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Domestic wastewater treatment using a combination of peat and coconut shells

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ABSTRACT

Domestic wastewater remains the main problem in solving environmental pollution. The type of treatment determines the domestic wastewater treatment procedure and the media used. The use of peat and coconut shell media in domestic wastewater treatment in developing countries with the morphology of peatland and tropical areas is of particular concern. The purpose of this study was to test the ability of the combination of peat and coconut shell media to reduce the pollution load of domestic wastewater disposed in student dormitories. The parameters used as indicators were biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammonia nitrogen (NH_4^+–N), and pH. Testing of domestic wastewater treatment plants using a combination of peat and coconut shell media was carried out in three replications to measure domestic wastewater parameters for 42 d. The results showed that the domestic wastewater effluent had a BOD of 159.1 mg L^{-1}, COD of 310.39 mg L^{-1}, TSS of 38, NH_4^+–N of 3.14, and pH of 8.21, on average. After applying a combination of peat and coconut shell media in a wastewater treatment plant, the results of domestic wastewater decreased to an average BOD of 49.31 mg L^{-1}, COD of 116.94 mg L^{-1}, TSS of 4.19, NH_4^+–N of 1.17, and pH of 6.69, and the level of efficacy of the removal was 66. 41% for BOD, 49.40% for COD, 80.58% for TSS, and 59.52% for NH_4^+–N.

Keywords: Coconut shells; Domestic wastewater; Peat; Wastewater treatment

1. Introduction

Household wastewater pollution remains a major global problem, especially in developing countries [1–3]. Rapid population growth and the lack of infrastructure to treat wastewater adequately affect the indiscriminate disposal of sewage [4]. The disposal of liquid waste that flows directly into the drainage involves the accumulation of large amounts of waste and the risk of environmental pollution, such as soil and surface water pollution [3,5].

Using river water, which is the raw material for clean water sources in Indonesia, especially in West Kalimantan, causes many obstacles in the quality of water, which is decreasing constantly. The decline in river water quality is caused by pollution, which is the result of wastewater disposal from housing and industry. [6–8]. Low quality water increases operational costs, which burdens local budgets. The economic impact of pollution affects human health both acutely and chronically [9,10].

Infectious diseases, such as diarrhea, can be transmitted through water. Continuous diarrhea can trigger stunting in children, in addition to other contagious diseases [11,12]. High quantities of microorganisms such as *Escherichia coli*, *Streptococcus faecalis*, *Vibrio cholera*, various types of viruses, and worm bugs found in domestic wastewater cause transmission diseases. According to the results from studies on the Kapuas River, Pontianak City which was done in June 2009, the density of coliform bacteria at

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high tide has increased to 160,825 MPN/100 mL. The lowest was 8,425 MPN/100 mL at the mouth of the Jawi River. These results show that the Kapuas River waters are contaminated with coliform bacteria that have passed the threshold for clean water requirements and domestic use (1,000 MPN/100 mL) [13].

Regulations regarding industrial waste disposal into rivers can be put into place to solve surface water pollution problems. The household aspect is a serious concern because the amount of waste produced is extensive, which lowers river water quality [14,15].

Household activities produce liquid waste that has complex contents. Domestic wastewater is classified as one of two types: black and gray wastewater. Black wastewater comprises of a mixture of feces and urine and can pose health risks. Gray wastewater comes from bathtubs, hand-washing tubs, and washing [16].

Peat is an organic substance derived from plant material with a lower ash content (less than 25% based on dry weight) [17]. Peat is composed of complex materials with significant elements, such as lignin, cellulose, and humic acid. These constituents, especially lignin and humic acid, carry polar functional groups, such as alcohols, aldehydes, ketones, carboxylic acids, and phenolic hydroxides involved in the chemical bonding of metals. Microscopically, peat has a cellular structure. Because of its polar functional groups, peat exhibits a considerable adsorption potential for dissolved solids, such as metals, and polar organic molecules can be used as adsorbents to remove metals from water or wastewater [17,18]. In horticultural peat, heavy metal ions from aqueous solutions increase their absorption capacity with increasing metal concentrations [19].

