efficiency was 40.8 ± 9.5% and 27.7 ± 5.7% for COD and BOD at a water load of 1.26 m^3/m^2.day. As for the TSS parameter, both models demonstrated equivalent treatment efficiency, with values of 77.7 ± 8.2% and 79 ± 3% for the crushed waste concrete and crushed stone filter material models, respectively.

Evaluation of grey water treatment efficiency with filter material using crushed waste concrete

Effective removal on pH and EC of greywater

The crushed waste concrete is more efficient than grinding stone for removal on BOD and COD in greywater. Therefore, the crushed waste concrete was studied under many conditions to evaluate the effectiveness of the treatment. The layers of filter materials were arranged as description in Figure 2, the experiments were carried out with continuous, discontinuous water inflow and various water inflow loads.

The pH of raw greywater supplied to the model during the research period ranged from 6.9 to 7.4. The models were run under the same conditions (I) for adaptation before changing the study conditions. There were the different water loads and types of supply flow as following II (0.84 m^3/m^2.day with continuous supply flow), II' (0.84 m^3/m^2.day with discontinuous supply flow), III (1.05 m^3/m^2.day with continuous supply flow), III' (1.05 m^3/m^2.day with discontinuous supply flow), IV (1.58 m^3/m^2.day with continuous supply flow), IV' (1.58 m^3/m^2.day with discontinuous supply flow), V (3.2 m^3/m^2.day with continuous supply flow), V' (3.2 m^3/m^2.day with discontinuous supply flow).

The results show that there is no significant difference between the input and output pH values of the treatment process. The difference in pH values between input and output during the research process, with different loads and different types of supply flow, fluctuates around ± 1. Thereforethe research model does not change the pH of wastewater and greywater supplied to the model, maintaining an approximately neutral pH range (6.8–7.3) (Figure 5).

The EC parameter in greywater represents the amount of dissolved salts. The results of this study, along with recent studies, show that the ability of EC treatment in greywater by filtration processes is effective when EC in greywater is at

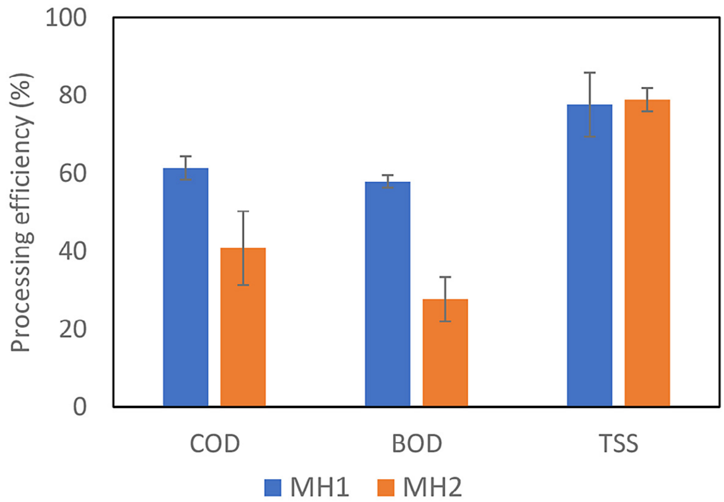

Figure 4. Chart of two models processing efficiency

a high level. The output EC of the research models range from 95 to 500 µS/cm, indicating that EC of raw greywater was not removed by several layers of materials in this study (Figure 6).

Effective removal on TSS of greywater

TSS concentration in greywater, measured under 8 experimental conditions, ranges from 126 to 164 mg/L. The results showed that the TSS treatment efficiency of the research model in 8 experimental conditions ranges from 56.3 to 90.2%, gradually decreasing with increasing water load. In this study, when the water load increased from 0.84 to 1.05 m^3/m^2.day, the TSS removal efficiency showed little variation, ranging from 83.3 ± 1.5 to 87.8 ± 2.4%. However, when the water load increased beyond to 1.05 m^3/m^2.day, the TSS removal efficiency tended to decrease, and in particular dropped sharply when the water load reached 3.2 m^3/m^2.day. At that time, the TSS treatment efficiency in greywater reached 62.4 ± 6.0 to 65.6 ± 4.6% (Figure 7). Compared with the study by Deng et al. (2023), which reported a TSS removal efficiency of 65% at a water loading rate of 3.6 m^3/m^2·day, the findings of this study are consistent. Furthermore, this result aligns with previous studies (Deng et al., 2023), indicating that TSS treatment efficiency depends on various factors such as filter

