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Research Article

The development of ozone-filtration using green mussels shells for laundry wastewater treatment

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Abstract. This study explores the potential of green mussel shells as a filtration medium for treating laundry wastewater. The research evaluated the effects of ozonation as a pre-treatment step and compared two filtration reactors, reactor one (R1) without green mussel shells and reactor two (R2) using green mussel shells. In this filtration system, hydrostatic force is used due to its reliability in determining the pressure difference between the upstream and downstream sides of the reactors. Treated wastewater samples were collected every 5 minutes to be analyzed. Several important water quality parameters are monitored, including pH, chemical oxygen demand (COD), and dissolved oxygen (DO). The odor and color of the laundry wastewater were also observed. Results showed the effectiveness of green mussel shells in improving wastewater quality, particularly in neutralizing pH, reducing COD, and increasing DO. The results of linear regression calculations showed that in R2, the pH decreased by around 26%, the COD concentration decreased by 76%, and the greater increase in DO was 118% from the concentration without treatment. This research showed that green mussel shells in R2 have the potential to be used as a filtration element to treat laundry wastewater as a sustainable solution, addressing both environmental pollution and water quality challenges.

Keywords: Green Mussel Shells, Laundry Wastewater, Ozon-Filtration, Filtration Medium, Clean Water

1. Introduction

Recently, laundry services have been increasing in many developing countries, including Indonesia. Semarang is one of the cities in Indonesia with a high populations, making laundry services a promising business in Semarang. The increasing business in laundry services also increases the volume of laundry wastewater produced. Laundry wastewater is high in surfactants and phosphate (Braga & Varesche, 2014). High surfactant concentrations in laundry wastewater will increase toxicity, harming the environment and living organisms (Esmiralda, Zulkarnaini, and Rahmadona, 2012). Phosphate in laundry wastewater reduces the oxygen in the water, leading to eutrophication or the growth of algae, cyanobacteria, and water hyacinth (Calabrese, 2020).

The solution to minimizing the impact of laundry wastewater can be treated through filtration, sedimentation, coagulation, and flocculation (Nair, 2008). Filtration separates substances using physics mechanisms or chemical and microbiology reactions through porous materials such as mollusk shells (Bermuli, Manganka, and Dundu, 2023). Green mussel shell is a potential material to be used as a filtration medium, and it can be found massively in the Semarang coastal area as a waste. The abundance of green mussel shell waste contributes to environmental pollution. Using green mussel shells as a filtration medium in laundry wastewater treatment is a way to solve two problems simultaneously.

Green mussels (*Perna viridis*) are mollusk bivalves from the Mytilidae family (Temmy, Anggoro, and Widyorini, 2018). Semarang City is one of Indonesia's cities with a long coastline (Wahyutomo, Suprayogi, and Wijaya 2016). One of the famous coastal areas in Semarang, Kampung Bahari Tambak Lorok, abundantly cultivates green mussels. Green mussels are easy to cultivate and have economic value as nutritious food, so they are widely cultivated in Tambak Lorok

Semarang (Normah and Asmah, 2016). Meanwhile, food processing produces huge amounts of green mussel shells, which can cause environmental and health problems due to the smell and can be a vector source.

Research has reported that green mussel shells contain 14-35% chitin and are suitable for use as biomaterials such as chitosan (Pratama et al., 2023). Chitosan is a chitin biopolymer derivative that is obtained during deacetylation (Al-Manhel, Al-Hilphy, and Niamah, 2018). Before the deacetylation process is carried out to extract chitosan, the other compounds, such as calcium carbonate ($CaCO_3$), should be removed (Kozma, Acharya, and Bissessur, 2022). Calcium carbonate on the green mussel shells will be converted into calcium oxide (CaO) when the shells are heated at high temperatures, making the reactivity higher. This means that the higher amount of CaCO3 contained in green mussel shells and the higher reactivity makes green mussel shells potentially useful as filtration agents (Pratama et al., 2023).

This research aimed to treat laundry wastewater by developing a water filtration system: Ozon-Filtration using green mussel shells. Green mussel shell waste efficiently increased water quality by measuring pH, Chemical Oxygen Demand (COD), and Dissolve Oxygen (DO).