Coconut shells comprise a large percentage of the waste from areas with the most elongated coastal strips globally, such as Indonesia. The untapped dark surface can become a breeding ground for disease-transmitting mosquitoes [20]. Anaerobic-aerobic domestic waste treatment uses wasp nest media as an adhesive to decompose bacteria. Coconut shells have the same function as adhesives for reproducing bacteria. Coconut shells have a lower risk of environmental pollution than wasp nest media made of plastic. When exposed to acidic waste, wasp nests made of plastic release plastic particles along with the discharge of treated water into the environment. Using coconut shells is therefore more economical than wasp nests in wastewater treatment.

The combination of peat and coconut shell media is expected to provide optimal results compared to processing using the media partially or separately by combining the concepts of Physics and Biology from the use of these two materials [21]. The combination of peat and coconut shell media in treating domestic waste applies concepts from physics and biology, where physical processing is done through peat media that can adsorb, which is different from activated carbon and has dual function adsorption and absorption [21]. Despite the advantages of other conventional processing processes such as domestic sewage treatment using membrane bioreactors, electrochemistry, ion exchange, and domestic waste treatment using activated carbon media, they have drawbacks, namely operations that require additional energy sources as membrane propulsion and electric current, and additional materials as for converting ions in wastewater requires relatively high costs, so it is rather difficult to apply on a household scale [21–25].

Domestic wastewater treatment related to urban and semi-urban areas with limited land and operational expertise requires new alternatives [26]. Small-scale and simple household wastewater treatment systems can be considered to overcome this problem. Using peat as a medium for absorbing pollutants in household wastewater by combining a moisture shell as a bacterial adhesive for the breakdown of organic matter in sewage can be an alternative in domestic wastewater treatment.

The selection of domestic waste treatment in areas with peatland morphology using peat media and coconut shells is a promising option. This assumption is based on the ability of peat and coconut shell media to remove organic matter from domestic waste at a low cost and because it is easily obtained from the surrounding environment. In addition, peat and coconut shells are more environmentally friendly and can be used directly without lengthy processing compared to activated carbon, which is more expensive and entails a longer process in carbon activation.

2. Materials and methods

2.1. Wastewater treatment system and operation conditions

The processing basin consists of five rooms: the initial settling room, the peat media biofilter room, the coconut shell biofilter tank, the peat biofilter tank, and the final settling room. The residual time of the waste was set at 1 h initial settling tank, 2 h peat filter tank, 2 h coconut shell media tank, 2 h peat filter tank, and 0.5 h final sedimentation tank (Fig. 1).

2.2. Study design

The experimental design was structured using pre-and post-design with a control. The aim of this study was to analyze the efficacy of domestic wastewater treatment incubation using peat and coconut shell media to reduce chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TTS), pH, and ammonia nitrogen (NH_4^+–N). The wastewater used in this study was obtained from the dormitory of the Poltekkes Kemenkes Pontianak, Siantan Hulu, Pontianak City. The study was conducted from in February–September 2020. Parameter checks were performed at the Chemistry Laboratory of the Faculty of Agriculture, Tanjung Pura-Pontianak University.

2.3. Domestic wastewater sampling

Domestic wastewater treatment plants were tested using a combination of peat and coconut shell media in the Pontianak Health Ministry Polytechnic student dormitory. The sewage treatment plant consisted of an initial sedimentation tank, a peat media biofilter tank, a coconut shell biofilter tank, and a final settling tank. The residence time in the initial holding tank was 1 h, the peat biofilter tank was 4 h, the coconut shell biofilter tank was 2 h, and the final sedimentation tank was 0.5 h. The peat biofilter tub consisted of two tubs before and after the coconut shell biofilter tub. Quality control is carried out using

