LATERITE SOIL AS NATURAL ADSORBENT TO REMOVE COLOUR IN THE WASTEWATER SAMPLE

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Abstract

This paper presents the removal of colour from a glove factory by using laterite soil as a natural adsorbent and the results were compared with the commercial activated carbon. Determinations were done using laterite soil that had been modified into three types of adsorbents, which are natural wash adsorbent, acid wash 10% and 40% adsorbent. Acid wash adsorbent is proven to be more effective in removing colour concentration compared to the natural wash adsorbent. By using natural wash adsorbent, the best condition for colour removal was at a dosage of 1g with pH 4 and contact time at 20 minutes, while acid wash 40% adsorbent needed only 0.3g of dosage at pH 6 with contact time only 15 minutes. This study shows that laterite soil can become one of the effective natural adsorbents, since it can remove almost 100% of the colour concentration in the water sample.

Keywords Adsorption, Laterite soil, Dyes, Activated carbon

Introduction

It has been recognised that wastewater will have a negative impact on the environment if it is not treated prior to releasing to receiving water. The content of wastewater is often viewed as pollutants due to high heavy metals, nutrient, suspended solids, COD and pathogen that come from industries, sanitary or community. The rubber industry is one of the industries that

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releases contaminated wastewater high in colour among the manufacturing industry in Malaysia. Removal of pollutants by conventional techniques such as coagulation seems difficult and does not reach the level of required discharge, where the colour range is at 15TCU for Class I (National Water Quality Standard). The presence of colour contamination in aqueous streams arising from the discharge of untreated sewage into the water stream, is one of the most important environmental problems (TD Pham et al., 2020).

Proper treatments are needed for wastewater before releasing it to the receiving water. One of the promising treatments to treat colour and heavy metal is adsorption (Syama et al., 2015). The adsorbent is the media that have been used in the industries to adsorb colour and heavy metals. The adsorbents that are based on chemical are expensive during their production. The commercial adsorbent has many disadvantages, such as performance of the adsorbent will depend on the types of the adsorbent and it requires chemical agents to improve the removal performance and high reactivation costs (Asere et al., 2019). Because of those disadvantages, other alternatives had been created to replace the commercial adsorbent. One of the ways is by using more environmentally friendly adsorbents that are readily available, cheap and have no chemical content called low-cost or natural adsorbent.

The main purpose of this research is to examine the removal of colour concentration from industrial wastewater by using the natural adsorbent laterite soil. This natural adsorbent will be compared with commercial activated carbon.

Literature Review

Colour in wastewater comes from many sources: such as batik production, glove production, fabric production and plastic production. All of these industries use dyes in their activities. This industry produces wastewater that contributes to water pollution, since dyes utilise a lot of chemicals. If the toxic chemical passes into the effluent, it will cause water contamination, and negative effects on human and animal health, which are not only limited to them but may be passed on to further generations in the way of inherited diseases, genetic mutations, birth defects and so on.

There are varieties of treatments that can be chosen to remove the colour from the industrial effluent, such as precipitation, floatation, cementing, electro precipitation, coagulation and separation by a membrane, solvent extraction, and the exchange of ions on resins. Among all those treatments, the adsorption process is preferable due to its easy and simple process, as well as its availability of a variety of adsorbents. Moreover, it has been proven to be an effective and attractive process for removing non-biodegradable pollutants, including colour from wastewater effluent.

Laterite soil is the formation of iron and aluminium rich surfaces in hot tropical areas due to continuous weathering of the parent rock. It is commonly known as oxisol, latosol and ferallitic soil in soil sciences. Laterite soil is soil that has a reddish colour as a result of the presence of iron compounds in the soil composition. This soil can be formed from iron-rich sediments, or the iron compounds may develop in the soil as it weathers (Pham et al., 2020). The composition and constitution of red and yellow soil earth may be substituted for bauxite in certain industrial operations. Clay is usually used as a natural adsorbent. Many similarities can be found in laterite soil and clay that made laterite soil can become natural adsorbent. The similarities are the pores that influence the adsorption process (Pandey, 2017) and the silicate mineral layer that is contained in it, making it possible to become an adsorbent. These layers are negatively charged, and this negative charge is normally balanced by hydrated cations placed in the interlayer spaces (Fufa et al., 2014). Studies about bentonite and sepiolite clays also have been carried out, showing their catalytic or adsorptive properties. The smectite group refers to a family of non-metallic clays primarily composed of hydrated sodium calcium aluminium silicate, a group of monoclinic clay-like minerals with the general formula of (Ca, Na, H)(Al, Mg, Fe, Zn)2(Si, Al)4O10(OH)2•nH2O (Liu and Zhang, 2017). The presence of silica, alumina and metal oxides in laterite probably makes it a good adsorbent (Pentari et al., 2016). The use of natural laterite soil as alternative adsorbents in wastewater treatment would provide several advantages due to their low cost, abundant availability, non-toxicity and potential of ion exchange for charged pollutants.

