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The Utilisation of Activated Carbon (AC) From Palm Shell Waste to Treat Textile Wastewater

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ABSTRACT

Heavy metals are widely used in textile industries and significant losses occur during the manufacturing and processing of textiles, and these lost heavy metals are eventually discharged in the effluent. Activated carbon (AC) is preferred adsorbent for removal of pollutants from aqueous and liquid phase. In this study, adsorbent from palm kernel shell (PSAC), an agricultural waste product were used to remove selected heavy metals which are copper, iron and zinc from textile wastewater. To investigate the effectiveness of palm shell activated carbon in removing heavy metals in textile wastewater, three reactors have been used for textile wastewater treatment. Reactor A treats textile wastewater using commercial activated carbon (PAC), Reactor B treats textile wastewater using activated carbon from palm shell (PSAC), while Reactor C acts as a control. The three reactors were tested against time with textile wastewater samples taken from a textile factory, RAMATEX Industries. The effectiveness of both activated carbon was obtained from the quality of effluent. The laboratory assay revealed that Reactor B was found to be better than Reactor A in removing all selected parameters. Reactor B had achieved 17.2% copper removal, 99% iron removal, and 50% zinc removal thus proving its ability to adsorb heavy metals more economically. Therefore it is concluded that PSAC have a potential to be an alternative low cost adsorbent to replace the conventional AC by optimizing the activation procedures, considering the contaminants to be removed.

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INTRODUCTION

The textile industry is one of the most complicated industries among manufacturing industry. Wastewater treatment is one of the major problems faced by textile manufacturers. The combination of the processes and products make the wastewater from textile plant contains many type of pollutants. Price competition, demand in high quality products, new and innovative products that are highly durable put further pressure to the industry as they have to use more dosage of chemicals and continually change to new chemicals to suit the market demand. This will finally result in the complication in the wastewater that is being discharged. Stringent legislation on discharge as the requirement of Environmental Quality Act of Malaysia and other developed countries give further challenges to the industry. Thus, there is a need for continous study and research on the wastewater treatment to find new methods of treatment in order to sustain this industry.

Heavy metals are among the most important pollutants in source and treated water, and are becoming a severe health problem. heavy metals are widely discharged in the wastewater from industries; such as cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), manganese (Mn), zinc (Zn) as well as mercury (Hg) are very toxic and harmful to living organisms by lowering the reproductive success, prevent proper growth and development, and even causing death [1]. Some of the heavy metals are important for our body requirement; however exceeding the tolerance limit may create harm to body functions.Therefore, heavy metals in industrial wastewater, which in this case textile wastewater must be removed before they are discharged to natural bodies.

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Concerning about Malaysia, most of the rivers are polluted and cannot be used as drinking source. According to Department of Environment (DOE) 10 percent of rivers in Malaysia are heavily polluted or dead, 63 percent are polluted and only 27 percent are healthy. These figures show the need of wastewater treatment before discharging to rivers or water bodies. This study is done to evaluate the performance of Palm Shell Activated Carbon (PSAC) to treat the textile wastewater before discharging to water source, thus decreasing the threat and deterioration to the environment and promising a more sustainable environment.

2.0 Literature Review:

2.1 Textile Wastewater:

The textile industry is very water intensive. Water is used for cleaning the raw material and for many flushing steps during the whole production. Produced wastewater has to be cleaned from fat, oil, colour and other chemicals, which are used during the several production steps. The cleaning process is depending on the type of wastewater, as not every textile plant uses the same way of production, and also on the amount of used water.

Different textile plants use different chemicals and different wastewater treatment. As the regulations become more stringent, prevention of transferring pollution problems from one part of the environment to another is promoted. This means that most of the textile industries have to develop their own site or in-plant facilities to treat their own effluent before discharge.

The impacts on the environment by textile industry have been recognized for some time, both in terms of the discharge of pollutants and of the consumption of water and energy [3]. Finishing processes can be categorized into purely mechanical and wet processes. The liquid phase for the latter type is primarily water, and, to a lesser extent, solvents and liquefied ammonia gas. Another important medium is steam. To achieve the desired effects, a range of chemicals, dyes and chemical auxiliaries are used.

Heavy metals exists in textile wastewater mainly present due to the dyeing process.The inorganic heavy metals, like Cd, Cu, Cr, Fe,Mn, Ni, Zn in ionic salts are directly absorbed by the marine and fresh water biota or are incorporated inground water in both cases i.e. the polluted groundwater and the marine foods which are being usedextensively by human being may lead to the diseaseslike cancer, tumor, brain diseases, psychiatricdiseases, sexual diseases etc. [4,5]. The effects of thepollutants may not be quite evident immediately butwith the passage of time their imperceptible effects areof fatal nature [6].

