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Adsorption of Heavy Metals and Dyes From Textile Wastewater by Using Eggshell

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ABSTRACT

Introduction: Textile industry is known as one of the generators that produced a large amount of wastewater pollutants due to the large quantities of water consumed during fabric processing. **Objective:** The objective of this study is to investigate the potential of eggshells as adsorbent for removal of pollutants from the textile industry wastewater without treatment. **Methodology:** The wastewater sampling at the selected area was conducted to identify the characteristics of the wastewater and compare the sample with Environmental Quality (Sewage and Industrial Effluent) Regulations 1974. Therefore, alternative treatment such as adsorption by using eggshell was investigated with different variables. **Result:** Based on the result, the wastewater does have a high reading of turbidity, high concentrations of BOD and COD, highly coloured effluents and heavy metals. All the characteristics of textile wastewater violated the permissible limit standard. The optimum condition in the removal of heavy metals and dyes by using eggshell was obtained. As for lead (Pb) and copper (Cu) show the highest percentages of removal up to 100% followed by the manganese (Mn) and zinc (Zn) which is 91% and 62% respectively. Meanwhile, the removal percentage for the dyes is 80% **Conclusion:** This study concluded that the textile wastewater containing high concentrations of pollutant including the heavy metals and dyes. In the study, the efficiency of the eggshell powder as adsorbent was identified.

Keywords: *Adsorption, eggshell, dyes, heavy metals, textile wastewater*

1. Introduction

Textile wastewater is generally recognized as one of the largest polluters due to the highly coloured, high concentrations of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved solids and total organic carbon (TOC) produced (Idris, et al., 2007). In addition, the strong colour is due to the persistent organics including several other pollutants such as nitrate, ammonia, sulphate, chloride, organic nitrogen, phosphate and heavy metals (Department of Chemical Engineering, 2017). The dyes-containing wastewater can lead to eutrophication phenomenon if it is not handle and treated properly by the treatment management system of the industry or organizations. The wastewaters generated from the textile industry are typically toxic and non-biodegradable in the environment, thus, hard to be removed because they can seep easily into the ground or dispersed in the water body. Furthermore, most heavy metals found in the textile effluent are includes zinc (Zn), copper (Cu), and lead (Pb). Those types of heavy metals are known as not biodegradable and can remain in the water body. Heavy metals have a high atomic weight and density at least 5 times greater than that of water. Their existence has raised a concern to the potential effects on human health and the environment. There are many stages in the fabric manufacturing that are energy and water consuming as well as presence of high chemical pollutant that lead to contamination (Future, 2017).

Therefore, in this study, the adsorption of heavy metals and dyes concentration was investigated by using eggshell as adsorbent. From the previous study, the eggshells have an ability to adsorb heavy metal effectively because it has good adsorbent properties such as CaCO3 and the presence of protein acid mucopolysaccharide can be developed into the adsorbent (Chumlong Arunletartaree, 2007).

2. Materials and Method

The wastewater sampling was conducted at textile industry at Rawang to determine the physical characteristics of the wastewater sample. Hence, the sample was compare to the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979, standard B. As for the adsorption method, the study was adapted from the research conducted by Chumlong Arunletartaree, 2007 and Ahmad Reza Yari, 2015 where both of the research investigated the use of eggshell as adsorbent. In addition, the controlled variables applied during this research in order to identify the optimum condition for the eggshell to adsorb maximum amount of the pollutants. The variables controlled including the pH value of the solution, the adsorbent dosage used (g) and the agitation time (minutes) at the constant temperature. Then, each of the variables was analyzed to identify the relationship of the different variables to the percentages of the removal.

2.1 Wastewater Sampling

Wastewater sampling was done for in-situ and ex-situ sampling. The in-situ sampling was conducted at the sampling point by measuring the temperature, pH and turbidity of the sample by using the pH meter (Hanna Instrument) and turbidity meter (Hach). As for the ex-situ sampling, the chemical oxygen demand (COD), biological oxygen demand (BOD), heavy metals and color concentrations was analysed at the laboratory of UiTM, Puncak Alam. The sampling method was adapted from Standard Method of Water and Wastewater (APHA, 2005). The obtained readings of each parameter then compared to the Environmental Quality (Sewage and Industrial Effluent) Regulations 1979.