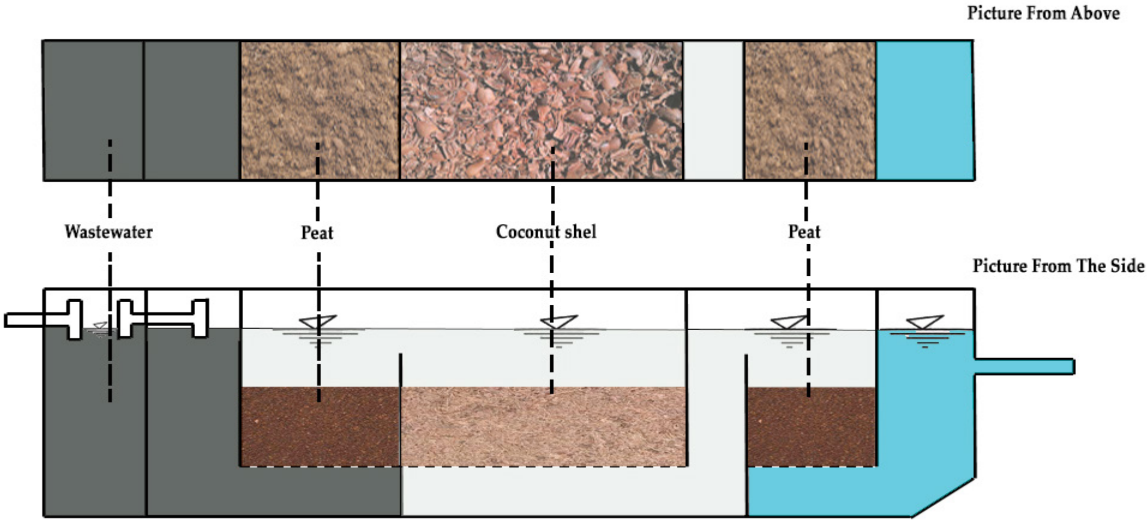

Fig. 1. Domestic Wastewater Treatment Plant Design.

three domestic waste treatment units with the same waste source. The wastewater sample was channeled into the late after several disposal sources were made into one flow to the domestic wastewater treatment tank. Sampling was carried out in the morning when the dormitory residents engaged in activities that produced domestic wastewater. The selection was carried out on late and late domestic wastewater treatment plants every week until the 7th week. This test was conducted to measure the BOD, COD, total suspended solids (TSS), NH_4^+–N, and pH without measuring total bacteria and coliform bacteria.

2.4. Peat sampling

The peat used as filter media was obtained from Parit Malaya village, Kubu Raya district, West Kalimantan. Peat was chosen as a filter medium because of its fiber content and as it is below 300 mm from the soil surface. The collection used a fiber container with the amount according to the volume from the installation of domestic wastewater treatment. The peat used does not undergo special preparations and is directly used as a filter medium.

2.5. Coconut shell sampling

The coconut shells used as biofilter media were obtained from Sungai Itik Village, Kakap District, Kubu Raya Regency, West Kalimantan. The coconut shells were separated from the fiber up to approximately 4–6 cm diameter. The amount of coconut shells used was 3/4 of the coconut shell biofilter tub volume. The coconut shells used were not specially prepared for direct use as a filter medium.

2.6. Data analysis

Determination of BOD, COD, TSS, NH_4^+–N, and oil values was calculated according to the equations contained in the Indonesian National Standard (INS) Test Method. In contrast, the pH and phosphate values were determined using instruments. The determination of the effectiveness of parameter reduction was calculated using Eq. (1).

$$\text{Effectiveness}(\%) = \frac{(A_0 - A_n)}{A_0} \times 100\% \quad (1)$$

where A_0 = pollutant level before processing; A_n = pollutant level after processing.

3. Results and discussions

3.1. Wastewater quality before and after treatment

The quality of waste in the dormitories and the process followed is shown in Table 1. Results of BOD, COD, TSS, NH_4^+–N, and pH of hostel wastewater are shown. TSS and NH_4^+–N values were lower than the maximum values reported in the literature. Activities that used a high amount of soap caused higher COD and BOD values. All parameters characterized pollution, and treatment efficiency depended on the cooking style and dishwashing products of the dormitory. Peats contain positively charged ions. Negatively charged ions in kitchen wastewater were attracted to and became stuck to the peat. When kitchen wastewater flowed through peat, the particles were absorbed by the peat and removed from the stream. Treated kitchen wastewater also showed better quality during the treatment period with decreased concentrations of BOD, COD, TSS, NH_4^+–N, and pH.