2.2 Activated Carbon:

Activated carbon is preferred adsorbent for removal of pollutants from aqueous and liquid phase.Activated carbon, also called activated charcoal, is a form of carbon processed to be riddled with small, low-volume pores that increase the surface area available for adsorption or chemical reactions. Activated carbon is a unique material; it is a member of a family of carbons ranging from carbon blacks to nuclear graphites, from carbon fibres and composites to electrode graphites, and many more. All come from organic parent sources but with different carbonization and manufacturing processes[7]. There are three methods of AC activation which are physical activation, chemical activation, and the combination of physical and chemical activation.

Activated carbon is the most widely used adsorbent because of its extended surface area, microporous structure, high adsorption capacity and high degree of reactivity. However, commercially available activated carbons are very expensive. There is a growing interest in using low cost commercially available materials for the adsorption of color. A wide variety of low cost materials such as agricultural by product, waste coir pith [8]and orange peel [9]are used as low cost alternatives to activated carbon. It has been reported that activated carbon from palm shell can effectively remove COD and color of domestic waste landfill leachate. Hence this research was undertaken to investigate the suitability of activated carbon as alternative and cheaper adsorption medium to remove heavy metals from textile wastewater.

MATERIALS AND METHOD

3.1 Textile Wastewater:

Textile wastewater samples was obtained from a textile mill, Ramatex Industries in Sri Gading, BatuPahat, Johor. The samples were preserved withdiluted nitric acid and storedat 4^{o}C.

The diagram in **Appendix II** illustrates the experimental work done in the laboratory. The three reactors were shaken at 120 rpm for 30, 60 and 90 minutes. The initial and final concentrations of selected heavy metals were recorded. The removal efficiency for selected heavy metals was determined using Eq.1.

$$\text{Percent removal} = \frac{(C_o - C_f)}{C_o} \times 100 \qquad \text{(Eq.1)}$$

Where:
C_o = initial heavy metal concentrations (mg/L)
C_f = final heavy metal concentrations (mg/L) (Halim*et al*., 2003)

3.2 Activated Carbon:

Commercial powder activated carbon, PAC was obtained from manufacturer in granular form. It was grinded and sieved using a 43-micron sieve. Palm shell activated carbon, PSAC was obtained directly from the manufacturer, SyarikatSaintifikBersatuSdn. Bhd.in powder form.Activated carbon is produced from carbonaceous source materials such as nutshells, coconut husk, peat, wood, coir, lignite, coal, and petroleum pitch. [10].In this study, we use PAC which was originated from palm shell bituminous coal, coconut shell and anthracite coal raw materials for liquid and vapor phase applications.

3.3 Characterisation of Activated Carbon:

Characteristics test for activated carbon were carried out by using the X-Ray Flourescence (XRF). A preliminary experiment was also done to determine the amount of heavy metals released by the activated carbon. The experiment was done by mixing 0.25 grams of each activated carbon into two Erlenmeyer flasks containing 250 milliliter of distilled water. After shaking them at 120 rpm for 24 hours, the mixture of distilled water and activated carbon were filtered and tested for the selected heavy metals by using AAS analysis.Concentration of heavy metals in raw textile wastewater sample were also determined by using theAtomic Absorption Spectrometer (AAS).

RESULTS AND DISCUSSIONS

4.1 Textile Wastewater Characteristics:

ThepH of textile wastewater samples were kept constant throughout the experiment. During sample collection, the pH of textile wastewater was 8.93, which is alkaline. In order to alter the pH to a constant value of 5, diluted sulfuric acid, H_2SO_4 was added into the sample. After conducting characteristic tests, the raw untreated textile wastewater effluent has the following heavy metals concentration as stated in Table 1, with comparison to the limit set by the National Environmental Quality Standards, NEQ.

Table 1: Heavy metals concentration of raw textile wastewater sample.

Heavy Metals	Sample Concentration (mg/l)	Concentration Limit by NEQS (mg/l)
Copper, Cu	0.128	1.00
Iron, Fe	0.400	2.00
Zinc, Zn	0.078	5.00
Chromium, Cr	0.005	1.0
Cadmium, Cd	0.001	0.1

All the heavy metals concentration in the raw textile wastewater are within the NEQS limits. In this study, the removal of three main heavy metals which shows the highest concentration which are copper, iron and zinc were investigated.

