RESEARCH ARTICLE

The effectiveness of coconut-dreg-based mudballs in kitchen wastewater treatment from restaurants and poultry shops

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Abstract:

This study investigates the effectiveness of coconut-dreg-based mudballs as a sustainable and cost-effective solution for treating kitchen wastewater from restaurant and poultry shop sources. Kitchen wastewater, characterized by its high organic load and potential pathogen content, poses significant environmental and public health risks if not adequately treated. Leveraging the principles of circular economy and sustainable waste management, coconut dregs, a by-product of the food industry, are harnessed for their potential in bioaugmentation to develop mudballs for wastewater treatment. Mudballs is a well-known biological treatment method for wastewater. Laboratory experiments were conducted to assess the removal efficiency of pollutants, including pH, dissolved oxygen (DO), turbidity, chemical oxygen demand (COD), and ammoniacal nitrogen, comparing the performance of coconut-dreg-based mudballs with conventional mudballs. Coconut- dreg-based mudballs demonstrated significant turbidity reduction (91.33%), COD reduction (84.84%), and effective ammoniacal nitrogen reduction (89.13%), particularly in kitchen wastewater from restaurants. The alkaline and fibrous nature of coconut dregs were identified as the key factors contributing to these favourable results. The enhanced effectiveness of coconut-dreg-based mudballs highlights their viability as a cost-effective and environmentally friendly alternative for kitchen wastewater treatment.

Keywords: circular economy, adsorbent, kitchen, bioaugmentation

1. INTRODUCTION

As defined in Malaysia Food Hygiene Regulations (2009), “food premises” is a term that defines premises employed for or to any of the following: food preparation, preservation, packaging, storage, transportation, distribution, or sale; or food relabelling, reprocessing, or reconditioning. Food premises, and food facilities, also known as; Food Service Establishment (FSE), play a vital role in meeting the growing demand for food products. However, these facilities generate substantial amounts of wastewater that contains high levels of pollutants, such as organic matter, nutrients, and suspended solids (Nayyar et al., 2021). Improper management and inadequate treatment of this wastewater can lead to adverse environmental impacts, including water pollution, eutrophication, and contamination of aquatic ecosystems (Ahmad et al., 2023). Therefore, there is a pressing need to develop effective and sustainable wastewater treatment methods specifically tailored to the characteristics of food processing wastewater.

Mudballs have gained attention as a low-cost and eco-friendly technology for water purification and environmental remediation (Maharjan & Ghimere, 2021; Ahmad Nazri & Ghazali, 2017). Mudballs are small spherical structures composed of bokashi – a mixture of clay, organic materials, microorganisms, and bran (EM Research Organization Inc., 2016). They have demonstrated promising results in various applications, such as soil restoration, river rehabilitation, and wastewater treatment (Park et al., 2016; Nayyar et., 2021). Mudballs act as natural filtration devices, absorbing pollutants and facilitating biological processes that aid in the degradation of organic matter and the removal of contaminants (Gumogda, 2022; Maharjan & Ghimere, 2021).

Coconut dregs, by-products of the coconut industry, have gained attention due to their high carbon content and fibrous nature (Madawala et al., 2023; Mohd Zin et al., 2017). These characteristics suggest that coconut dregs have adsorbent properties and can act as a filtration material for pollutant removal in wastewater treatment. Coconut dregs are abundantly available in tropical countries like Malaysia and are also known as a low-cost material, making them an attractive option for sustainable wastewater treatment applications (Rosni et al., 2020). However, its potential in treating kitchen wastewater is still underexplored. Untreated kitchen wastewater presents a serious environmental risk especially when the kitchen wastewater is discharged straight into the sewers and into water bodies. This is due to its properties that are laden with high organic matter, fats, oils, and grease (Nayyar et al, 2021; Tan & Wong, 2019). Additionally, wastewater characteristics from a particular kitchen from food premises vary significantly and determine the type of treatment it requires. Diverse methodologies were used to address the issues that can be found in previous studies, with an emphasis on protecting water quality and eliminating pollutants (Nayyar et al., 2021; Al-Gheethi, 2019; Mihelcic et al., 2014).

