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Agricultural Wastewater Treatment Using Coal, Coconut Fibre, Citronella And Clay As A Biofiltration

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Abstract

River water quality has decreased due to agriculture wastewater discharge. Statistic data in 2021 showed 22.6 thousand of water pollution cases were reported in Malaysia, which is a critical issue to the aquatic plants and animals. Thus, this paper aims to measure removal efficiency of a natural and economically designed bio-filter. The bio-filter was made of coal, coconut fibre, citronella, and clay to treat agricultural wastewater and compared the water quality before and after filtering. Selected parameters (TSS, BOD, COD, and NH_3-N) were assessed in the wastewater samples before and after the operation of a bio-filter on a laboratory scale. The result shows that bio-filter success to improve the agriculture wastewater quality. Consequently, we recommend that this bio-filter can be further tested on a larger scale and potentially used in the agriculture wastewater industries.

Keywords: Wastewater, Bio-filter, Agriculture, Industry, Water quality.

Introduction

There are different types of wastewater, including storm and groundwater, plant and shed washdown, irrigation overflow and runoff, agricultural effluent, and others. Agricultural is a highly intensified industry in many parts of the world that producing a range of wastewaters which requiring a variety of treatment technologies and management practice. Polluted rivers located near agricultural regions will have odours and colours that repulsive to the locals. Part of the river pollution issue is due to wastewater produced by the agricultural sector of paddy fields. Both the inhabitants and the visitors to the area feel uneasy about this scenario, which also gives the visitors a negative impression about the local agriculture practices.

Discharged effluent has negative impacts on the environment, particularly on rivers. The environment and human health can be affected if the wastewater is not treated before discharge into the environment. These effects can cause harm to fish and aquatic populations, oxygen depletion, beach closures, restrictions on recreational water use and restriction on aquatic lives. Threrefore, effluent from paddy fields must be cleaned beforehand to reduce river contamination. Thus, this paper aims to measure removal efficiency of the wastewater by using a natural and economically designed bio-filter which contain of four materials such as coal, coconut fibre, citronella, and clay to treat the agricultural wastewater.

Literature Review

The theory of biofilters are referring to a pollution control technique using a bioreactor containing living material to capture and biologically degrade the pollutants. Many types of wastewater treatment technologies are being developed to protect the environment. In treating various types of wastewater worldwide, biofiltration, an attached growth system, performs very well (Loh, Z.Z., Zaidi, N.S., Yong, E.L. et al. (2022)). Charcoal, coconut fibre, citronella, and clay are natural raw materials that were employed in this study in developing a cost-effective bio-filter.

The shell of a coconut is used to make charcoal. It is often utilized as fuel for homes and businesses settings. It is always in demand for the work done by goldsmiths, blacksmiths, and laundries. Typically, activated carbon is produced using coconut shell charcoal. Activated carbon has the characteristics of high fixed carbon content, more surface area and low ash content which enable it suitable to be an effective filer media (Kaviya, Jayabalakrishnan, Maheswari & Selvakumar, 2020). Activated carbon from coconut shells has numerous unique benefits, including adsorb particular molecular species. Traditional techniques, including the drum, pit, destructive distillation, etc., are used to carbonize the coconut shell directly. Dry charcoal was utilized to reduce the number of organic pollutants and debris in the wastewater (Mang'era Samwel Mnyoro, Renalda N. Munubi, Lars-Flemming Pedersen, Sebastian W. Chenyambuga (2022)).

Coconut husk is one of the agricultural wastes that can serve as natural adsorbents for wastewater treatment (Elbehiry, Alshall, Elhawat & Elbasiouny, 2021). A study from India suggests that low-cost, durable coconut fibre might be used for denitrification wastewater. In that study, a biofilm made of coconut fibre was employed in an anoxic bioreactor, primarily used to remove nitrate nitrogen. Using the relationships between total nitrate, dissolved orthophosphates, and chemical oxygen demand (COD), the removal of nitrate nitrogen has been examined (J.K. Anuradha De Silvaa, A.K. Karunaratnea, V.A. Sumanasinghea, 2019).

Citronella has a grass-like look and is a brilliant green colour plant with sharp edges. It grows well in tropical areas with abundant rainfall and good sandy soils. Some Cymbopogon cultivars produce Citronella commercially available worldwide based on their place of origin, culinary uses, and oil qualities. Citronella is one of the aromatic plants that have shown the properties of hyperaccumulators, phytostabilizers and biosorbents (Mishra & Chandra, 2022). In a study conducted in Ghana, the Citronella plant was used to acclimatize wastewater (Agyemang Richard Osei; Yacouba Konate; Felix Kofi Abagale, 2019). Another recent study conducted in Indonesia had reported Citronella plant could be used for cadmium heavy metal phytoremediation due to its high root dry weight and shoot dry weight (Sulastri, Sabrina & Mukhlis, 2022).

