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Characterization of Kenaf Fibre-Retting Wastewater

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Abstract: ***Characterization of wastewater from kenaf water retting process was implemented in this study. Kenaf water-retting process was implemented in the laboratory. After ten days of retting process completed, wastewater from the retting process was used in the experiment. Parameters measured were including BOD, COD, colour, turbidity and other important parameter used to evaluate pollution level in the wastewater sample. All analyses results were compared to allowable limit that regulated by Department of Environment (DOE) Malaysia. From the analyses, it shows that concentrations of BOD and COD were recorded in the range of 70-230 and 2000-3800mg/L respectively. While other parameter such as TSS, colour and turbidity were observed between 200-500mg/L, 1000-1200PtCo and 180-280NTU correspondingly. Most of the parameters analyzed were not complied with law and regulations set by DOE. Other than that, presence of inorganic and organic compounds was identified in the sample. Concentration of inorganic compound was detected in low concentration. Whilst, more than thirty types of organic compounds were recognized in the wastewater sample, and most of the organic compound existed comes from the plant itself. The wastewater cannot be released into water stream without any proper treatment process. Due to high amount of wastewater generated from the retting process, treated wastewater can be considered to be reused in the next retting cycle or for land irrigation.***

Keywords: kenaf fibre, water retting, wastewater, characteristic, water pollution

1. Introduction

Kenaf, or known as *Hibiscus cannabinus L.* in scientific name is categorized under *Malvaceae* family that close to hollystock plants. Kenaf is known to lives in tropical and subtropical atmosphere and it can grow rapidly which is providing high production yields. This plant is acknowledged for its potential as a source to produce plant-based raw material and also capable to absorb carbon dioxide (CO_2) higher than other plant. Kenaf consists of multiple useful components, e.g. stalks, leaves, and seeds. Within each of these plant components, there are various usable portions like fibres and fibre strands, proteins, oils, and allelopathic chemicals [1]. Basically, kenaf stem consists of core, bast (outer) and inner bast. In 2005, Malaysian Government starts to introduce new plant in replacing tobacco with other plant to former tobacco farmer in order to help the farmers to increase their income through National Kenaf and Tobacco Board (LKTN). Therefore, kenaf was selected to replace tobacco due to its potential becoming plant commodity. There are lots of actions have been taken in promoting kenaf to the farmers, including providing kenaf seed, fertilizer, and machinery for farming. Nevertheless, this campaign still not succeeds in cultivating kenaf in big scale. After five years of promoting kenaf, LKTN accomplished to grow this plant in five states which are Kelantan, Terengganu, Kedah, Perlis and Pahang. In 2009, these states were produced kenaf fibre with amount of 2911 tons. To-date related government agencies still working hard in promoting kenaf to higher level. Unique properties possess by this plant make it usable for many products from accessories to design products. Moreover, kenaf can be used as raw material in construction and also as adsorbent. It also can be used as a substitute for fibreglass and synthetic fibre. Kenaf possesses a lot of potential for specific use including utilize it as a green composite for textile. Whole stalk of kenaf (bast and core fibres) has been identified as a promising fibre source for paper pulp [2],[3]. The bast and core either can be pulp together or separated and pulped individually depending on the pulping process and the paper pulp to be produced [4].

Retting can be defined as loosening or separation process of bast fibres into individual fibres which is important as a raw material for product development. Retting is defined as treatment degrading the pectin-rich middle lamella connecting adjacent fibre cells to release bast fibres. Retting method plays an important role in producing a good quality of fibres [5],[6]. Effective retting involves degradation of pectin and other cementing materials, which act as binding agents between the individual bast fibres as well as between fibre bundles and the epidermal and core tissues [7]. There are various types of retting, for an example using chemical, dew- or water-retting. Commonly water-retting procedure is selected because it is simple and often produced a good quality of fibre. However, large amount of water in fibre separation (retting) process is required to obtain the fibres. For 10,000kg of jute, approximately 432m^3 of water is used in water-retting process [8],[9]. Since kenaf and jute are from one family known as *Malvaceae* so the retting process is same. In the future, amount of wastewater will be increased tremendously when the amount of fibre production will be greater than before as kenaf become one of the commodities in Malaysia. Typically water that has been used in the process will be released to the watercourse without any treatments. The condition of wastewater that turbid and produces odour makes it unacceptable by public. This problem can be resolved with an appropriate treatment process. The objectives of this study were measured concentration of pollutants in the wastewater sample and compared with DOE's standard and regulation.

