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Feasibility of Banana (*Musa sapientum*) Trunk Biofibres for Treating Kitchen Wastewater

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ABSTRACT

Kitchen wastewater that is discharged to the environment is one of the contributing factors to water pollution in Malaysia and other developing countries. Various techniques have been employed to remove the pollutants namely, physical, chemical and biological treatment. Biosorption is one of the biological treatments that has emerged as a new technology for the removal and recovery of pollutants, which is more environmental friendly. This study focuses on the effectiveness of the kitchen wastewater treatment systems using low-cost natural fibre of banana trunk (*Musa sapientum*) as biofibre to remove COD, ammonia nitrogen, suspended solids, turbidity, colour, and oil and grease from kitchen wastewater. The optimum adsorption capacities of banana trunk biofibres were investigated under several conditions, namely, pH, absorbent dosage, speed and contact time. The optimum pH was found to be 6. The experimental results obtained were satisfactory at a dosage of 2 g at 150 rpm. The banana fibres show satisfactory COD removal of 88%, ammonia nitrogen of 84%, suspended solids of 83%, turbidity of 75%, the colour of 67% and oil and grease of 68% respectively. Maximum removal was achieved at 2 hours contact time. The study reveals that the banana fibres could be acceptable for efficient removal of organics and nutrients present in the kitchen wastewater.

INTRODUCTION

Malaysia has been progressing from an agricultural exporter to a major exporter of food and beverages, petroleum, textiles, clothing, palm oil, wood products and many more (Zain et al. 2004). Wastewater generated from food operation has distinct characteristics that make it different from common municipal wastewater managed by public or private wastewater treatment plants, as it is biodegradable and nontoxic, but it is well known for its high concentration of COD, BOD and suspended solids. The constituents of food and wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit, milk and meat products and due to the seasonal nature of food processing and post-harvesting (Onet 2010 and Silambarasan 2012).

Kitchen wastewater that is discharged to the environment is one of the contributing factors to water pollution in Malaysia and other developing countries. Such condition is a result of many kitchens which are continuously emerging to cater the need of the public due to exploding population. The wastewater that is directed to the drainage system without any sort of pretreatment is mainly composed of fats, oil and grease (FOG) as well surfactant (dishwashing detergent). These contaminants could cause many detrimental environmental impacts, including fouling and clogging in the drainage and sewer system, generate unpleasant odours and introduce extra burden to the municipal wastewater collection and treatment works which eventually leads to decreased efficiency (Turunawarasu et al. 2013).

The treatment of this waste has been addressed by several techniques such as coagulation, biosorption, adsorption, filtration, screening and more. Among the various techniques, adsorption process is one of the effective methods for removing organic and inorganic pollutants in a waterway system (Kumar et al. 2000). Low cost adsorbent could be generated from agriculture waste because of their low-cost and widespread availability. Some examples of agro wastes that have been used for the removal of pollutants are oil palm empty fruit bunch (Vinod 2012), date-palm (Riahi 2008), barley straw (Ibrahim et al. 2010) and walnut shell (Srinivasan & Viraraghavan 2008).

Therefore, this study focuses on the effectiveness of the kitchen wastewater treatment systems using low-cost natural fibre of banana trunk (*Musa sapientum*) to reduce suspended solids (SS), turbidity, chemical oxygen demand (COD), colour, ammonia nitrogen, pH, and oil and grease. Treatment system is expected to effectively remove pollutants that are present in the wastewater and thus suitable for reuse in agricultural activities. In this study, the use of fibre is a natural fibre banana trunk, selected based on factors that it is not in use, easily available and economical.

MATERIALS AND METHODS

Biosorbent material: Banana is an herbaceous plant of the genus *Musa* spp. of the family Musaceae and cultivated primarily for its fruit. For this study, raw banana trunk was collected from a plantation in Kampung Parit Payung, Muar, Johor with latitude 2°1'18.26'N and longitude 102°34' 43.85'E. This raw banana trunk was used as an alternative in treatment of kitchen wastewater in this study. Nodes of the raw banana trunk were first removed and the remaining parts were cleaved in longitudinal direction to thin slabs, with 20-30 cm in length, by the slicer. After cut into pieces, the banana trunk was washed with tap water to remove dust and dirt. Furthermore, the banana trunk was dried under sunlight before been dried in an oven for 24 hours at 105°C until a constant weight (Fig. 1).

Characteristic of kitchen wastewater, UTHM: Table 1 gives the concentration of pollutants in kitchen wastewater, UTHM. The concentration of pollutants in kitchen wastewater was analysed. The pollutants have been selected for further study of pollutant removal by banana trunk fibre. From the results, normalization of concentration and biosorbent dosage has been made to obtain a suitable working range of parameters for this study.