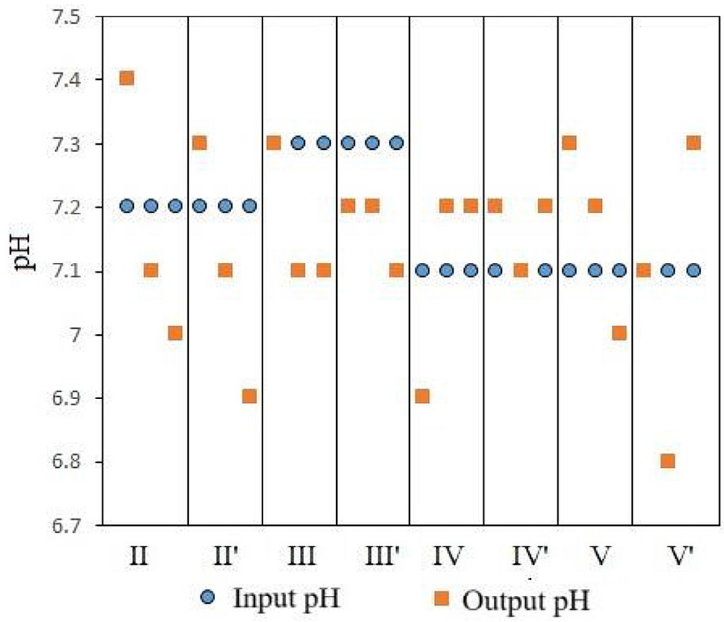

Figure 5. pH changes during the operation of the research model with different water loading loads

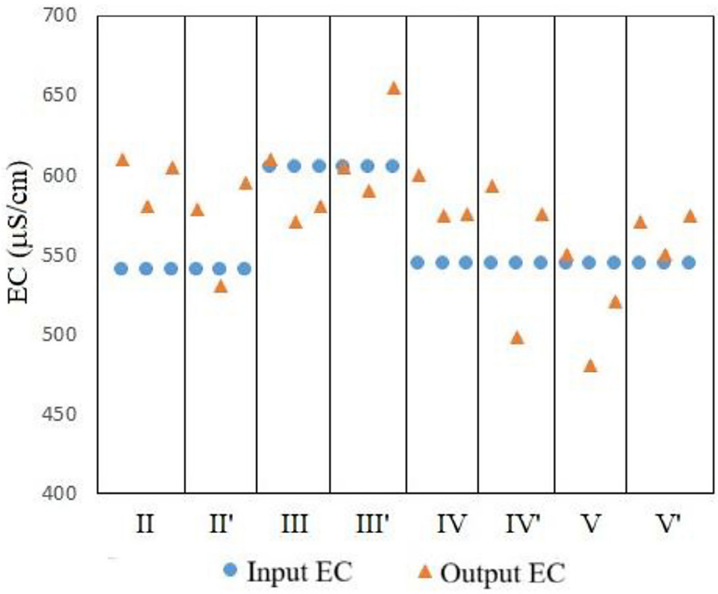

Figure 6. EC changes in during the operation of of the research model with different water loading loads