2.2 The Adsorption of Heavy Metals from the Textile Wastewater

The adsorption method was adapted from several studies including Chumlong Arunletartaree, 2007 and Mayur, et al., 2013. The discarded eggshell was collected from the local restaurants at Puncak Alam and was washed thoroughly with the distilled water to remove the contaminants. Then, the eggshell was dried in hot air oven at 40 ^{o}C for 30 minutes. The dried eggshell was grounded to get a powder adsorbent within the size of 0.250-0.420 mm. The adsorbent was used without further treatment.

After the preparation of adsorbent, the initial concentrations of the heavy metals analysed by using Atomic Absorption Spectrophotometer (AAS) to compare the sample concentration to the final concentration of the heavy metals after the treatment. The optimum parameter analysis began with the different pH used which was pH 4, 6, 9 and 12. At this phase, the other variables which were adsorbent dosage and contact time were constant. For example, the adsorbent dosage and contact time was constant at 0.5g and 90 minutes respectively. Then, the 50 ml each of wastewater samples prepared was shake by using rotary shaker. After the treatment by using eggshell, the final concentration was measured again by using AAS to identify the effectiveness of the adsorbent. After determine the optimum pH value, the next variables were investigated by the same procedure. As for the adsorbent dosage, the different amounts used were 0.2g. 0.5g, 0.8g and 1.0g. Whereas, the agitation contact time is 30 minutes, 60 minutes, 90 minutes and 120 minutes. The procedures keep repeated to obtain the best result. The data was tabulated and recorded. The removal efficiency was calculated by using the formula of:

$$\text{Removal efficiency (\%)} = \frac{(Ci-Co)}{Ci} X\ 100 \qquad \text{Eq.1}$$

where,

Ci = Initial concentration (mg/l)

Co = Final concentration (mg/l)

3. Results and Discussion

3.1 Wastewater Sampling of the Textiles Wastewater

Table 1 show that the results obtained after the textiles wastewater sampling was done at in-situ and ex-situ. According to the results, it is shows that the most readings obtained exceed the permissible limit standard of Environmental Quality (Sewage and Industrial Effluent) Regulations 1974. The characteristics of wastewater samples were influenced by several factors such as the intensity of activity, operation, fabric, chemical agents and type of dyes used at the time of processing.

Table 1. The textiles wastewater characterization and comparison of the result with Environmental Quality (Sewage and Industrial Effluent) Regulations 1974

Sampling	Characteristics	Standard	Sample		
			1	2	3
In-Situ	Turbidity (NTU)	N/A	43.1	40	41.6
	Temperature (℃)	40	38	37.2	39.3
	pH	5.5-9.0	10.1	9.3	10.24
Ex-Situ	Chemical Oxygen Demand (mg/L)	100	780	710	724
	Biological Oxygen Demand (mg/L)	50	171	100.2	120
	Total Colour (ADMI)	200	939	935	937

Exceeded the Permissible Limit

In this study, the in-situ sampling was conducted to measure the turbidity, pH, and temperature. The reading for turbidity of sample 1, sample 2, and sample 3 are 43.1 NTU, 40 NTU and 41.6 NTU respectively. The colour present is the dark-blue coloured due to high concentration of colour that released from each textiles process. The temperature reading for textiles wastewater showed a high temperature which was up to 39.3^{o}C. The readings of temperature are almost exceeded the permissible limit which is 40 ^{o}C.

The reading of BOD for the textiles production process are high as the sample 1 have higher pollutant of BOD which is 171 mg/L followed by the sample 2 and sample 3. Whereas, the reading of COD for sample 1, sample 2 and sample 3 are 780 mg/L, 710 mg/L and 724 mg/L respectively. The COD of wastewater sample is in general is higher than that of BOD_5 because more compounds can be chemically oxidized than can be biologically oxidized. The next parameter measured during the ex-situ sampling is total colour. The reading obtained for sample 1 of the wastewater is highest between the three samples which is 939 ADMI (Table 3).

Table 2. The Initial Concentrations of heavy metals in the Textile Wastewater.