2. Method

2.1. Material

The materials used in this research were laundry wastewater from laundry services around Tembalang, green mussel shells collected from the Tambak Lorok, fine sand, pebbles, coarse sand, activated carbon, and bio-foam aquarium filters. The equipment used in this research were aquariums such as reactors, water pumps, pH meters, ozone generators, hoses, and beaker glass.

Figure 1. (A) Green Mussel Shells, (B) Fine Sand, (C) Pebbles, (D) Coarse sand, (E) Activated Carbon, (F) Oven, (G) pH Meter, (H) COD meter, and (I) DO meter.

2.2. Preparation Of Ozon-Filtration Equipment

The ozone generator produces ozone (O_3) using either the corona discharge or ultraviolet (UV) radiation method, where oxygen molecules (O_2) are split into oxygen radicals that recombine to form ozone. Once introduced into laundry wastewater, ozone acts as a powerful oxidizing agent that directly oxidizes pollutants, breaking down complex organic compounds into more straightforward, less harmful substances. Additionally, ozone decomposes in water to generate hydroxyl radicals (•OH), further enhancing the oxidation process by aggressively attacking contaminants. This mechanism effectively removes dyes, surfactants, and other organic compounds, reducing the chemical oxygen demand (COD) and improving water quality. Moreover, ozone disinfects the wastewater by destroying bacteria, viruses, and other pathogens through oxidative damage to their cell walls and genetic material. Figure 2 shows the oxidation process in laundry wastewater using ozone.

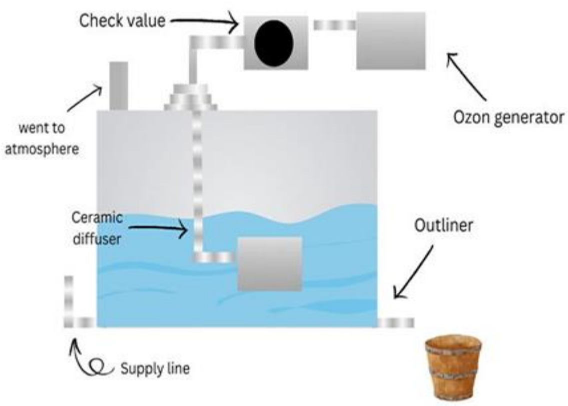
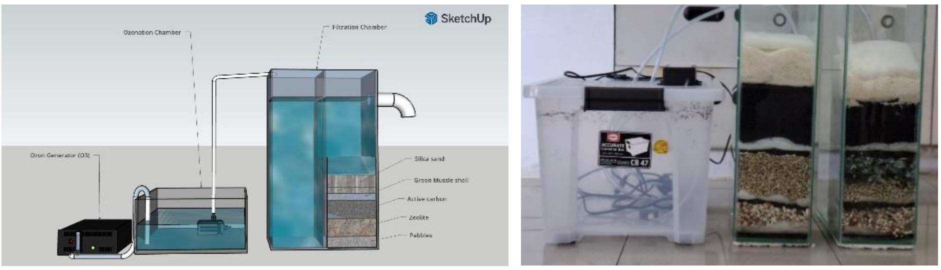


Figure 2. Ozon treatment on laundry wastewater before the filtration process.

2.3. Filtration Column Preparation

The filtration column is made of glass measuring 30 x14x49 cm and is equipped with an ozonation tank, as shown in Figure 3a. The research procedure begins with preparing the materials to undergo the pre-treatment process. Pre-treatment processes were done by heating the green mussel shells using an oven for 2 hours and soaking the coarse sand, pebbles, charcoal, and fine sand to enhance filtration efficiency. The pre-treatment process is also done for the laundry wastewater. Ozone generators were used to treat the laundry wastewater for 20 minutes.

Filter column preparation was done by preparing the aquarium as the reactor. In this filtration system, hydrostatic force is used due to its reliability in determining the pressure difference between the upstream and downstream sides of the reactors. Coarse sand, pebbles, charcoal, bio-foam aquarium filter, and fine sand in reactor 1 were arranged from the bottom to the top, respectively. The filter element arrangement in reactor 2 was coarse sand, pebbles, green mussel shells, charcoal, bio-foam aquarium filter, and fine sand in reactor 2 was arranged from the bottom to the top, respectively. The filtration system can be seen in the Figure 3b.