4.2 Activated Carbon Characteristics:

X-Ray Flourescence (XRF) experiment conducted on both type of activated carbon shows the following results in Table 2 and Table 3.

Table 2: Components and its concentration percentages in PSAC.

Formula	Concentration (%)	Formula	Concentration (%)
Al	0.035	Mg	0.025
Ca	0.095	Mn	0.001
CH_2	98.7	P	0.073
Cl	0.068	Rb	0.002
Cu	0.002	S	0.030
Fe	0.106	Si	0.121
K	0.734	Zn	0.003

Table 3: Components and its concentration percentages in PAC.

Formula	Concentration (%)	Formula	Concentration (%)
Al	0.01	K	0.403
Ca	0.051	Mg	0.013
CH_2	99.2	P	0.054
Cl	0.063	S	0.066
Cu	0.001	Si	0.102
Fe	0.015	Zn	0.001

The XRF results show the presence of similar component in both PAC and PSAC namely methylene (CH2), aluminium (Al), calcium (Ca), potassium (K), Iron (Fe), chlorine (Cl), copper (Cu), magnesium (Mg), and silica (Si). This indicates that AC from palm shell may replace the conventional AC by optimizing the activation procedures, considering the contaminants to be removed [11].

4.3 Copper (Cu) Removal

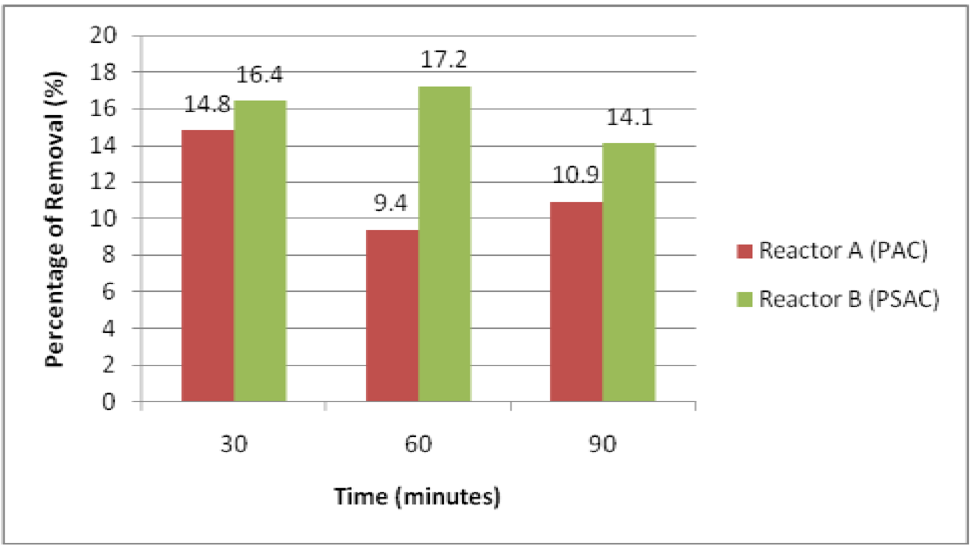

Fig. 1: Removal efficiency of copper by Reactor A and B.

The textile wastewater effluent had initial copper concentration of 0.128 mg/l while the concentration after treatment ranged from 0.109 mg/l to 0.116 mg/l for PAC and 0.106 mg/l to 0.110 mg/l for PSAC. Figure 1 shows the removal efficiency of copper by Reactor A and B. The results indicate that the copper removal efficiency of PAC shows best performance at 30 minutes shaking time while PSAC shows best performance at 60 minutes shaking time.