Heavy metals	Initial concentrations (mg/L)
Lead (Pb)	0.084 mg/L
Zinc (Zn)	0.134 mg/L
Manganese (Mn)	0.732 mg/L
Copper (Cu)	0.85 mg/L

Table 3: The Initial Concentration of dye in the Textile Wastewater.

Dyes	Initial concentrations (ADMI)
Total colour	937 ADMI

* ADMI = American Dye Manufacturers Institute

3.2 The Adsorption of Heavy Metals from the Textile Wastewater

Figure 1 shows there are different results obtained for each heavy metal based on the pH controlled. The efficiency removal for lead (Pb), zinc (Zn), manganese (Mn) and cop-copper (Cu) were 77%, 37%, 82% and 87% respectively. Therefore, the optimum pH was fixed at pH 4 where it was more acidic than others and used for the next wastewater treatment processes.

The next phase continued by using the constant parameter which is pH and contact time. It is shows that the most effective adsorbent dosage for almost heavy metals is 0.5g, whereas copper (Cu) was at 0.8g. The efficiency removal for lead (Pb), zinc (Zn), manganese (Mn) and copper (Cu) were 77%, 37%, 82% and 84% respectively. Therefore, the optimum adsorbent dosage was fixed at 0.5g where it was more effective than others and used for the next wastewater treatment processes.

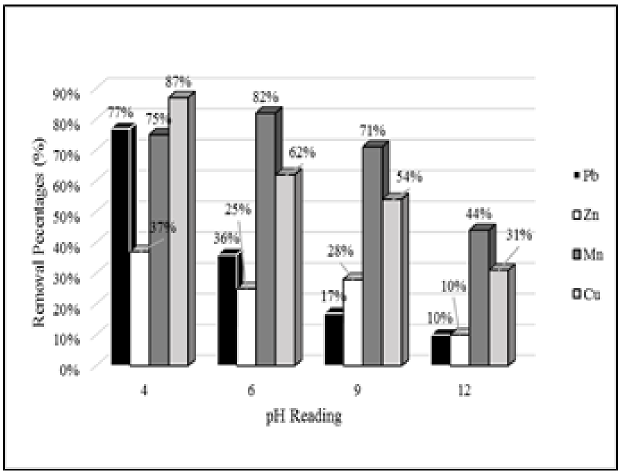

Figure 1. The removal percentages (%) of heavy metals at different pH

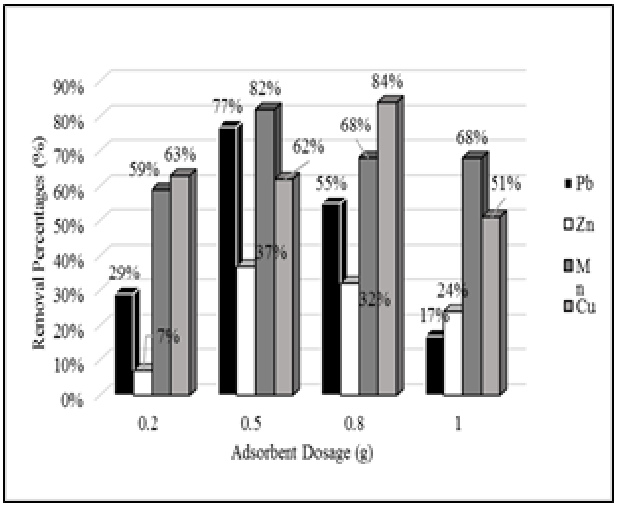

Figure 2. The removal percentages (%) of heavy metals at different adsorbent dosage (g)

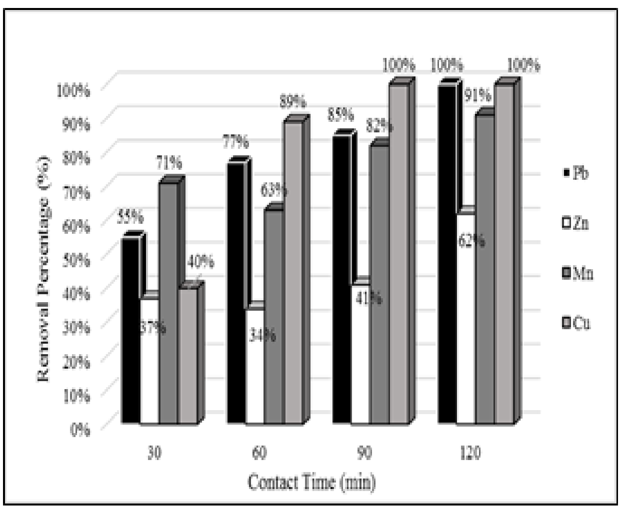

Figure 3. The removal percentages (%) of heavy metals at different contact time (min)