3.2. Waste treatment to reduce BOD

Fig. 2 shows the BOD concentrations for dormitory wastewater before and after treatment using peat and coconut shell media. The combined application of peat and coconut shell media is considered to provide sufficient microorganisms to degrade organic pollutants in wastewater. The mean BOD concentration for primary waste was 159.16 mg L^{-1}. After filtering with peat and coconut shell

Table 1
Greywater quality before and after treatment with peat and coconut shell filter media (number of samples, $N = 3$; mean ± standard deviation)

Day	Parameter									
	BOD		COD		TSS		NH_4^+–N		pH	
	mg L^{-1}		mg L^{-1}		mg L^{-1}		mg L^{-1}		–	
Standard[a]	30		100		30		10		6–9	
1	Pre	Post (Mean ± SD)	Pre	Post (Mean ± SD)	Pre	Post (Mean ± SD)	Pre	Post (Mean ± SD)	Pre	Post (Mean ± SD)
1	119	53 ± 3	433	124.67 ± 1.5	28	3.67 ± 0.58	2.57	1.78 ± 0.09	8.5	6.67 ± 0.15
7	149.2	44.67 ± 3.51	373	127 ± 1.5	24	2.33 ± 0.58	2.26	1.32 ± 0.02	8.7	6.57 ± 0.12
14	165.2	97.17 ± 0.57	413	181 ± 9.6	48	4.33 ± 0.58	2.39	1.17 ± 0.04	7.8	6.57 ± 0.06
21	89.7	27.33 ± 2.52	93.4	88.53 ± 3.2	100	4.67 ± 0.58	3.68	1.28 ± 0.02	8.8	7.17 ± 0.12
28	289	42.67 ± 1.53	103.3	94.38 ± 2.8	20	4.67 ± 0.58	3.7	0.90 ± 0.09	8.5	6.60 ± 0.10
35	181	35.67 ± 1.53	454	101.67 ± 4.4	40	6 ± 1	3.7	0.90 ± 0.06	7.6	6.53 ± 0.15
42	121	44.67 ± 3.51	303	100.67 ± 2.7	6	3.67 ± 0.58	3.7	0.86 ± 0.01	7.6	6.70 ± 0.10
Mean	159.16	49.31	310.39	116.94	38	4.19	3.14	1.17	8.21	6.69

[a]Domestic Wastewater Quality Standard [27].

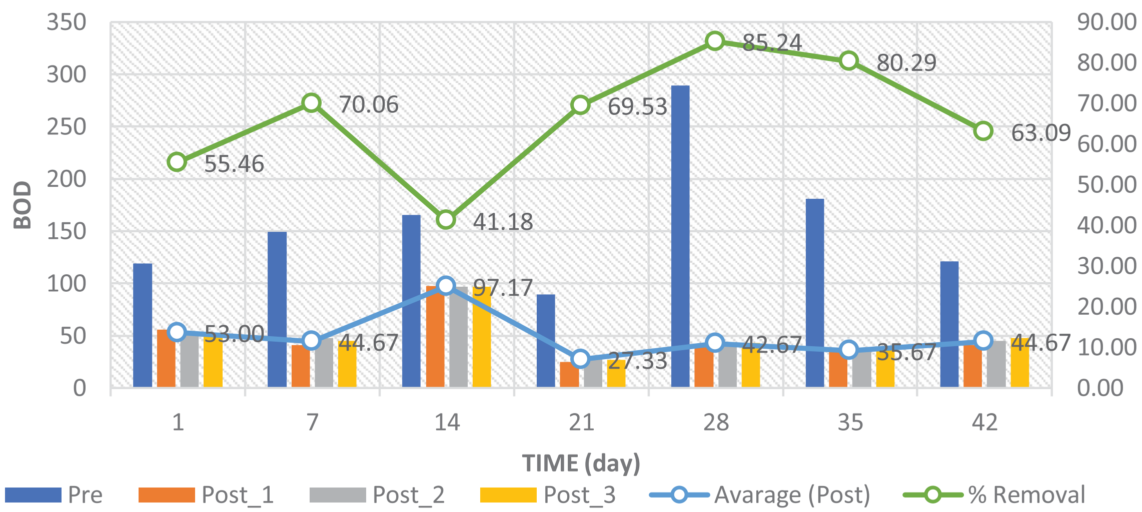

Fig. 2. Efficacy of removal of BOD.

filter media, the BOD concentration was gradually reduced to 53, 44.67, 97.17, and 44.67 mg L^{-1} on the 1st, 7th, 14th, and 42nd days, respectively. The percentage of deletions ranged from 41.18% to 85.24%.