In order to improve the adsorption capacity, raw laterite soil needs to be modified and activated. A bottom-up synthesis method for active soil preparation with uniform pores might offer an alternative way to further optimise the sorption properties (Bouraie & Masoud, 2017). The acid treatment will attack the soil structure and enhance the adsorption capabilities. It was observed that the adsorption properties went through a maximum with the concentration of the added acid (Espantaleon et al., 2003). Usually, acid hydrochloric (HCL) will be used in the acid treatment wash (Bouberka et al, 2005) before being put in the oven for the drying process. The ammonium chloride breaks down under the heat and the formed acid will create the porosity responsible for the improvement in the specific surface area of the soil, and thus enhancing the adsorption phenomena (Elass et al., 2011).

Methodology

Method Flow Chart

Figure 1 shows the overall flow of this research. First, the water sample was collected from Alliance Rubber Sdn.Bhd. Then the soil is modified to become the adsorbent. The orbital shaker was used to perform the batching test and adsorbent test was run to find the best parameters. The filtration method was used to separate the adsorbent and the treated water. Last but not least, the result for colour removal was tested by using a spectrophotometer.

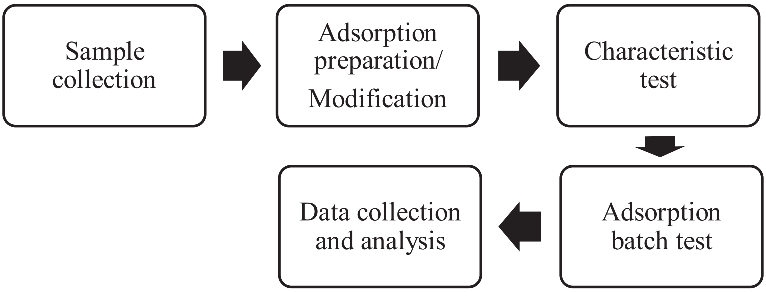

Figure 1: Research flow chart

Source of Water Sample

Wastewater was sampled from The Alliance Rubber Products Sdn. Bhd. in Nibong Tebal, Penang. It is a glove factory that produces low protein gloves, protein-free gloves and polymer-coated gloves. The wastewater sample was collected from the recovery tank before further treatment. The initial pH of the sample water was around 2 but it is not consistent. The container was shaken properly before the samples were taken for the experiment each time.

Adsorbent Preparation

Natural wash adsorbent

Laterite soil was washed with distilled water only to remove some colour and earthy matter in the soil, so that the colour of the soil would not affect the colour of the sample water. To remove some of the soil colour, 50g of the laterite soil was blended using a blender with 50ml of distilled water. The distilled water was then removed from the laterite soil using the filtration method. The laterite soil that had been filtered was then placed in an oven for drying at a temperature of 105°C for 15 hours. After the drying process, the dry laterite soil was grounded and sieved to pass 150µm. The same processes were repeated until the colour of the soil was reduced, compared to the raw soil. The soil was stored in the container and can be used as the adsorbent in the experiment.

Acid wash 10% and 40% adsorbent

Laterite soil was modified by using the acid wash method to enhance the adsorption capabilities. This type of adsorbent was prepared by using hydrochloric acid (HCL) solution to activate the soil. 50g of soil was dissolved in 10% and 40% of HCL solution for 30 minutes, and then washed with distilled water. The HCL and soil were separated by using the filtration method. The filtration method was repeated until the filtered water pH was around 7. This is to make sure that the adsorbent is free from HCL residues before being used as the adsorbent. After that, the soil that had been filtered was put in the oven at 105°C for 15 hours. After the drying process, the dry laterite soil was grounded and sieved to pass 150µm. The soil was stored in the container and can be used as the adsorbent in the experiment.

Laboratory Test

After the modification to change the surface properties of natural laterite soil by using distilled water, 10% HCL and 40% HCL, the soil was ready to be used in the experiment as the adsorbent. The initial concentration value of colour in the wastewater sample was determined by using the standard method APHA DR2800 Spectrophotometer Method 8025 for colour. The initial values were recorded to be compared with the value after the adsorption experiment had been done.

Batch Experiment

Batch experiments in this study were conducted at ambient temperature by manipulating the influence of adsorption factors such as adsorbent dosage, pH and contact time.

The first batch was done for the best dosage of adsorbent by changing the amount of the adsorbent, but the other parameters were kept constant. Five water samples with a volume of 100ml were put in the 250ml of the conical flask. The adsorbent was added in the conical flask with different dosages, 0.1g, 0.3g, 0.5g, 0.8g and 1.0g, and then the conical flask was put in the shaker at

150rpm with a contact time of 30 minutes. After 30 minutes, the adsorbent in the water sample was removed by using the filtration method. The treated wastewater sample was tested using HACH instrument DR2800 Spectrophotometer to obtain the percentage of removal of colour concentration.

Table 1: Value for each test parameter for the first batch experiment

Test parameters	Value
Contact time (minute)	30
Speed of shaker (rpm)	150
pH	3.11
Adsorbent dosage (g)	0.1, 0.3, 0.5, 0.8, 1

Then, the second batch was used to find the best pH for the adsorbent. The test was done by changing the pH of the wastewater sample at pH 3, 4, 6, 8 and 10, while contact time and speed of the shaker were kept constant. Five samples were prepared and the best dosage for each adsorbent obtained from the first batch experiment was used in this second batch experiment. Table 2 shows the summary of the second batch experiment.