2. MATERIALS AND METHODS

Laboratory-based experiments were conducted to evaluate the performance of coconut- dreg-based mudballs in treating kitchen wastewater obtained from a restaurant and a poultry shop in Bandar Puncak Alam. Physico-chemical parameters, including pH, DO, turbidity, COD, and ammoniacal nitrogen, were measured to assess removal efficiency percentage. A comparative analysis was conducted between coconut-dreg-based and conventional mudballs to determine their respective effectiveness in wastewater treatment.

Mudballs preparation

Both types of mudballs – conventional and coconut-dreg-based mudballs were prepared before collecting the kitchen wastewater samples. The steps in preparing the mudballs were described in Figure 1.

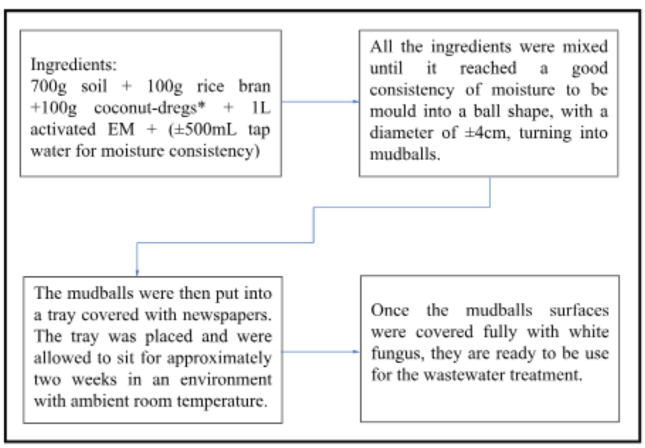

Figure 1. Mudball preparation

The mudball formulations were tested in three batches as part of a pilot study, and the final formulations that came from the preliminary investigation were used in the later stages of the research.

Samples collection and experimental setup

Kitchen wastewater samples were obtained from a restaurant and a poultry shop located in Bandar Puncak Alam, Selangor. Designated as sampling points A and B, respectively, the collection involved using a grab sample technique, extracting 4 litres of kitchen wastewater from each location. Then, the wastewater samples are categorized as follows:

A1 = Kitchen wastewater from restaurants treated with conventional mudballs

A2 = Kitchen wastewater from restaurants treated with coconut-dreg-based mudballs B1 = Kitchen wastewater from poultry shops treated with conventional mudballs

B2 = Kitchen wastewater from poultry shops treated with coconut-dreg-based mudballs. Daily observations and data collection were conducted for 22 days to ensure a comprehensive assessment of the kitchen wastewater treatment. The characterisation of both types of kitchen wastewater samples was initiated on the first day of the experiment through comprehensive laboratory analysis.

Figure 2 shows the experimental setup for kitchen wastewater from restaurant and poultry shop, together with the application of conventional and coconut-dreg-based mudballs.

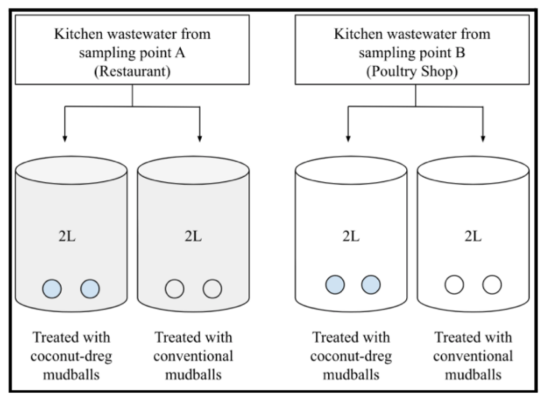

Figure 2. Experimental Setup

Data collection and analysis

Throughout the study, various instruments were employed to gather data and insights. These instruments include a pH meter for measuring pH and temperature in degrees Celsius (°C), a turbidity meter for assessing turbidity in Nephelometric Turbidity Units (NTU), a DO meter for determining dissolved oxygen (DO) levels in parts per million (ppm), a COD reactor for analysing Chemical Oxygen Demand (COD) in milligrams per litre (mg/L), and a DR2800 device for quantifying ammoniacal nitrogen concentration, also in milligrams per litre (mg/L).