Using media in wastewater treatment affects the quality of the resulting process. Peat media with a combination of coconut shells can remove waste parameters. BOD provides a domestic wastewater parameter. The effectiveness of the variety of coconut shell peat media in removing BOD in wastewater reached an average of 66.41%, and on the 28th day, it reached 85.24%. The ability to remove BOD from domestic waste has also been shown in research using activated carbon from coconut husks as an adsorbent in batches and columns to reduce BOD at a safe level below the threshold within 200 min [28].

3.3. Waste treatment to removal of COD

The COD removal efficiency for the residence wastewater treatment is shown in Fig. 3. The mean COD concentration in the hostel wastewater was 310.39 mg L^{-1}. The COD concentration was higher than the BOD of a particular sample considering the amount of organic matter in the sample. After treatment using peat media and coconut shells, the COD concentration decreased gradually to 124.67 mg L^{-1} on the 1st day and to 100.67 on the 42nd day, with an effectiveness of 66.77%.

The COD content in domestic waste is higher than that in wastewater [17]. The concentration of COD in domestic waste is influenced by organic wastewater levels: the higher the organic substances in the wastewater, the higher the COD value. Utilization of gastric media for removal can filter the organic material and coconut shells as a medium for bacteria can effectively reduce waste COD. In addition to the press affecting COD removal, the contact time determines the ability of the treatment plant to effectively reduce the COD of wastewater. Balance between the adsorbent and adsorbate is required to reach the optimum value [28].

3.4. Waste treatment to removal of TSS

Fig. 4 shows a graph of TSS against time for domestic wastewater before and after treatment. The highest TSS concentration before domestic dormitory waste was treated with peat and coconut shell filter media. The results of the domestic wastewater before processing showed that the TSS concentration was between 6 and 100 mg L^{-1}. In this study, TSS levels were found to be lower after treatment. This shows that the TSS value decreased the next day from 28 to 3.67 mg L^{-1}. The removal efficiency ranged from 30.74%–76.76%.

The presence of TSS in domestic wastewater declined after the water passed through the peat filter media and coconut shells. Dumping can occur because of colloids, which are negatively charged in wastewater. Harmful particles are provided with positive ion bonds from the peat media [29].

3.5. Waste treatment to removal of NH_4^+–N

Fig. 5 shows a graph of NH_4^+–N after treatment with peat media and coconut shells against the residence time

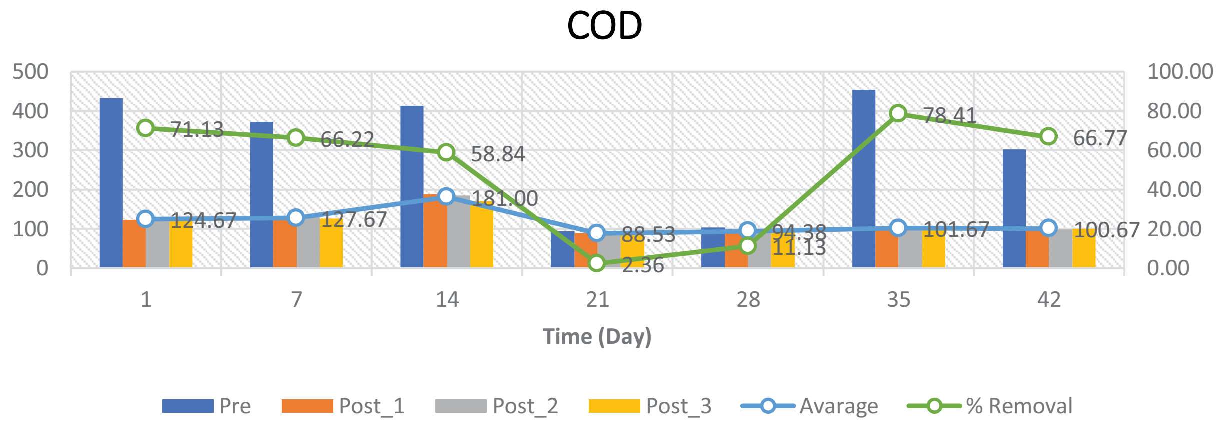

Fig. 3. Efficacy of removal of COD.