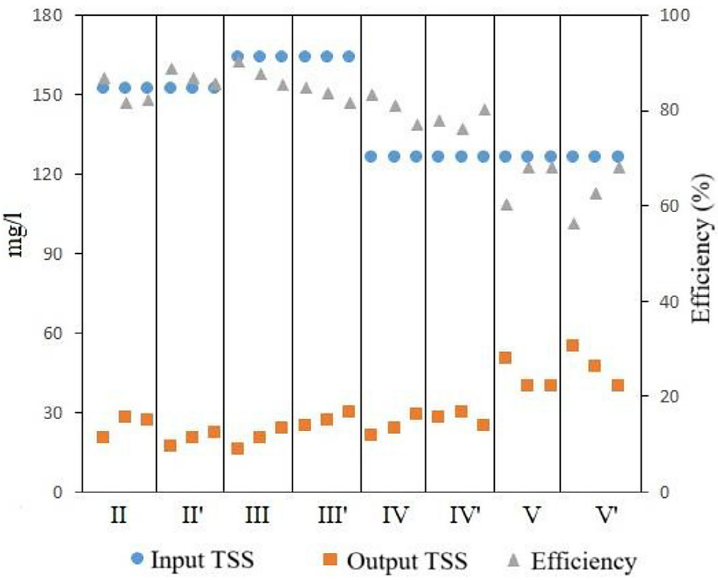

Figure 7. Effective removal on TSS of greywater from research models

material, porosity, water loading, and water velocity through the filter material layer.

Additionally, the difference in TSS removal efficiency between continuous and discontinuous inflow types at the same water loading was not statistically significant (within a 95% confidence interval).

Effective removal on COD of greywater

The results showed that when the water load increased to 3.2 m^3/m^2.day, the COD treatment efficiency tended to decrease. This suggests that at this loading rate, the contact time may be insufficient for microorganisms to adequately process pollutants in the greywater. The difference in COD treatment efficiency between the water loading load of 1.58 m^3/m^2.day and 3.2 m^3/m^2.day was statistically significant with a 95% confidence interval (Figure 8).

The research results also showed that the highest COD removal efficiency in grey water was achieved with a loading rate of 1.58 m^3/m^2.day, with an average efficiency of 73.3 ± 1.0% for continuous inflow and 74.8 ± 1.1% for discontinuous inflow. However, However, the difference in COD removal efficiency between these two inflow conditions at the same loading rate was not statistically significant within the 95% confidence interval.

The study showed that each type of filter material and design model has a specific capacity for treating COD at different water loading rates. The study by (Babaei et al., 2019) reported similar results: when the organic loading increased from 3.15 gCOD/l.day to 19.23 gCOD/l.day, the COD treatment efficiency in greywater from the sand, silicate, and GAC filter models ranged from 27% to 68%.

Moreover, the result of this research is much higher than the study of Zipf et al. (2016) with sand filter column and activated carbon achieving the highest COD treatment efficiency of 56%. In addition, with high efficiency water loading at 1.58 m^3/m^2.day and reduced efficiency at 3.2 m^3/m^2.day, it shows that the research model filter system has loading parameters equivalent to low load biological filter tank (1–2 m^3/m^2.day).

Effective removal on BOD_5 of greywater

The research model was carried out with 8 operating conditions to evaluate the BOD_5 treatment efficiency of the studied greywater. The results of BOD_5 treatment efficiency of greywater under 8 conditions are shown in the Figure 9.

The efficiency of BOD_5 removal in wastewater by treatment processes depends on many factors, such as the concentration of organic matter, the number of microorganisms, the presence of microorganisms that inhibit the biodegradation process, or toxins such as residual chlorine in water or some detergent products existing in greywater. The research model used crushed waste concrete material as a substrate for microorganisms to adhere to and develop.

The BOD_5 of grey water supplied to the model operating under research conditions ranged from 170 to 190 mg/l. The BOD_5 of treated wastewater ranged from 40 to 75 mg/l, achieving a treatment efficiency of 61.8 ± 5.1% to 78.1 ± 1.5%. The research results showed that the BOD_5 treatment efficiency of the model was lower than that reported by (Anh et al., 2024; Maheesen et al., 2011), in which a trickling biological filter treatment model with fiber- reinforce plastic and river rock media achieved more than 85% BOD_5 removal. However, the results of this study showed a higher treatment efficiency than of a slow filtration model using sand and quartz media with a filtration speed of 2 m/hour, which achieved a maximum BOD_5 removal efficiency of 67%, which can be used for irrigation purpose (Al-Ismaili et al., 2017).