Daily readings were taken for in-situ parameters; pH, temperature, turbidity, and DO. Meanwhile, for ex-situ parameters; ammoniacal nitrogen and COD were analysed using initial and final readings only, where the readings were taken before (initial) and after (final) the mudballs were added to the wastewater. Hence, the effectiveness of the treatment can be measured effectively through the removal percentage calculation.

Descriptive analysis and statistical testing, specifically the Independent T-test, were employed to assess the variations and significance difference in these parameters. This structured approach allows for a thorough examination of water quality dynamics, providing insights into key environmental indicators through a combination of daily and point-specific measurements.

3. RESULTS AND DISCUSSION

3.1 Characterisation of kitchen wastewater from Restaurant and Poultry Shop

The initial value of kitchen wastewater from the restaurant and poultry shop upon sampling and before adding the mudballs are shown in Table 1. The table provides insights into the general characteristics of the influent from both kitchen wastewater sources.

There is a difference in pH levels between the two types of kitchen wastewater. The restaurant wastewater is more acidic (pH 4.01), while the poultry shop wastewater is relatively neutral (pH 5.41). This difference may be attributed to the nature of food preparation and cleaning practices in each setting. Restaurants often use acidic ingredients or produce acidic by-products, influencing the pH of their wastewater (Parwin & Paul, 2020). Thus, the lower pH value in the restaurant may be attributed to acidic substances commonly found and used in the restaurant's kitchen, such as organic acids from food residues (Nasaruddin & Radin, 2021). In contrast, the poultry shop, dealing with raw poultry and associated organic matter, tends to yield a more neutral pH. Additionally, the higher pH in the poultry shop might be linked to the presence of alkaline substances associated with meat processing facilities. Consequently, temperature readings were relatively consistent between the two sampling points, with values of 24.6°C and 24.7°C, respectively, suggesting a comparable thermal environment was taken care of upon sampling. It is relevant to include temperature as a parameter when determining the removal rate in kitchen wastewater treatment, due to the fact, that it may affect the effectiveness of the treatment processes or influence the behaviour of pollutants in the wastewater. Temperature can also affect the rates of chemical reactions and microbial activities, which are crucial factors in wastewater treatment (Nasaruddin & Radin, 2021; Gurd et al, 2019).

However, substantial variations were noted in turbidity, DO, ammoniacal nitrogen, and COD. The higher turbidity level in the restaurant (303.1 NTU) compared to the poultry shop (134.87 NTU) could be indicative of increased suspended particles and solids, possibly originating from specific food preparation activities and washing processes in the restaurant. On the other hand, dissolved oxygen results revealed minimal differences, with both sampling points registering low dissolved oxygen concentrations (0.28 ppm for the restaurant, and 0.20 ppm for the poultry shop). This suggests that both sources of wastewater have limited oxygen content, potentially due to organic matter decomposition (19). Whereas, ammoniacal nitrogen levels are higher in the poultry shop wastewater (9.1 mg/L) compared to the restaurant wastewater (4.6 mg/L). The elevated ammoniacal nitrogen in the poultry shop influents may arise from the breakdown of nitrogen-containing compounds present in meat products (Uhlig et al., 2024; Zakri Ahmad et al., 2019).

Furthermore, the COD values demonstrate notable differences, with the restaurant wastewater having a considerably higher initial COD (4974 mg/L) than the poultry shop wastewater (1894 mg/L). This variation in COD concentration reflects the diverse composition of organic and inorganic substances in the wastewater, influenced by the types of food processed and cleaning agents used in these establishments. These results demonstrate the differing characteristics of kitchen wastewater and highlight the need for tailored treatment strategies based on the specific characteristics of influents from different food service establishments.