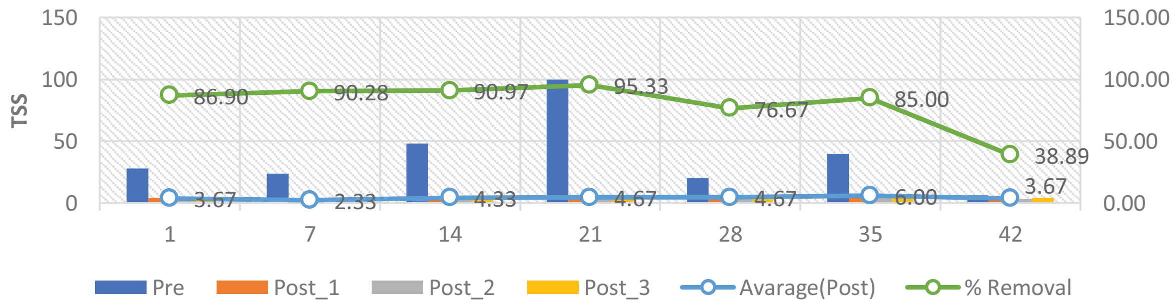

Fig. 4. Efficacy of removal of TSS.

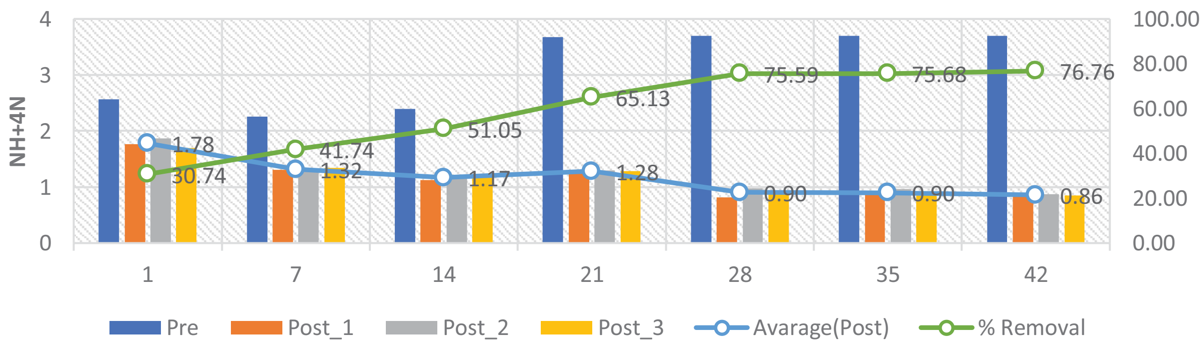

Fig. 5. Efficacy of removal of NH_4^+–N.

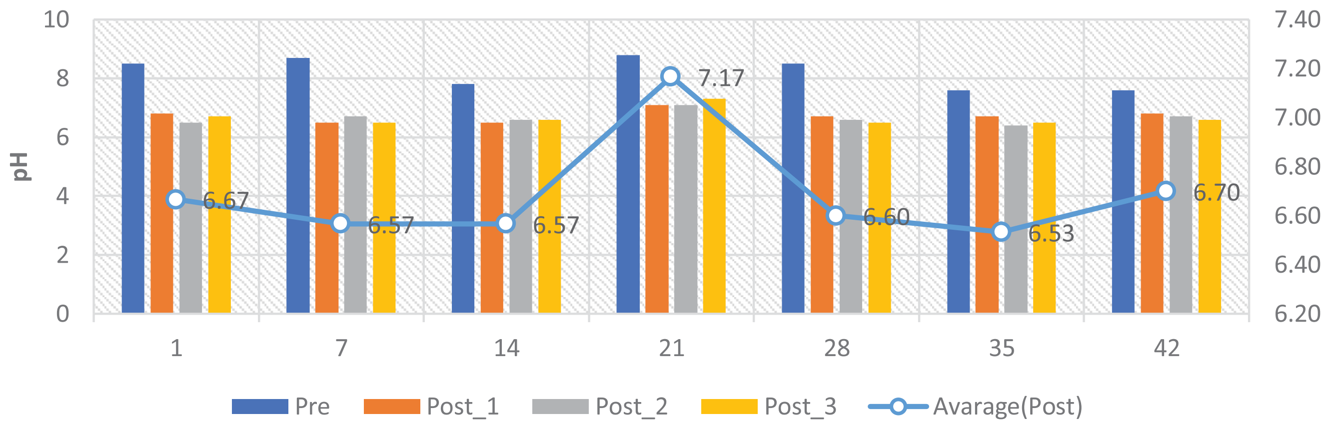

Fig. 6. Efficacy of wastewater treatment against pH.