The results from the BOD5 treatment of greywater from the research model showed that the BOD5 treatment efficiency increased when the water loading rose from 0.8 to 1.58 m^3/m^2.day, and then decreased when the loading increased to 3.2 m^3/m^2.day. In the two conditions of continuous and discontinuous water inflow at the same loading level, there was no significant difference in BOD_5 treatment efficiency, except at the water loading of 0.84 m^3/m^2.day. At this loading level, when discontinuous inflow was applied in the model, the treatment efficiency decreased

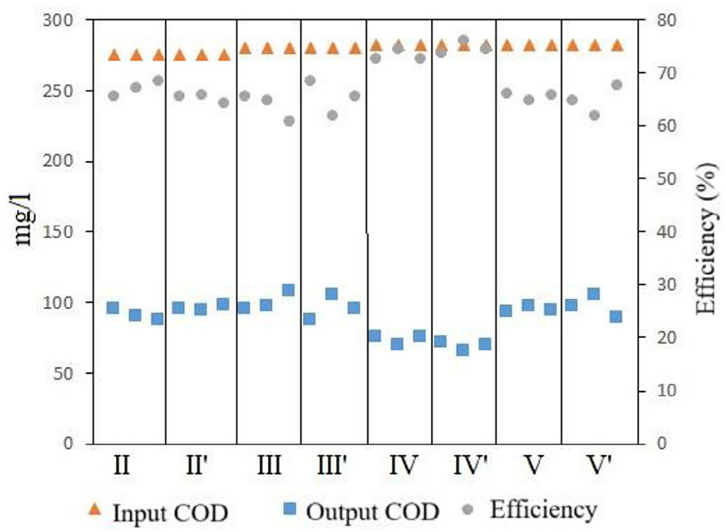

Figure 8. COD processing efficiency of greywater by model using crushed waste concrete and activited carbon filter materials

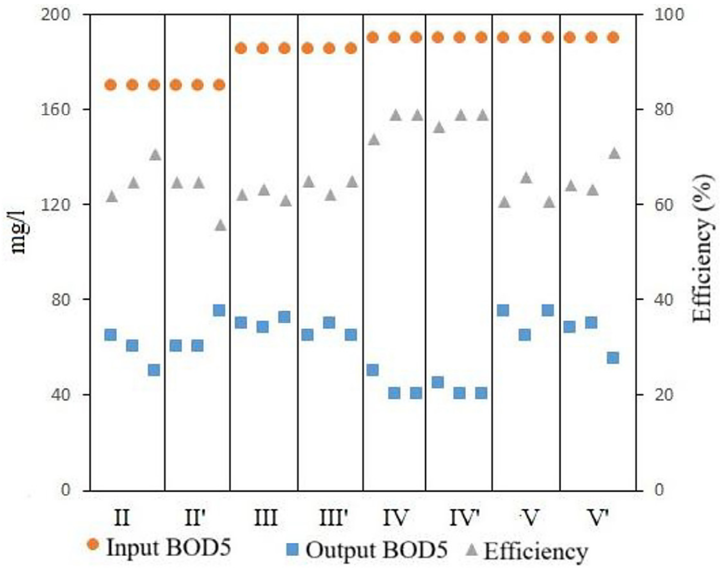

Figure 9. BOD_5 processing efficiency of greywater by model using crushed waste concrete and activited carbon filter materials

compared to continuous inflow, possibly due to the sudden increase in load and the low-density biofilm. This could be attributed to an insufficient substrate supply, which a have affected the formation of a sufficiently dense biofilm

BOD5 treatment efficiency decreased significantly when increasing water loading from 1.58 m^3/m^2.day to 3.2 m^3/m^2.day. This decrease was due to increased filtration velocity through the filter material layer, reducing the contact time between wastewater and microorganisms on crushed waste concrete and activated carbon.

Effective removal on TKN of greywater

The efficiency of nitrogen treatment in greywater by the research model was evaluated through the results of monitoring the efficiency of TKN treatment in greywater changing between the influent and effluent of the model. The study monitored and evaluated the efficiency of TKN treatment in water under 8 operating conditions of the research model at 4 water loading rates of 0.84, 1.05, 1.58 and 3.2 m^3/m^2.day. The results are shown in Figure 10.