Preparation of samples: The prepared sample undergoes T 264 om-97 TAPPI test method before analysis for chemical composition of banana trunk finer. Chemical composition in these samples such as cellulose, lignin and hemicelluloses was determined in accordance with the respective TAPPI standard method; T 222 om-98 (lignin content). For cellulose and hemicellulose, the methods were different, where cellulose content was analysed by Kurschner-Hoffer method, and hemicellulose by chlorination method.

Surface observation: The samples were observed under a scanning electron microscope (SEM), to study its fibre morphological properties.

Experimental design: All experiments were conducted using the batch method of varying pH, biosorbent amount, contact time and shaking time to determine the maximum removal of pollutants. Table 2 gives the range for each parameter of pollutants. Biosorbents were filtered through 0.45 µm filter paper and kept in an airtight container for further analysis of scanning electron microscopy (SEM).

Table 1: Concentration of pollutants in kitchen wastewater.

Parameters	Values Sample
pH	5.96
Ammonia Nitrogen (mg/L)	30.70
Chemical Oxygen Demand (mg/L)	851
Suspended solids (mg/L)	363
Turbidity (NTU)	192
Color	605
Oil and Grease (mg/L)	632

Table 2: Working range of sorption study.

Parameters	Elements
pH	2,3,4,5,6,7,8,9,10
Biosorbent dosage (g)	0.10,0.50,1,1.5,2,2
Contact time (min)	15-1440

Table 3: Chemical composition of banana fibre (*Musa sapientum*).

Properties	Percentage
Cellulose (%)	58.5
Hemicellulose (%)	15.4
Lignin (%)	13.2
Weight (g)	1

Table 4: Result of parameter under optimum condition.

Parameters	Optimum Condition
pH	6
Biosorbent amount (g)	2
Agitation rate (rpm)	150
Contact time (minutes)	120

RESULTS AND DISCUSSION

Chemical analysis: From Table 3, it was found that banana trunk fibre has high cellulose (58.5%) content. Hemicellulose contents are also high in banana trunk fibre i.e., 15.4%. The presence of cellulose is very important and can be used as an adsorbent to remove oil, heavy metal and pollutants (Kudaligama et al. 2005). Lower lignin content is normally found in non wood fibre and functions as an adhesive to bind the cellulose in fibre. Lower lignin content makes the fibre strength to increase and difficult to break. Banana trunk fibre gives low lignin content with 13.2%. A clean biosorbent is important to enhance the efficiency of the biosorption process. The chemical composition aspects have been considered in the previous literature, such as coconut and oil palm, and have been reported extensively. Banana trunk fibre has been reported to have a lower lignin (18.6%) rather than oil palm (20.5%) and coconut (32.8%) which suggests that it can undergo bleaching more easily and has a high fibre strength (Khalil et al. 2006).

Fig. 1: Banana trunk fibre (*Musa Sapientum*).

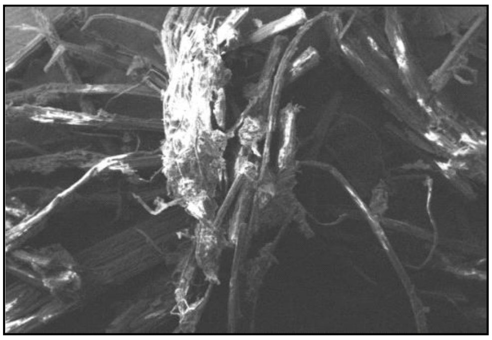

Fig. 2: Surface area of banana trunk fibre.

Morphological analysis: Scanning electron microscopy (SEM) analysis of the fibre is shown in Fig. 2. Banana trunk fibre gives high fibre content because of the arrangement of fibre. The SEM analysis also shows many bundles of packed fibres on the surface area of banana trunk fibre. The surface of banana trunk fibre is filled with many fibre matrices that were condensely packed together.

Effect of pH: The pH is very important for controlling the process of adsorption for removal of pollutants in kitchen wastewater. The solution affects the surface charge of the adsorbents as well as the degree of ionization of different pollutants, where the hydrogen ions and hydroxyl ions are adsorbed quite strongly (Ibrahim et al. 2010). The effect of pH in this adsorption batch study was carried out with a different initial pH range between 2 to 10. As shown in Fig. 3, the parameters were higher at pH 6 where the removal of COD and ammonia nitrogen on the banana trunk fibre is 83% and 84%. After reaching pH 6, the percentage of parameters were decreased by 79% and 76% at pH 7. The increase in biosorption levels with an increased in pH can be explained by the availability of negatively charged groups at the biosorbent surface which is necessary for the sorption of metals to proceed (Ekmekyapar et al. 2006). When the pH is decreased, concentration of protons increased and the competition binding the active sites on the surface of the biosorbent by the H^+ and metal ions began. Protonated active sites were incapable of binding the metal ions, leading to free ions remaining in the solution (Witek-Krowiak et al. 2011). Thus the optimum pH value that is suitable for the experiment is pH 6.