(a) (b)

Figure 3. Experimental set-up a). 3D design of wastewater system. b). Ozonation tank, Reactor 1 (without green mussel shells), and Reactor 2 (with green mussel shells).

2.4. Water Quality Parameters

Laundry wastewater as a sample was measured for pH (Figure 11), COD (Figure 12), DO (Figure 13), and observed for physical properties such as odor and color. The laundry wastewater filtration was done using 2 different reactors, Reactor 1 (R1) and Reactor 2 (R2). Treated wastewater samples were collected every 5 minutes.

3. Result and Discussion

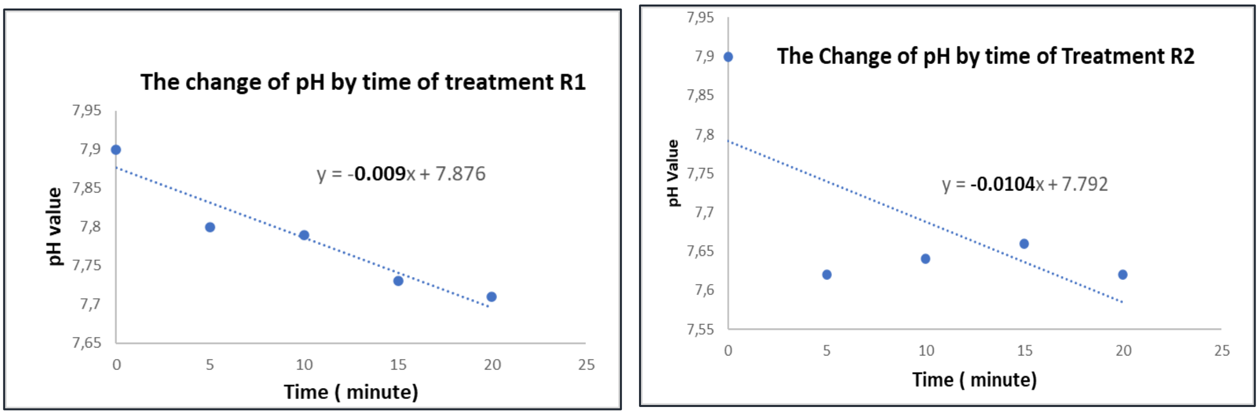
3.1. Ozon for Laundry Wastewater Pre-Treatment

Ozonation has been used widely as a biological treatment to increase biodegradability and remove color in textile waters. Ozon is commonly used for chemical degradation (Sopiah, 1999). In this research, the laundry wastewater was pre-treated through ozonation, and color degradation was observed in the water. It is supported by the research (Sevimli and Kınacı, 2002) that oxidation of wastewater with ozone is effective in removing the color.

3.2. pH Profile on Ozon-filtration

pH profile of laundry wastewater after treatment can be seen in Figures 4 a and b. From the results of linear regression calculations, pH decreased for R1 by 0.009 and R2 by 0.014, which is around 26% of the pH before treatment. pH value fluctuates in each sample on both reactors. A significant decrease in pH value was shown in reactor 2. It happens due to the existence of green mussel shells.

Calcium oxide is present in green mussel shells as part of their mineral content. It is derived from the thermal decomposition of calcium carbonate ($CaCO_3$) when shells are heated. In this research, the green mussel shells were heated using an oven for 2 hours. Laundry wastewater is typically alkaline due to detergents (high pH). When CaO is present in the filter column, it reacts with laundry wastewater to form calcium hydroxide. Calcium hydroxide can then neutralize excess alkalis through precipitation reactions, bringing the pH closer to neutral (Swaminathan, Pachhade, and Sandhya, 2005). Good quality water has a pH value of nearly 7 or Neutral (Widyaningsih, 2011). Graphic 1 and 2 showed that filtration using green mussel shells in reactor 2 was more effective in reducing the pH.