Clay is a kind of rock that forms inside sedimentary basins or as a result of the breakdown of crystalline rocks like granite that are already there. The primary raw materials utilized in the production of a variety of ceramic items are clays. Clays typically have distinct qualities because of their naturally complex physical, chemical, and mineralogical characteristics. Clay qualities and features are crucial for the most excellent technical performance of regional goods. According to a study conducted in Thailand, porous baked clay bio-filters can be used in place of conventional plastic filters to minimize the amount of plastic pollution in the aquatic environment (S. Taesopapong, C. Ratanatamskul, and P. Pornchaiwiseskul, 2020).

The combination of these four materials, which are charcoal, coconut fibre, citronella, and clay are used as a bio-filters in this study, which is expected able to improve water quality parameters in the agriculture wastewater.

Research Methods

The test model for this project is a plastic container with a rectangular form that will hold the filter. The four primary components are divided using geotextiles and stain steel (Figure 1).

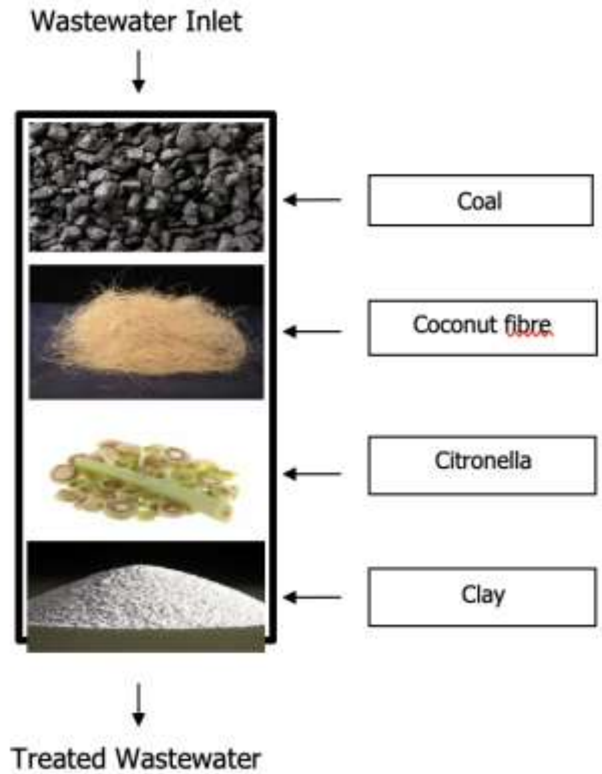

Figure 1. Design of bio-filter

The rice field wasterwater samples of this study were collected from Sungai Haji Dorani, Sabak Bernam, Selangor (Figure 2). These wastewater samples were taken from the paddy field during October to November 2020. American Public Health Association's (APHA) Standard Procedures for the Examination of Water & Wastewater, methodological requirements were followed when doing the water sampling and analysis (American Public Health Association, American Water Works Association, Water Environment Federation, 1999). The water samples were collected as stated below according to APHA methods:

1. Discrete grab samples must be taken at a specified or designated area marked as final discharge and time. (Note: Take note environmental condition during sampling).
2. Mark location of sampling in plant or site layout (if available).
3. Take photograph of sampling location.
4. For precaution purpose, wear glove and surgical mask before sampling.
5. Observe the right bottle cap color code based on test parameter required. (Note: Preservation already added in the lab before sampling. Add preservative if the pH more than 2).
6. Collect individual portions in a wide-mouth bottle.
7. Analyze (pH & temperature) individual samples as soon as possible after collection and preferably at the sampling point. (Note: If water is flowing (eg: river), measure directly on water body. If stagnant water, pour into the beaker 100ml and measure).
8. Record pH, temperature, date and time in worksheet.

9. Keep the sample in storage ice box and deliver to laboratory as soon as practicable after collection.

Sample Container & Preservation:

- Blue cap bottle (1L) - Inorganic analyses
- Red cap bottle (500ml) - Heavy metal (Note: Preserve with HN03 to pH <2, 4°C, refrigerate)
- Yellow cap bottle (500ml) - Chemical oxygen demand (Note: Analyse as soon as possible, or preserve with H2S04 to pH <2, refrigerate).

The collected samples were delivered to Mizulab Sdn. Bhd., an accredited laboratory, for examination (SAMM Reg. Num: 423) according to the standard ISO/IEC 17025 SAMM (ISO/IEC 17025 SAMM. Requırements For The Accredıtatıon Of Sıte Calıbratıon And Testıng Laboratorıes). The wastewater samples were examined based on the chosen metrics of Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Ammoniacal Nitrogen.

Figure 2. Sampling location at paddy field nearby Sungai Haji Dorani, Sabak Bernam, Selangor.

Results and Discussion

The removal effectiveness of total suspended solid using the biofilter is displayed in Table 1. As the suspended solid is filtered by the coconut fibre utilised, the total suspended solid before and after filtering decreases. The removal efficiency for the total suspended solid parameter according to our bio-filter was 6.13%. We considered this findings was acceptable within a small scale laboratory’s bio-filter, where as, in a natural constructed wetland in a large area may perform well and can remove 80-95% total suspended solid (Divyesh Parde, Aakash Patwa, Amol Shukla, Ritesh Vijay, Deepak J. Killedar, Rakesh Kumar, 2021).