2. Materials and Methods

2.1 Preparation of kenaf bast-fibre

Kenaf used in the experiment was harvested from Taman Pertanian Universiti (TPU), Universiti Putra Malaysia

Serdang, Selangor. The bast-fibres were separated from the core manually and kept in the cold room to preserve their moisture content

2.2 Water for kenaf retting process

In Malaysia, kenaf industry commonly uses river water as a medium for the retting process. For that reason, the same approach was used in this research to generate the wastewater that similar with the industry. For this experiment, river water was selected as a water source for the retting and water was collected from Sungai Langat in Hulu Langat, Selangor.

2.3 General procedure of water-retting process

The general method employed exactly same as industrial and small farmer practices with a few modifications. After the bast-fibres were harvested from the field and manually separated from its core, the fibres were weighed using electronic balance and immersed into water container. The bast was submerged into the water for 10days in ambient temperature as shown in Figure 3.2 with the ratio of fibre to water is 1g of fibre with 40ml of water. Amount of fibres and water used in this experiment was according to the work suggested by previous researchers [10]. They investigated different fibre-to-water ratio for kenaf water-retting process with the same period of retting, which is 10days and found that 1:40 is the best and an effective ratio. After 10days, the fibres were removed from the container and the wastewater sample ready to be used for experiment. The wastewater was kept in clean container and stored in the cold room with temperature below 5°C.

2.4 Analysis of wastewater

2.4.1 Characterization of wastewater

Analysis of wastewater was executed to characterize physical and chemical of the kenaf-retting wastewater according to standard procedure [11] used for water and wastewater samples.

(a) Analysis of inorganic compound in wastewater

Possibility of heavy metal exists in the wastewater was investigated through analysis using Intercouple Plasma (ICP-OES, Perkin Elmer 7300DV). All samples were required to go through pre-treatment process before analysis. A 100mL of wastewater sample was poured into a 200mL beaker. Then, 5ml of nitric acid (HNO_3) with 65% concentration was pipette into the sample. After that, sample mixture was heated on hot plate equipped with stirrer function until the volume of sample was lower than 100mL. When the sample volume below 100ml, the hot plate was switched off and the sample mixture was added with distilled water until it reach 100mL. The sample was filtered using filter paper afterwards and it was ready for analysis.

(b) Analysis of organic compound in wastewater

Analysis using gas chromatography was made to determine the specific compound existed in the sample. Therefore, Gas Chromatography Mass Spectrophotometer (GC-MS) was utilized to investigate specific types of organic compound exist in the wastewater. There is no special pre-treatment required for this sample only filtering the sample and keep it at low temperature to avoid any compound vaporized due to temperature before analyze the sample using GC-MS. All the samples were sent to accredited laboratory for an analysis.

3. Results and Discussions

3.1 Characteristics of wastewater

After retting process, the wastewater sample was immediately analyzed according to procedure provided [11]. The results of wastewater characterization were listed in Table 1. The values of parameter were varied depend on different conditions of kenaf in terms of moisture content. The characteristic of wastewater were measured for fifteen times.

Table 1 Analyses results from the wastewater characterization

Parameter	*Value*	*Unit*	*Allowable limit*		
			A	*B*	*Unit*
pH	3.5 - 5.5	-	6.0-9.0	5.5-9.0	NA
Total Solids (TS)	2200 – 2400	mg/L	NA	NA	
Total Suspended Solids (TSS)	200.0 – 500.0	mg/L	50	100	mg/L
Volatile Suspended Solids (VSS)	150.0 - 300.0	mg/L	NA	NA	
Chemical Oxygen Demand (COD)	2000 – 2500	mg/L	80	300[1]	mg/L
			80	200[2]	mg/L
Biological Oxygen Demand (BOD_5)	70.0 – 230.0	mg/L	20	50	mg/L
Colour	1000 - 1200	PtCo	100	200	[3]ADMI
Turbidity	180.0-280.0	NTU	NA	NA	
Sulphate	200.0 – 250.0	mg/L SO_4^{2-}	NA	NA	
Sulphide	290.0 – 400.0	µg/L SO^{2-}	0.5	0.5	mg/L
Phosphorus	30.0 – 40.0	mg /L	NA	NA	
Ammoniacal Nitrogen	4.0 – 20.0	mg/L NH_3-N	10	20	mg/L
Nitrite	0.15 – 0.35	mg/L NO_2-N	NA	NA	
Nitrate	4.5 – 7.0	mg/L NO_3-N	NA	NA	