TKN at the effluent of the treatment model reflects the efficiency of converting and removing organic nitrogen and ammonia nitrogen. The removal process occurs simultaneously during the absorption process, separating suspended solids containing organic nitrogen or ammonia nitrogen when wastewater passes through the filter material layers of the model. In addition, the removal of TKN in wastewater using this research model occurs through a nitrification mechanism, facilitated by a group of nitrifying bacteria growing on the concrete substrate and activated carbon, which serve as filter materials. The oxygen required for this process is supplied from the surface of the filter model, following the direction of the inlet water flow.

The TKN content in the wastewater studied in the experiment for the model was greywater with low TKN content, ranging from 5.2 to 5.7 mg/l. The initial treatment efficiency with a surface water loading of 0.84 m3/m2.day was quite low, removed in 18.6–22.4%. The TKN treatment efficiency increased when the surface water loading increased; however, the TKN removal efficiency in the water loading range of 1.05 to 3.2 m^3/m^2.day also fluctuated and remained unstable The explanation was that when the water loading level exceeded 1.05 m^3/m^2.day, the amount of TKN removed increased, possibly due to an increase in oxygen availability within the filter layer, which enhanced the nitrification process and allowed the nitrifying bacteria in the filter layers to function more effectively.. The TKN treatment efficiency with filter materials made of crushed waste concrete or crushed bricks, ash and slag were not very high. According to (Deng et al., 2023), the ammonia removal efficiency in wastewater using concrete, brick, and ash filter materials was 17%, 2%, and 6%, respectively.

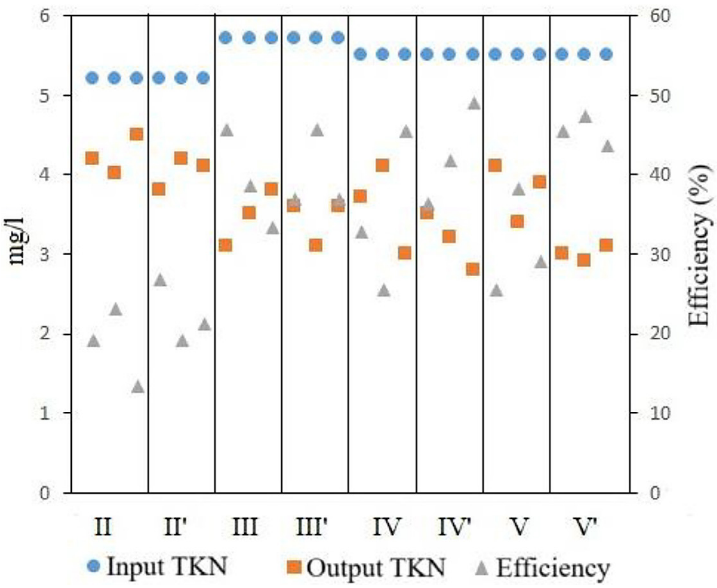

Figure 10. TKN processing efficiency of greywater by model using crushed waste concrete and activited carbon filter materials

Effective removal on total phosphorus of greywater

The efficiency of total phosphorus treatment in greywater of the research model with experimental conditions is described in the Figure 11.

The total phosphorus content in the grey water studied and treated in the model was relatively low, ranging from 5.8 to 6.1 mg/L. The treatment efficiency of P depends on the phosphorus absorption capacity of the filter material and the filtration velocity through the media. The results show that with a low water loading, 0.84 m^3/m^2.day, the research model is capable of treating 48–50% of phosphorus in grey water, with the pH of grey water in the neutral range of 7–7.2. This result is consistent with the study of (Deng et al., 2023) when comparing the phosphorus adsorption capacity in wastewater of bricks, concrete and ash and slag. The results showed that concrete has the ability to treat phosphorus in water by approximately 50% with low phosphorus concentrations in wastewater and pH in the neutral range.

With adsorbent materials, the ability to release phosphorus from the material into water has the potential to occur at low or high pH. However, according to the study by (Deng et al., 2023), the phosphorus adsorption capacity of some materials decreases as the pH increases. The highest phosphorus adsorption efficiency of crushed waste concrete in the study of Deng et al. was at pH 7. In addition to the ability of concrete filter media to adsorb phosphorus from greywater, activated carbon also played an important role in removing phosphorus in the studied greywater.