Effect of biosorbent amount: Biosorbent dose seemed to have a great influence on the biosorption process. Dose of biomass added into the solution and the number of binding sites available for adsorption are determined (Zafar et al. 2007). Fig. 4 shows that the parameter removal depends on the amount of biosorbent. The results show that 2 g of banana trunk fibre gives the maximum sorption of parameters with 88% of COD removal. The percentage removal is increased with the increase in biosorbent amount. The study by Yu et al. (2000) also yielded a similar result, where the percent removal of metal increases rapidly with increase in the concentration of the biomass, due to the greater availability of the exchangeable sites or surface area at higher concentration of the sorbent. At a given metal concentration, the lower the biosorbent dosage in suspension, the higher will be the metal/biosorbent ratio and the metal retained by sorbent unit, unless the biomass reached saturation (Romera et al. 2007).

Effect of shaking speed: Fig. 5 shows the effect of agitation rate on the adsorption of parameters by the banana trunk fibre. Therefore, the optimum agitation rate of adsorption of parameters was 150 rpm for banana trunk fibre and the highest percentage removal of COD (83%), ammonia nitrogen (77%), suspended solid (34%), colour (53%), turbidity (40%) and oil & grease (48%) was found (Fig. 5).

Effect of contact time: Fig. 6 shows the biosorption efficiency of parameter removal by banana trunk fibres as a function of contact time. With the increase in contact time, the COD, ammonia nitrogen and suspended solids removal increased by 71%, 80% and 83% at 2 hours of contact time. A large number of vacant surface sites are available for adsorption. After a lapse of some time, the remaining vacant surface sites are difficult to be occupied due to repulsive forces between the adsorbate molecules on the banana trunk fibre surface and in the bulk phase. At the initial stage of adsorption, pollutants are adsorbed into the mesopores that get almost saturated with the pollutants. As a result, the driving force for mass transfer between the bulk liquid phase and the solid phase decreases with the passage of time. The pollutants have to traverse further and deeper into the pores encountering much larger resistance. Hence, this result in the slowing down of the adsorption during the later phase of adsorption (Srivastava et al. 2006).

Parameter removal under optimum condition: In order to get optimum condition, four parameters were examined, namely, pH, biosorbent amount, contact time and shaking time. The optimum values from batch study were applied to obtain maximum removal of pollutants in kitchen wastewater. Table 4 shows the optimum condition of pollutants. From the results, 88% of COD, 84% of ammonia

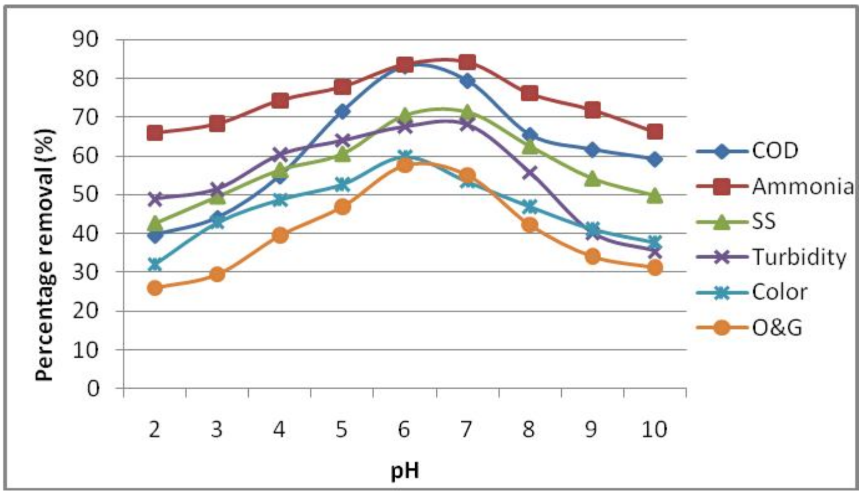

Fig. 3: The percentage removal of parameters from kitchen wastewater using banana trunk fibre by effect of pH (BTF dosage = 2 g, shaking speed = 150 rpm and time = 2 h).