NA – Not available

The wastewater results were compared with the allowable limit that regulated by Department of Environment (DOE) Malaysia [12]. It is important to identify either the wastewater is allow to be released into water stream or required further treatment. Table 1 also shows the allowable limit of pollutants that can be released into watercourse. Standards A and B are referred as area point of effluent release before water intake and after water intake point, respectively.

[1] For pulp mill effluents
[2] for other industry effluent
[3] American Dye Manufacturer Institute

From the analyses, pH of wastewater was found to be in acidic range, which is 3.5 – 5.0. Organic acid from the kenaf plant diffuses into water during fibre-separation process, and this occasion may influence the pH of wastewater. The pH value of wastewater did not comply with the standard regulated by (DOE) Malaysia, either for Standards A or B.

Concentration of total solids (TS) in the wastewater was more than 2000mg/L. Presence of solids in the wastewater may come from the fibres of kenaf, and also from soil that adhere to the kenaf plant. Total solids were consisting of total suspended solids (TSS) and total dissolved solids (TDS).

Table 1 show that the concentrations of TSS were between 200mg/L to 500mg/L. The concentration were considered higher than allowable limit by environmental regulation, which is only allow 50mg/L for standard A and 100mg/L for standard B. However, TSS only contributes about 8.33% to 20.83% from the total solids. Therefore, there is possibility that TDS served as the main contributor to the concentration of TS in the wastewater. Presence of dissolved solids was an indicator to existence of any minerals, salts, metals, cations or anions in the wastewater. The value of volatile suspended solids (VSS) obtained from the experiment in the range of 150 to 300mg/L. The concentration of VSS was closed to the concentration of TSS, and it showed that wastewater contain more organic compound instead of solid particles.

Chemical oxygen demand (COD) also presences in high concentration between 2000 to 3800mg/L. COD term was referred as indicator to measure organic matter that exists in the wastewater [13] and the results obtained were agreed with findings reported by them, since the origin of wastewater come from plant that contained organic acids and other element. The value of COD concentration from the kenaf-retting wastewater beyond allowable limit set by DOE.

For biological oxygen demand (BOD_5) parameter, this parameter was detected between 70.0 to 230mg/L. The concentrations of BOD_5 were considered low as compared to the COD concentration. Nevertheless, BOD_5 concentration in the wastewater slightly higher compared to the acceptable limit by DOE. In comparison, COD concentrations were higher than BOD_5 due to more compounds in the wastewater can be chemically oxidized than biologically oxidized [13].

The ratio of BOD_5/COD of wastewater is always being described by researcher as biodegradability level of materials by which organic matter containing wastewater is readily broken down in the environment [14]. From the results obtained from an analysis shows that the BOD_5/COD ratio of wastewater before treatment is ranging from 0.018 to 0.115 and if the BOD/COD ratio less than 0.1, it indicates the presence of large portions of hard-biodegradable COD [14].

Concentration of colour measured in the experiment was 1000 to 1200PtCo. The measurement of colour was true colour. The term of colour is referred as mean true colour, which is colour of sample that exists after turbidity was removed from the sample [11]. The value indicated that colour in the wastewater was not originated by suspended solids. It might due to the compounds from the fibres that dissolved into the water. The concentration of colour was considered high. The measurement unit for colour used in the experiment was Platinum Cobalt (PtCo) instead of mg/L because the appearance of colour in the sample was natural colour. In the regulation, the regulation did not mention acceptable limit for colour in PtCo unit. However measurement of colour is based on synthetic wastewater generated from textile industry, so comparison of colour between the standard and the wastewater sample cannot be decided.

Parameter of turbidity was detected between 180.0 to 280.0mg/L. Generally, turbidity has direct relation with presence of solid particle in wastewater sample. The result of turbidity cannot compare with the DOE standard, since this parameter not available in the regulation.