CONCLUSIONS

The study was conducted on a laboratory scale to investigate greywater treatment using filtration materials sourced from local and waste materials, with water inflow. Several conclusions were drawn from the study process.

Greywater treatment was efficient for potential irrigation reuse through filtration using a combination of local materials as coconut fiber, crushed concrete, and activated carbon coconut.

The operating conditions with continuous and intermittent water inflow in the research model showed no significant differences in the removal efficiency of pH, EC, COD, BOD_5, TKN, and total phosphorus in greywater.

The operating conditions with intermittent water inflow, with 3 hours of water loading followed by 1 hour of rest, this approach is suitable for greywater treatment in the household.

The removal efficiency of BOD_5 and COD reached 75% at a hydraulic loading rate of 1.58 m^3/m^2 per day with intermittent water inflow. The concentrations of BOD_5 and COD in the outflow were 41.7 ± 2.9 mg/L and 69.3 ± 3 mg/L, respectively. This treated water can be stored for reuse in irrigation for several days

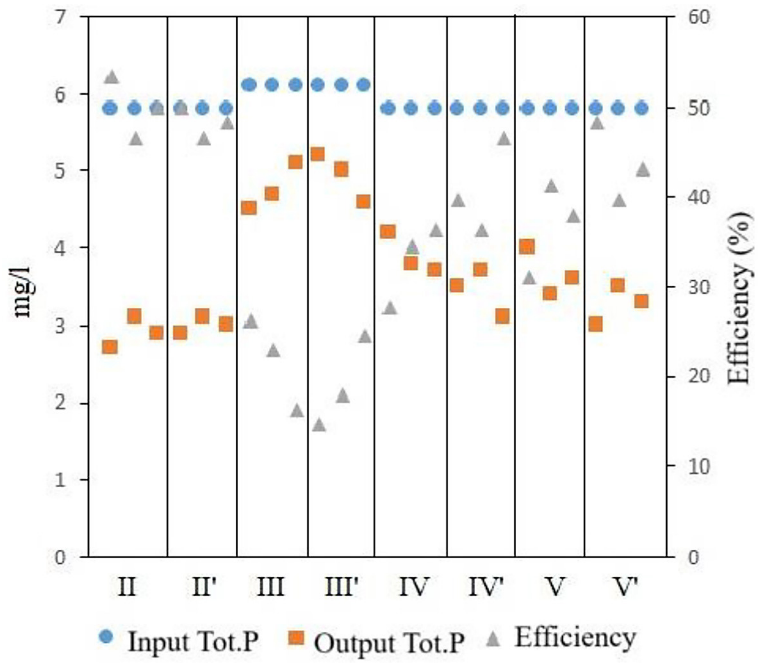

Figure 11. Total phosphorus processing efficiency of greywater by model using crushed waste concrete and activated carbon filter materials

without negatively impacting the environment, due to the decomposition of organic components in greywater.

The removal efficiencies for BOD_5, COD, TKN, TSS, and total phosphorus were 78.1 ± 1.5%, 74.8 ± 1.1%, 42.2 ± 6.4%, 78.0 ± 2.0%, and 40.8 ± 5.3%, respectively. Meanwhile, pH and EC showed no significant differences between the inflow and outflow of intermittently supplied water at a hydraulic loading rate of 1.58m^3/m^2 per day. The physicochemical quality of the treated greywater in this study meets the standards for reuse in irrigation in water-scarce areas.

The quality of treated greywater was improved compared to some studies using other filter materials, demonstrating its potential for reuse in the irrigation of plants in water-scarce areas.

Preliminary research has demonstrated the potential for utilizing local materials and common waste products in greywater treatment for reuse in crop irrigation in water-scarce regions. However, the study is limited in its assessment of the diversity of microorganisms present on the filtration media, the mechanisms of biofilm formation, and clogging. Further research is essential to address the limitations of this study concerning real wastewater, improve the efficiency of EC removal in greywater, and enhance post-treatment disinfection to achieve greater reuse potential.

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