3.2 Effectiveness of coconut-dreg-based mudballs in treating kitchen wastewater from restaurant

Based on the average parameter results obtained from the restaurant, it is evident that coconut-dreg-based mudballs exhibit better performance in treating kitchen wastewater from restaurant compared to conventional mudballs as shown in Table 2.

For pH levels, both types of mudballs demonstrated an improvement from their initial value. Coconut-dreg-based mudballs achieved a higher final pH value of 8.29 compared to 6.8 for conventional mudballs. This suggests the alkaline nature of coconut dregs, contributing to a more pronounced pH adjustment during treatment. Moreover, temperature readings indicate the minimal variation between conventional mudballs and coconut-dreg-based mudball treatments, with averages of 23.65°C and 23.60°C, respectively. This consistency implies that both mudballs maintain similar thermal conditions during the treatment process.

Table 1. Summary of restaurant's and poultry shop's kitchen wastewater characteristics upon sampling.

Kitchen Wastewater	pH	Temp (°C)	Turbidity (NTU)	DO (ppm)	NH_3-N (mg/L)	COD (mg/L)
Restaurant	4.01	24.6	303.1	0.28	4.6	4974
Poultry Shop	5.41	24.7	134.87	0.20	9.1	1894

Table 2. Effectiveness of coconut-dreg-based mudballs in treating kitchen wastewater from restaurants

Types of Mudballs	Parameters	Unit	Results			Removal Efficiency
			Initial	Final	Average	
Conventional mudballs	pH	-	4.01	6.8	5.41	N.A.
	Temperature	°C	24.6	22.7	23.65	N.A.
	Turbidity	NTU	303.1	161.6	232.35	46.68
	DO	ppm	0.28	0.12	0.20	57.14*
	COD	mg/L	4974	2031.5	3502.75	59.16
	NH3-N	mg/L	4.6	2.12	3.36	53.91
Coconut-dreg-based mudballs	pH	-	4.01	8.29*	6.15	N.A.
		°C	24.6	22.6	23.60	N.A.
	Turbidity	NTU	303.1	26.29	164.70	91.33*
	DO	Ppm	0.28	0.13	0.21	53.57
	COD	mg/L	4974	754	2864	84.84*
	NH3-N	mg/L	4.6	0.5	2.55	89.13*

Note:
N.A. – Not Applicable for removal efficiency percentage
* – Highest reading for removal percentage
NH3-N – Ammoniacal Nitrogen, COD – Chemical Oxygen Demand, DO – Dissolved Oxygen

Meanwhile, DO concentrations in conventional mudballs-treated wastewater average at 0.20 ppm, while coconut-dreg-based mudballs exhibit a slightly higher average DO value of 0.21 ppm. This minor difference suggests that both mudball types contribute similarly in maintaining oxygen levels in the treated influent. Consequently, the removal efficiency for DO indicates a more substantial decrease for coconut-dreg-based mudballs, emphasising their potential to deplete oxygen content in wastewater, a crucial aspect of treating organic pollutants. More importantly, turbidity removal is notable, especially for coconut-dreg-based mudballs, with a significant reduction from 303.1 NTU to 26.29 NTU. This can be associated with the fibrous composition of coconut dregs, which acts as an effective filter, significantly decreasing suspended particles (Rosni et al., 2020).

As for chemical parameters, the average (and removal efficiency percentage) COD in the treated kitchen wastewater from restaurant with conventional mudballs is notably higher at 3502.75 mg/L (59.16%) compared to the treated kitchen wastewater from restaurant with coconut-dreg-based mudballs-treated wastewater with an average COD of 2864 mg/L (84.84%). This outcome indicates that the coconut-dreg-based mudballs are more effective in reducing COD, reflecting their enhanced capacity for organic matter removal (Bahri et al., 2020). Conversely, the concentration of ammoniacal nitrogen in wastewater treated with conventional mudballs averages at 3.36 mg/L, while coconut-dreg-based mudballs-treated wastewater records a lower average ammoniacal nitrogen concentration of 2.55 mg/L. The coconut-dreg-based mudball's capacity to achieve a lower ammoniacal nitrogen level concentration after the treatment underscores its effectiveness in nitrogen removal from kitchen wastewater. Thus, coconut-dreg-based mudballs have higher removal efficiencies for COD and ammoniacal nitrogen (84.84% and 89.13%, respectively), indicating that they are more effective at reducing organic and nitrogenous pollutant concentrations.