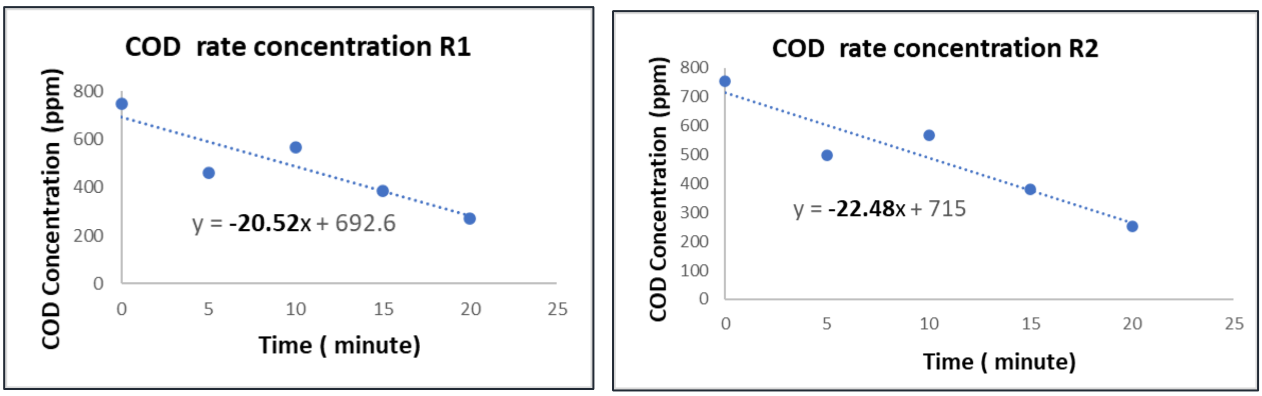
(a) (b)

Figure 4. The change of pH level by time on a). reactor 1 (R1), b). reactor 2 (R2)

3.3. COD Profile on Ozon-filtration

From the results of linear regression, as shown in Figures 5 a and b, there was a decrease in COD concentration in R1 of -20.52 and R2 of -22.48. A more significant decrease occurred in R2 of 76% from the concentration without treatment. The high concentration of COD on sample T1 indicates that laundry wastewater is polluted because the organic compounds in laundry detergents affect increasing COD. The results of the research showed that green mussel shells are promising in enhancing the quality of water.

Acetyl groups in green mussel shells help reduce COD in laundry wastewater through deacetylation to produce chitosan. The deacetylation process removes acetyl groups from chitin in green mussel shells, producing chitosan. Chitosan helps bind and collect organic particles in wastewater. By binding organic particles, chitosan helps reduce COD levels in laundry wastewater, as COD measures the oxygen needed to decompose organic matter in water (Verayana and Iyabu, 2019).

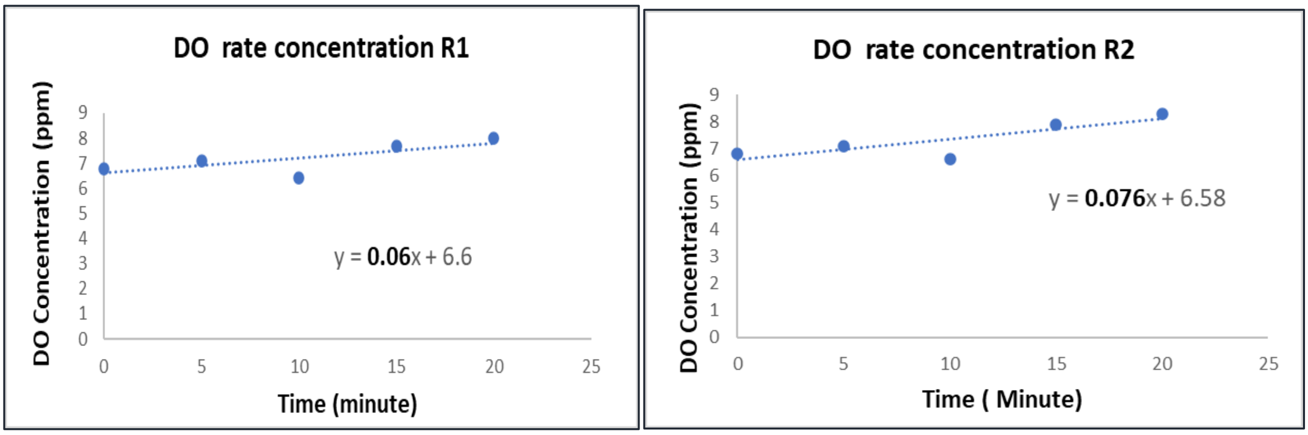


(a) (b)