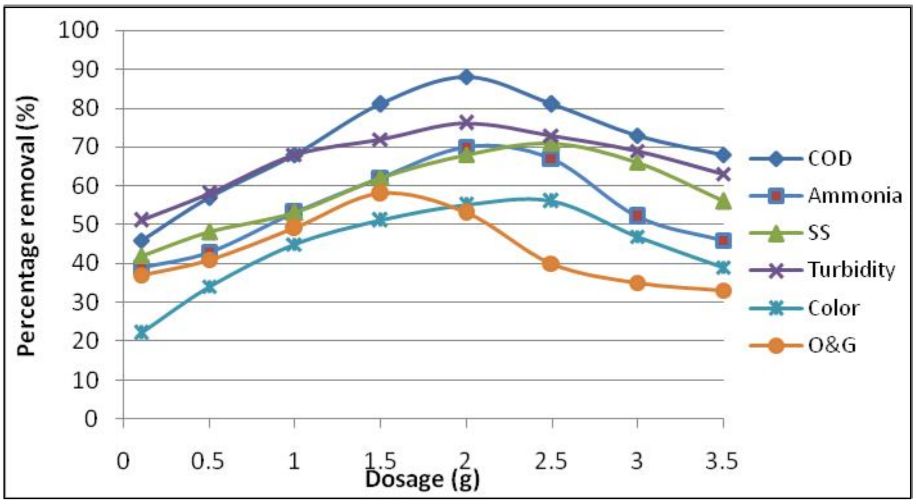

Fig. 4: The percentage removal of parameters from kitchen wastewater using banana trunk fibre by effect of biosorbent amount (pH = 6, shaking speed= 150 rpm and time= 2 h).

nitrogen, 83% of suspended solids, 75% of turbidity, 67% of colour, and 68% of oil and grease were removed. The removal of COD is higher compared to removal of ammonia nitrogen. The data revealed that maximum removal of pollutants can be achieved from optimum conditions.

CONCLUSIONS

This work revealed that banana trunk biofibre has a potential to be used as biosorbent for pollutant removal in kitchen wastewater. Among other pollutants, COD reached the highest removal of 88%. This removal was achieved at pH 6, biosorbent dosage 2 g, 150 rpm shaking speed, and 2 hours contact time.

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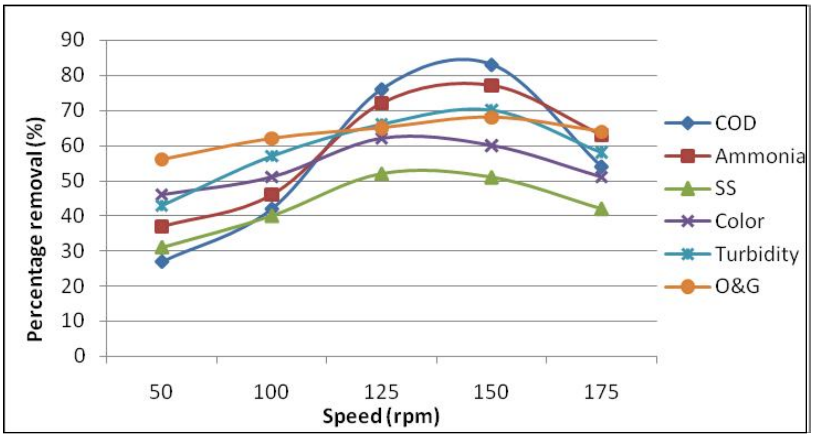

Fig. 5: The percentage removal of parameters from kitchen wastewater using banana trunk fibre by effect of shaking speed (pH= 6, BTF dosage=2 g and time = 2 h).

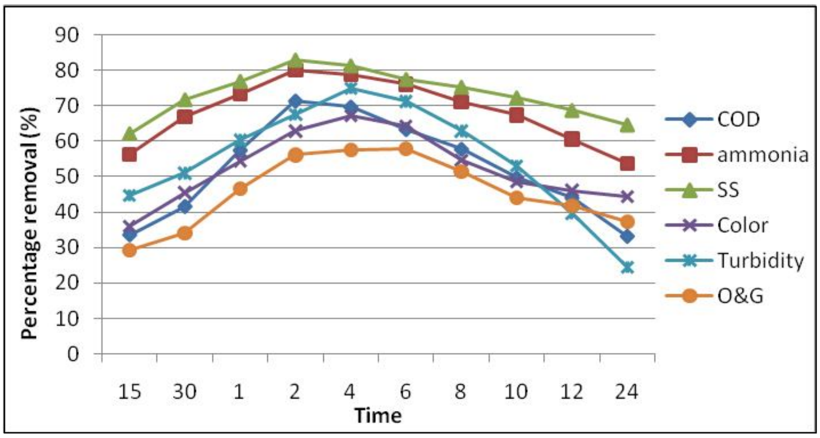

Fig. 6: The percentage removal of parameters from kitchen wastewater using banana trunk fibre by effect of contact time (pH=6, shaking speed= 150 rpm and BTF dosage= 2).

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