The comparative analysis between the conventional and coconut-dreg-based mudballs in treating kitchen wastewater from the restaurant reveals significant differences in key parameters of this research. For restaraunt wastewater, coconut-dreg-based mudballs significantly improved pH ($t(42) = –2.58$, $p = 0.013$) and turbidity ($t(42) = 5.59$, $p < 0.001$) compared to conventional mudballs, indicating better clarification of kitchen wastewater. Other parameters, including temperature, DO, COD, and AN, showed no significant differences (all $p > 0.05$).

After the treatment, the wastewater treated with coconut-dreg-based mudballs appeared to be clearer compared to the wastewater treated with conventional mudballs. Interestingly, the treated kitchen wastewater from restaurant with coconut-dreg-based mudballs develops a layer of fats, oil, and grease (FOG)– which shows the capabilities of coconut dregs to filter FOG compared to the wastewater treated with conventional mudballs that seems to be more concentrated and did not develop any noticeable layers of surfactants through the period.

3.3 Effectiveness of coconut-dreg-based mudballs in treating kitchen wastewater from poultry shop

Meanwhile, according to the average reading results from the poultry shop, the data comparison shows that coconut-dreg-based mudballs are also slightly more effective than conventional mudballs in treating kitchen wastewater from poultry shop.

In the poultry shop's kitchen wastewater treatment, the pH value of the coconut-dreg-based mudballs increased more from the initial to final readings, reaching an average of 7.03 compared to 6.91 for conventional mudballs. Consequently, turbidity was significantly reduced in coconut-dreg-based mudballs, reaching an average (and removal efficiency percentage) of 78.97 NTU (82.90%) compared to 86.79 NTU (71.30%) in conventional mudballs. Recognising the porous nature of coconut dregs, effective adsorption and filtration of suspended particles occurred, resulting in clearer and cleaner treated water. Additionally, both DO and COD levels improved progressively in coconut-dreg-based mudballs treatment, with the final DO value decreasing from 0.20 to 0.11 ppm and COD decreasing from 1894 mg/L to 810.5 mg/L. The declination of DO reading proves the treatment to be effective as biological processes are active in the water (Brown et al., 2025; Dharmarathne et al., 2013). Furthermore, ammoniacal nitrogen levels decreased from 9.1 mg/L to 5.45 mg/L. These findings suggest that using coconut-dreg-based mudballs improves a slightly better performance in terms of oxygenation, organic pollutant removal, and nitrogen removal efficiency, though it was not that significant.

Independent t-tests for poultry shop kitchen wastewater showed no significant differences between conventional and coconut-dreg mudballs for all parameters—including pH, temperature, turbidity, DO, COD, and AN (all $p > 0.05$). This indicates that both mudball types performed similarly in treating poultry shop wastewater.

Additionally, the findings from the comparison of removal efficiency percentage between conventional mudballs and coconut-dreg-based mudballs in treating kitchen wastewater from poultry shops reveal distinct patterns. In terms of pH, coconut-dreg-based mudballs suggest a more pronounced alkalizing effect, aligning with the alkaline characteristics of coconut dregs (Madawala et al., 2023). For turbidity reduction, coconut-dreg-based mudballs outperformed conventional mudballs with a pollutant removal rate of 82.90%, showcasing the effectiveness of coconut dregs in clarifying water. Furthermore, in terms of chemical oxygen demand (COD) removal, coconut-dreg mudballs demonstrated a pollutant removal rate of 57.21%, indicating their efficient capacity for organic pollutant removal. This is also likely attributed to the adsorption properties of coconut dregs (Vievard et al., 2023). The enhanced removal percentage observed in coconut-dreg-based mudballs indicates their potential, also as a sustainable and effective solution for treating kitchen wastewater from poultry shops.