Sulphate and sulphide were recorded averagely 225.0 and 335.0mg/L respectively. Whilst, for phosphorus, ammoniacal-nitrogen, nitrite, nitrate parameters were analyzed and found in the range of 0.25 and 20.0mg/L. Possibility the existence of these elements in the wastewater sample, may be its come from the fertilizer used for kenaf plant or soil at the area of kenaf cultivated area. From those elements detected in the samples, only sulphide and ammoniacal-nitrogen parameters were listed in the DOE standard. Concentration of sulphide was higher than permissible limit for both standard A and B, while, concentration of ammoniacal-nitrogen slightly higher for standard A, but, lower compared with allowable limit for standard B.

3.2 Presence of other compound in the wastewater

Presences of heavy metals in wastewater were determined using ICP-OES. Table 2 listed several types of inorganic compounds existed in the sample. The presence of these elements possibly comes from the soil at plantation or from the fertilizer used. All inorganic compounds detected in the samples were lower than permissible limit set by DOE regulations [12].

Table 2 List of inorganic compound identified in the sample

Element	*Concentration, mg/L*	*Standard deviation*	*Allowable limit (mg/L)*	
			A	*B*
Calcium	20.36	0.134	NA	NA
Magnesium	34.37	0.217	NA	NA
Manganese	0.313	0.0053	0.20	1.0
Zinc	0.108	0.0007	2.0	2.0
Kalium	237.9	0.60	NA	NA
Arsenic	0.0077	0.0074	0.005	0.05
Ferum	1.096	0.0088	1.0	5.0

Other than inorganic compounds, organic compounds were detected in the sample. Around 30 types of organic compound were detected in the sample and tabulated in the Table 3. Most of the compounds detected were fatty acids that exist abundantly in the plant and also important for the growth of the plant. Fatty acids comprise of straight chain of hydrocarbons that possessing a carboxyl (-COOH) group at one end of carbon chain. These fatty acids possibly influence the pH value of wastewater samples.

Table 3 List of specific organic compound detected in the sample

No	*Name of compound*	*No*	*Name of compound*
1	*Tetradecanoic acid*	16	*9,12-octadecanoic acid*
2	*Dodecanoic acid*	17	*Methyl ester*
3	*Undecanoic acid*	18	*Stearolic acid*
4	*Pentadecanoic acid*	19	*9-octadecynoic acid*
5	*Pentacyclic acid*	20	*Acetic acid*
6	*N-hexadecanoic acid*	21	*Ethanoic acid*
7	*Hexadecanoic acid*	22	*Glacial acetic acid*
8	*Z-9-tetradecanoic acid*	23	*Butanoic acid*
9	*Eicosanoic acid*	24	*Butyric acid*
10	*Arachid acid*	25	*N-butyric acid*
11	*Octadecanoic acid*	26	*2-propanone*
12	*2-(2-hydroxethoxy)ethyl ester*	27	*Undecanoic acid*
13	*Z-8-methyl-9-tetradecanoic acid*	28	*n-decanoic acid*
14	*Oleic acid*	29	*Dodecanoic acid*
15	*9-octadecanoic acid*	30	*Ethylacetic acid*

4. Conclusions

Wastewater generated from kenaf-retting process was producing high content of colour, organic compounds in terms of COD and also solids. Colour possibly did not cause by solid particle that can be seen physically, but due to compound or element exist in the wastewater sample. Organic compounds were influenced value of pH in the wastewater and main contributor for COD concentration. Ratio of BOD5/COD of wastewater indicated that wastewater was difficult to degrade biologically. The wastewater can be characterized as heterogeneous sample that contain various types of organic and inorganic compounds. As overall, most of the parameters measured either did not comply with the standard that regulated by DOE Malaysia or not listed in the standard, except for inorganic compounds. However, measurement of colour is based on synthetic wastewater generated from textile industry, so comparison of colour between the standard and the wastewater sample cannot be decided. It can be concluded that further treatment is required for this wastewater to ensure pollutants in the wastewater meet the acceptable limit before discharge into the water stream. Due to high amount of wastewater generated, there is possibility for this wastewater to be reused for other application after treatment process.

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