4.4 Iron (Fe) removal:

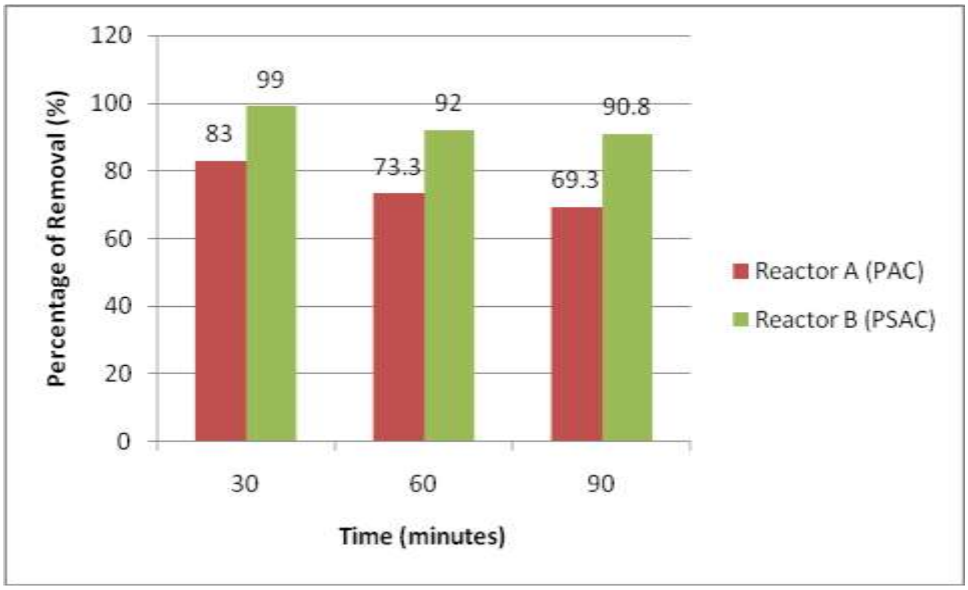

Fig. 2: Removal efficiency of iron by Reactor A and B.

The textile wastewater effluent had initial iron concentration of 0.400 mg/l while the concentration after treatment ranged from 0.068 mg/l to 0.123 mg/l for PAC and 0.004 mg/l to 0.037mg/l for PSAC. Figure 2 shows the removal efficiency of iron by Reactor A and B. The results indicate that the iron removal efficiency of both PAC and PSAC achieve peak performance at 30 minutes shaking time.

4.5 Zinc (Zn) removal:

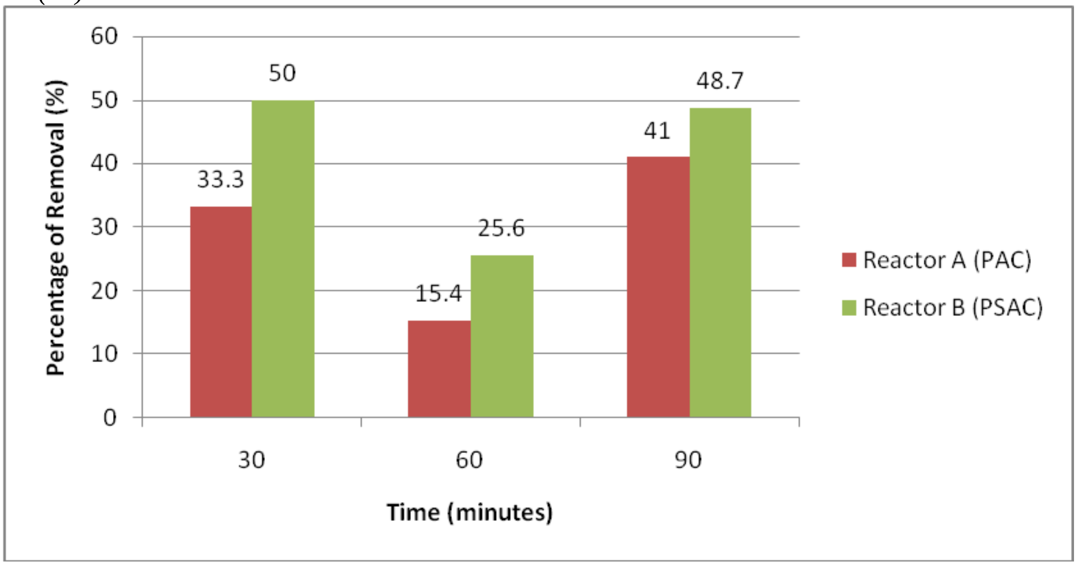

Fig. 3: Removal efficiency of zinc by Reactor A and B.

The textile wastewater effluent had initial zinc concentration of 0.078 mg/l while the concentration after treatment ranged from 0.066 mg/l to 0.046 mg/l for PAC and 0.039 mg/l to 0.058 mg/l for PSAC. Figure3 shows that the percentage removal of zinc frorRactor A and B. The results indicated that the zinc removal efficiency of PAC achieve maximum performance at 90 minutes shaking time while PSAC shows maximum performance at 30 minutes shaking time.

Based on the experiments, the results show that heavy metals removal by PSAC was better than PAC in the selected parameters. The main mechanism responsible for heavy metals removal in this adsorbent is the huge surface area of activated carbon which gives it countless bonding sites. When heavy metals contained in textile wastewater passes the carbon surface, they attach to the surface and. This reason explained the heavy metals removal in both reactors.