for wastewater before treatment. The highest value of NH_4^+–N was obtained during processing using peat media and coconut shells from the graph. 2.26 to 3.7 mg L^{-1}. A higher NH_4^+–N value indicates the odor level emanating from the dormitory on days 21–42. Dormitory wastewater likely contains significant amounts of nitrogen. However, dormitory wastewater is still below the threshold value for wastewater quality, namely 10 mg L^{-1}. The presence of NH_4^+–N in domestic waste is influenced by the particles of food, oil, and fat. The percentage of NH_4^+–N removal efficiency ranged from 30.74%–75.68%. Peat and coconut shell media can remove NH_4^+–N from domestic dormitory wastewater. Ammonia nitrogen content in wastewater is caused by food, oil, fat, and other products that contain nitrogen and by-products of the decomposition process of organic matter in sewage. The coconut shells, which function as bacterial attachment, serves as biofilter medium.

3.6. Waste treatment against pH

Fig. 6 shows a graph of the pH condition of domestic wastewater after treatment with peat media and coconut shells against the residence time for wastewater before treatment. The graph shows that the pH value of the waste decreased from 8.21 to 6.69 after passing through the peat and coconut shell filter media fibers.

The ability of peat to lower the pH of domestic wastewater, which is more alkaline, cannot be separated from the peat media. Peat produces humic and folic acids. Metals react with the carboxylic and phenolic acid groups of the acid to release protons or, at a sufficiently high pH, with their anion sites replacing the metal. As the initial concentration increased; the equilibrium pH decreased. This is consistent with the ion exchange principle because the more nickel ions are adsorbed on the peat, the more hydrogen ions are released, thus lowering the pH [30].

Domestic waste, which is rich in organic matter with low pH, the pH increases. The increase in pH is influenced by the number of microorganisms that form lactic acid. The two microorganisms have a symbiotic relationship with the decomposition of organic matter in the wastewater. The pH value is related to the activity of microorganisms during organic waste processing. The movement of microorganisms affects the pH value and the pH, in turn, affects the microorganisms. The pH value also affects microorganisms that live mostly in the neutral pH range [31].

The high efficacy and capacity of domestic wastewater treatment plants by utilizing peat and coconut shell media shows promise in reducing contaminants in domestic wastewater. Apart from the advantages of reducing wastewater contaminants, peat and coconut shell media are environmentally friendly because peat and coconut shell particles that decompose for a long time and are released in the background can still be tolerated as they are products of organic materials. Filter media, such as activated carbon, are more effective than peat media as an adsorbent material, but activated carbon requires high operating costs to provide [32–34].

Peat and coconut shell media for removing wastewater contaminants have met the threshold values set by the Ministry of Environment and Forestry of the Republic of Indonesia, namely BOD of 300 mg L^{-1}, COD of 100 mg L^{-1}, TSS of 30 mg L^{-1}, NH_4^+–N of 10 mg L^{-1}, and pH of 6–8 [27]. However, two parameters did not reach the predetermined threshold values, namely BOD and COD. The COD and BOD parameters that have not been met are closely approach the threshold value. The threshold value was not achieved because domestic wastewater contamination in these parameters was very high, namely BOD of 159 mg L^{-1} and COD of 310.39 mg L^{-1} on average. The limitation of this research is that further studies have not been carried out regarding the handling of the filter media used; therefore, further testing of this aspect is required.

4. Conclusions

The use of peat and coconut shell media used in combination can predict the parameters of domestic waste at a household scale. The use of a combination of peat and coconut shell as filter media for domestic waste can significantly reduce waste with the following average pre-treatment parameters: BOD, 159.16 mg L^{-1}; COD, 310.39 mg L^{-1}; TSS, 38 mg L^{-1}; nitrogen NH_4^+–N, 3.14; and pH 8.21, with an effective BOD derivative of 64%, COD of 50.69%, TSS of 80.58%, NH_4^+–N of 59.52.

Conflict of interests

The authors declare that they have no conflict of interest.

Data availability

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

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