However, in comparison between the two types of kitchen wastewater, the coconut-dreg- based mudball exhibits a lower performance in treating kitchen wastewater from poultry shops compared to the other types of kitchen wastewater.

Table 3. Effectiveness of coconut-dreg-based mudballs in treating kitchen wastewater from poultry shops

Types of Mudballs	**Parameters**	**Unit**	**Results**			**Removal Efficiency**
			Initial	Final	Average	
Conventional mudballs	pH	-	5.41	8.41	6.91	N.A.
	Temperature	°C	24.7	22.6	23.65	N.A.
	Turbidity	NTU	134.87	38.71	86.8	71.30
	DO	ppm	0.20	0.11	0.18	45.00
	COD	mg/L	1894	855	1374.5	54.86
	NH3-N	mg/L	9.10	5.45	7.28	40.12
Coconut-dreg-based mudballs	pH	-	5.41	8.64	7.03*	N.A.
		°C	24.70	22.70	23.70	N.A.
	Turbidity	NTU	134.87	23.06	78.97*	82.90*
	DO	Ppm	0.20	0.11	0.19	45.00
	COD	mg/L	1894	810.50	1352.25	57.21*
	NH3-N	mg/L	9.1	2.7	5.9	70.32*

Note:
N.A. – Not Applicable for removal efficiency percentage
* – Highest reading for removal percentage
NH3-N – Ammoniacal Nitrogen, COD – Chemical Oxygen Demand, DO – Dissolved Oxygen

Remarkably, after treatment, the wastewater treated with coconut-dreg-based mudballs in poultry shops appears clearer than the wastewater treated with conventional mudballs, despite showing a reddish to darkened appearance from the outside. Interestingly, both treatments in the poultry shop's kitchen wastewater, whether using coconut-dreg-based or conventional mudballs, develop elements layer of fats, oils, and grease (FOG), indicating the efficacy of both treatments in different wastewater scenarios. The key distinction lies in the FOG layer distribution, with the coconut dregs treatment demonstrating better filtration based on the more developed surface layers compared to the conventional mudball treatment in kitchen wastewater from poultry shop. This enhanced surface-layer formation is likely due to the higher fibre content and natural porosity of coconut dregs, which promote greater adsorption and trapping of suspended solids and FOG particles.

The independent t-tests were employed to evaluate the effectiveness of two types of mudballs, conventional and coconut-dreg based, in treating kitchen wastewater from restaurants. Coconut-dreg-based mudballs showed significantly better performance than conventional mudballs in restaurant wastewater, particularly in improving turbidity ($p < 0.001$) and pH ($p = 0.013$), indicating superior clarification and buffering capacity. In contrast, no significant differences were observed between the two treatments in poultry shop wastewater (all $p > 0.05$), suggesting that both mudball types perform similarly under high-FOG poultry wastewater conditions. Overall, coconut dregs offer clear advantages in restaurant settings, while their benefits are less pronounced in poultry shop applications.

4. CONCLUSION

In conclusion, the utilization of coconut-dreg-based mudballs is more effective in treating kitchen wastewater from Food Service Establishments (FSE) compared to conventional mudballs. Specifically, coconut-dreg-based mudballs exhibit enhanced effectiveness in treating restaurant wastewater compared to poultry shop wastewater, as evidenced by notable disparities in average values and removal efficiency percentages across selected parameters.

This discrepancy is largely attributable to the varying pH levels of the wastewater sources, with restaurant wastewater being predominantly acidic while poultry shop wastewater tends to be more basic. Given those coconut-dreg-based mudballs possess inherent alkaline properties, they demonstrate a greater capacity to neutralise the acidic nature of restaurant wastewater, thereby facilitating more substantial improvements in treatment efficacy when compared to the less acidic poultry shop wastewater. These findings underscore the importance of considering the specific characteristics of wastewater sources when evaluating the performance of treatment methods.

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