According to the result, there are different adsorption levels obtained for each heavy metal based on the contact time controlled. In a conclusion, the optimum condition for the adsorption of heavy metals was identified through the experiment conducted. The optimum condition is at pH 4 solution with 0.5g adsorbent dosage that was agitated for 120 minutes. The result of the experiment displayed in the figure 2.

3.3 The Adsorption of Dyes from the Textile Wastewater

According to the results, the best removal of dyes is at amount of 2.0 g adsorbent dosage which is the highest amount used in the experiment. The removal percentages (%) readings after the adjusted amount of adsorbent dosage of 0.6g, 1.0g, 1.5g and 2.0g are 24%, 32%, 40% and 44% respectively. The lowest amount of adsorbent dosage showed the least effective removal dyes by using adsorbent powder.

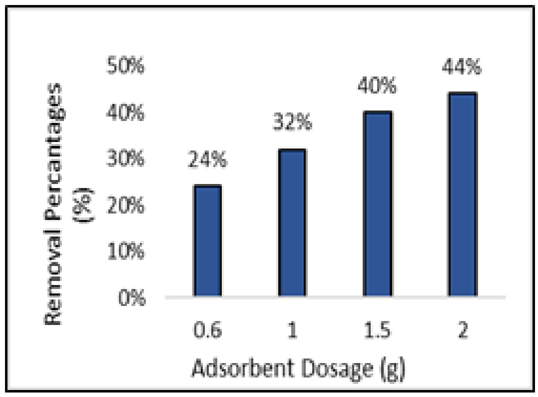

Figure 5. The removal percentages (%) of dyes at different contact time (min)

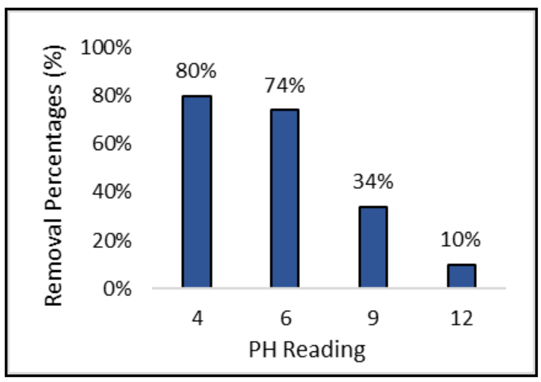

Figure 6. The removal percentages (%) of dyes at different pH

4.0 Conclusion

According to the findings, this study concluded that the textile wastewater containing high concentrations of pollutant including the heavy metals and dyes and almost all of the characteristics violated the permissible limit standard stated by the Environmental Quality (Sewage and Industrial Effluent) Regulations 1974. In the study, the efficiency of the eggshell powder as adsorbent was identified. Therefore, the optimum parameter for removal of heavy metals are pH 4 solution, 0.5 g of adsorbent dosage and 120 minutes of time taken was able to remove 100% of the heavy metals concentrations in the sample analysed. Meanwhile, for removal of dyes, the optimum condition is pH 4, 2.0 g of adsorbent dosage and 15 minutes time taken to agitate the wastewater sample able to remove 80% of dyes concentration in the sample analysed. The data was analysed by the SPSS in order to ensure the significant of the result and to achieve the hypothesis of the study. The t-test was conducted for removal of heavy metals analysis whereas Pearson' correlation analysis was conducted for removal of dyes analysis. Based on the removal of heavy metals analysis, the p-value for pH, adsorbent dosage and contact time were 0.034, 0.865 and 0.034 respectively. Whereas, for removal of dyes analysis, the analysis showed the correlation between the variables and the removal percentages as the result obtained for adsorbent dosage, contact time and PH were 0.931, -0.361 and -0.985 respectively .In a conclusion, the research hypothesis was accepted due to the eggshell capacity in removing the pollutants selected in the textile wastewater sample.

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