Table 1. Removal Efficiency of Total Suspended Solid (n=3)

Total Suspended Solid	Readings (mg/l)			Mean (mg/l)
	Sample 1	Sample 2	Sample 3	
Before	0.5028	0.5025	0.5031	0.5028
After	0.4718	0.4716	0.4725	0.4720
Removal Efficiency (%)				6.13 %

Biochemical oxygen demand removal effectiveness is shown in Table 2. According to the findings, the amount of microorganisms in the sample water has decreased after filtering, which is proven by the decreased BOD results in all water samples after filtering. The BOD measurements showed a removal effectiveness of 28.8% in our bio-filter. A previous study also found a significant removal of BOD by using sugargane based activated carbon (Surafel Mustefa Beyan, S. Venkatesa Prabhu, T. Tsegaye Sissay, A. Abraham Getahun, 2021).

Table 2. Removal Efficiency of Biochemical Oxygen Demand (n=3)

Biochemical Oxygen Demand	Readings (mg/l)			Mean (mg/l)
	Sample 1	Sample 2	Sample 3	
Before	5.88	6.10	6.36	6.11
After	3.62	3.63	5.81	4.35
Removal Efficiency (%)				28.80 %

Table 3 displays the effectiveness of reducing chemical oxygen demand. Indirect measurements of the concentration of organic matters in water are frequently performed using the Chemical Oxygen Demand (COD) test. The results showed that the sample water's COD value decreased after filtering, and the declined COD was less than the COD of unfiltered sample water. The bio-filter contributes to the removal of bacterial contaminants. According to calculated result, the elimination effectiveness of COD parameter was 22.7%.

Table 3. Removal Efficiency of Chemical Oxygen Demand (n=3)

Chemical Oxygen Demand	Readings (mg/l)			Mean (mg/l)
	Sample 1	Sample 2	Sample 3	
Before	42	43	42	42.3
After	35	33	30	32.7
Removal Efficiency (%)				22.7 %

The effectiveness of nitrogen ammonia removal is seen in Table 4. The removal efficiency for ammoniacal nitrogen parameter by our bio-filter was 80.2%. When compared to the results obtained before sample water was filtered, the ammoniacal nitrogen readings obtained showed decline trend. The concentration of Nitrogen is lower at water body near to the water surface compared to deep water zone due to plankton's nutritional needs for nitrates and ammoniacal nitrogen.

Algal blooms are caused by an increase in plankton production at higher levels of surface-layer nitrogen content. Every kind of surface water may experience this. A high nitrate concentration can lead to eutrophication, which is an overabundance of nutrients that depletes the environment's oxygen supply and kills fish. Using this biofilter in treating agriculture wastewater may reduce the eutrophication phenomena, a phenomena due to high level of ammoniacal nitrogen present in the water body which can result in fatalities of the aquatic life.

Table 4. Removal Efficiency of Ammoniacal Nitrogen (n=3)

Ammoniacal Nitrogen	Readings (mg/l)			Mean (mg/l)
	Sample 1	Sample 2	Sample 3	
Before	25.00	25.00	22.30	24.10
After	5.55	4.50	4.26	4.77
Removal Efficiency (%)				80.2 %

The material used for water filter is one of important factor to make sure the water filter model is strong. The material used to build this biofilter is made up from plastic as is not easily broken and durable. Besides that, the cost of plastic is affordable and can be brought by the farmers conviniently as the price of plastic is low in the market. The farmers also can reuse any plastic wastes for the filtration processes by applying the correct filtration techniques. It is vital for us to understand and use the suitable water treatment technique which bring advantages to the agriculture farmers in overcome issues such as economic barriers, health and safety issues, legal restrictions, and lack of access to viable water sources as these are the major constraints commonly faced by the agriculture farmers.

Conclusion

In general, we may conclude that this study has demonstrated that the materials we utilised, coal, coconut fibre, citronella, and clay as a bio-filter to treat the agricultural wastewater can decrease the mean of the water quality parameters that have been examined. The removal efficiency for Total Suspended Solid, Biochemical Oxygen Demand, Chemical Oxygen Demand, and Ammoniacal Nitrogen were recorded at 6.1%, 28.8%, 27.7%, and 80.2%, respectively. Thus the bio-filter may improve the quality of effluent discharged from agriculture wastewater. We can either substitute the use of coal to coconut shell-based activated carbon. Coconut shell-based activated carbon integrates with Chinese wood, bamboo, coal, coconut shell and other activated carbon materials, and uses the process of steam activation, chemical activation, granulation and kinds of activated carbon production technology to supply different shapes of cylindrical, spherical, agglomerated and powder activated carbon. Other than that, more innovative studies that using different natural materials can be carried out to test their effectiveness in filtering the wastewater pollutants, such as using banana steam or dragon fruit extract.

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