The adsorbent achieve efficient removal of heavy metals associated with the porous surface of AC. High surface area result in higher adsorption capacity of pollutants. Apart from that, high dosage of adsorbent will offer great availability of exchangeable sites for metal ions (Onundi et al., 2010). PSAC has been reported to remove heavy metals such as lead, chromium and copper ions in wastewater due to presence of some functional groups on PSAC that have chemical attraction towards metal ions, such as hydroxyl, lactone and carboxylic.

Under the condition fixed in the experiment (pH 5, dosage 1.0 g/L, and shaking speed 120 rpm), PSAC shows highest efficiency where it were able to remove 17.2% of copper at 60 minutes shaking time, 99% of iron at 30 minutes shaking time and 50% of zinc at 30 minutes shaking time. Meanwhile PAC has a maximum removal rate of 14.8% for copper and 83% of iron at 30 minutes shaking time, and 41% zinc removal at 90 minutes shaking time.

5.0 Conclusions:

According to the results and discussion, the activated carbon has great performance in removing selected metals (copper, iron and zinc) in textile wastewater effluent taken from RAMATEX Industries, BatuPahat. Palm shell activated carbon, PSAC had the potential to remove up to 99% of iron and is a better, more efficient adsorbent compared to commercial activated carbon, PAC according to measured parameters. The highest removal efficiencies for iron and zinc achieved is at 30 minutes shaking time while for the removal of copper is 60 minutes shaking time. PSAC obtained the highest removal efficiency in removing all selected parameters compared to PAC.

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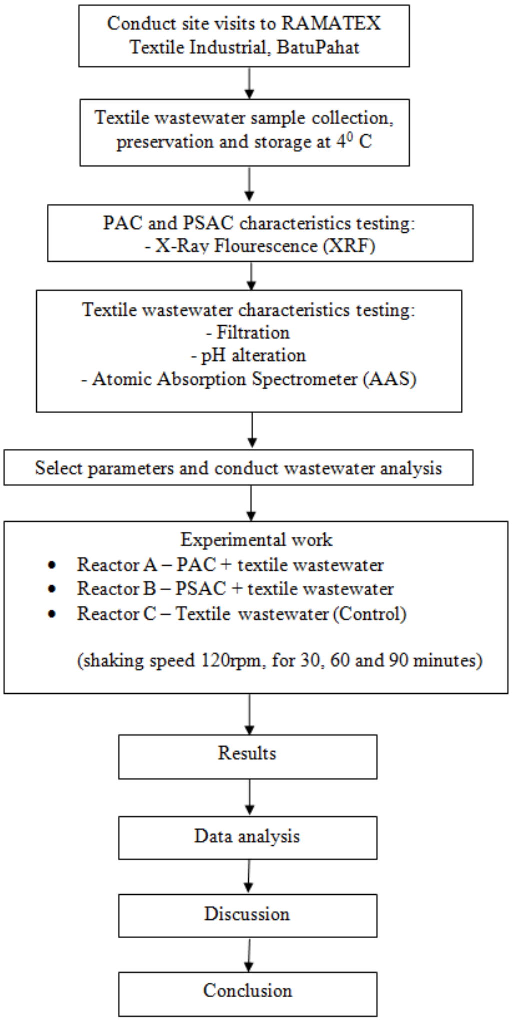
Appendix I



Appendix I: Research methodology.

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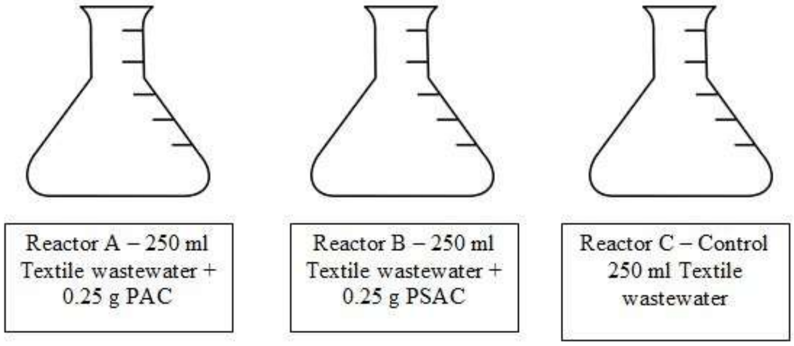
Appendix II



Appendix II: Textile wastewater experimental work.