Figure 5. COD rate concentration on a). reactor 1 (R1), b). reactor 2 (R2)

3.3. DO Profile on Ozon-filtration

From the results of linear regression, as shown in Figures 6 a and b, there was an increase in DO concentration at R1 of 0.06 and R2 of 0.076. A more significant increase in DO occurred at R2 of 118% from the concentration without treatment. Dissolved oxygen (DO) refers to the molecular oxygen present in water. It is a critical parameter for assessing water quality, as its concentration influences numerous chemical and biological reactions in aquatic systems (Li, Zou, and Jiang, 2022). As the COD level decreases, the Dissolved oxygen (DO) increases. Green mussel shells in reactor 2 help increase the DO levels in laundry wastewater through the aeration process. The porous structure of crushed green mussel shells increases the surface area for gas exchange. This allows oxygen from the air to dissolve into the wastewater, increasing the DO levels. Additionally, the filtration process helps remove organic matter and contaminants that consume oxygen, further contributing to higher DO levels (Verayana and Iyabu, 2019).



(a) (b)

Figure 6. DO rate concentration on a). reactor 1 (R1), b). reactor 2 (R2).

3.4. Filtration System Performances

The effectiveness of the ozone-filtration process is demonstrated by the percentage increase in DO and the reduction in COD and pH observed in both reactors. Reactor 2, which utilized green mussel shells, exhibited greater efficiency compared to the reactor without green mussel shells. This superior performance can be attributed to the unique properties of green mussel shells, particularly their high calcium carbonate ($CaCO_3$) content, which enhances the neutralization of pH by reacting with acidic and alkaline components in the wastewater. Additionally, the presence of chitin and chitosan in green mussel shells facilitates the adsorption and removal of organic pollutants, contributing to a more significant reduction in COD. Furthermore, the porous structure of the crushed mussel shells increases the surface area for aeration, leading to higher dissolved oxygen (DO) levels in the treated water. These combined factors make green mussel shells an effective and sustainable filtration medium for improving laundry wastewater quality (Table 1).

Table 1. Filtration System Performances

Parameters	Phenomenon	Value (%)	
		R1	R2
COD	Decrease	71,91	74,07
DO	Increase	15,00	18,07
pH	Decrease	2,53	3,80

4. Conclusion

The findings of this study demonstrate the effectiveness of green mussel shells as a filtration medium for treating laundry wastewater. The integration of an ozonation pre-treatment followed by filtration through green mussel shells significantly improved water quality by reducing COD, stabilizing pH, and increasing DO levels. The results showed that Reactor 2 (R2), which incorporated green mussel shells, achieved a 76% reduction in COD, a 26% decrease in pH, and a 118% increase in DO, highlighting the potential of this approach as an efficient and sustainable water treatment solution. The presence of calcium oxide in green mussel shells played a crucial role in neutralizing pH levels. At the same time, the chitin and chitosan content contributed to the reduction of organic pollutants, leading to a significant decrease in COD. Additionally, the porous nature of the mussel shells facilitated aeration, enhancing DO levels in the treated water. These mechanisms collectively demonstrate the suitability of green mussel shells as an eco-friendly and cost-effective filtration medium for wastewater treatment. While this study confirms the viability of green mussel shells in wastewater treatment, further research is needed to optimize its application on a larger scale. Future studies could explore the filtration system's long-term performance, the mussel shells' regeneration potential, and the effectiveness of this approach in treating other types of industrial wastewater. Additionally, integrating this method with other advanced treatment techniques could further enhance its efficiency and applicability in real-world scenarios. By utilizing green mussel shell waste, this research not only provides a solution for laundry wastewater treatment but also contributes to sustainable waste management by repurposing shell waste into a valuable filtration material. This approach aligns with environmental conservation efforts, addressing coastal areas' water pollution and shell waste accumulation issues.

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