Table 2: Value for each test parameter for the second batch experiment

Test parameters	Value
Contact time (minute)	30
Speed of shaker (rpm)	150
pH	3, 4, 6, 8, 10
Adsorbent dosage (g)	Use the best dosage from the first batch

The third batch was used to find the best contact time for each adsorbent and the summary can be seen in Table 3. For this batch, only four samples were prepared for a contact times of 5, 10, 15 and 20 minutes. The speed of the shaker remained constant by using the best dosage and the best pH obtained from the previous batch experiment.

Table 3: Value for each test parameter for the first batch experiment

Test parameters	Value
Contact time (minute)	5, 10, 15, 20
Speed of shaker (rpm)	150
pH	Use the best pH from the second batch
Adsorbent dosage (g)	Use the best dosage from the first batch

Characterisation Study

X-Ray Fluorescence test (XRF)

X-ray fluorescence (XRF) spectrometer is an x-ray instrument used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. It is important to know the elements in the material used. In this study, the XRF test was run to obtain the elements contained in the modified laterite soil to become the adsorbent. By running the test, the result will show the highest to lowest components contained in the samples in the form of percentages.

XRF test was tested by using XRF MiniPAL 4 and the manufacture method. The principle of the XRF was based on the beam from the X-ray. An excitation source such as X-ray is used to irradiate a sample which in turn fluorescence. The characteristic of X-ray fluorescence is detected and analysed. The entire process is interfaced with a computer that provides general instrument control, data generation and processing.

Result and Discussion

Characteristic Study

According to Ishiguro et al. (2016), clay, sand and soil can be used as natural adsorbents due to its high aluminium and silica content in the substance. After obtaining the percentage of components through the XRF test, the results of each component in the soil were presented in a table form in the value of percentage.

Table 4: XRF result for natural wash adsorbent result

Compound	Al	Si	S	K	Ca	Ti	Fe	Cu	Zr	Pd
Concentration unit (%)	27.4	36.8	1.45	0.9	0.23	2.15	28.92	0.16	0.49	0.77

Table 5: XRF result for acid wash 10% adsorbent

Compound	Al	Si	S	K	Ca	Ti	Fe	Cu	Zr	Pd
Concentration unit (%)	25.5	37	3.31	1.06	0.16	2.28	26.67	0.17	0.47	0.72

Table 6: XRF result for acid wash 40% adsorbent

Compound	Al	Si	S	K	Ca	Ti	Fe	Cu	Zr	Pd
Concentration unit (%)	19.3	44.8	3.5	1.37	0.16	2.7	14.1	0.21	0.429	0.75

From Table 4, the highest element contained in natural wash adsorbent is Silica (Si), which is 36.8%, followed by Ferum (Fe) and Aluminium (Al), which are 28.92% and 27.4%. Results for the acid wash 10% can be seen in Table 5. Like natural wash adsorbent, acid wash 10% adsorbent also has a high percentage in silica, ferum and aluminium, which are 37%, 26.67% and 25.5%. Then, Table 6 shows the result for elements in acid wash 40% adsorbent. Like the previous results, acid wash 40% adsorbent also has a high percentage of silica, ferum and aluminium, which are 44.8%, 14.1% and 19.3%. From the results, it is proven that laterite soil, either in raw or modified conditions, has high percentage of silica and aluminium sulphate that enable it be used as a natural adsorbent. It also had been proven by previous experiments by other researchers (Chen et al., 2011) that soil can become an adsorbent because of the silicate mineral layer contained in it, and the presence of silica, alumina, and metal oxides in laterite make it a good adsorbent.

Batch Experiments

Batch experiments were done for three modified adsorbents to remove colour that had been taken from the glove factory. Not only that, the results are also being compared with the commercial activated carbon being presented in graphical forms. The explanation covered all the adsorbents and its percentage of colour removal by manipulating three aspects: dosage, pH and contact time, where these parameters are the main factors affecting the removal percentage. The commercial activated carbon was taken from Fudojaya Sdn. Bhd. After the batch experiment was done, the results gained were tested using APHA Method DR2800 Spectrophotometer. All the data were presented in graphical form by gathering all the results in one graph for comparison purposes.

All the results for colour removal were gathered in three graphs that can be seen in Figures 2, 3 and 4, where Figure 2 for best dosage, Figure 3 for best pH and Figure 4 for best contact time. Figure 2 shows that the highest percentage of colour removal by using activated carbon was at 99.5% with a dosage of 1.0g. This percentage removal was the highest compared with the result by using laterite soil as adsorbent. However, by using 0.3g acid wash 40%, colour can be removed 98.9% almost 99% and not a big difference as 99.5%. Figure 3 shows the best pH for each adsorbent. The best pH for activated carbon is at pH 6, just the same as the best pH for other adsorbents, but the percentage removal was 98.7% compared to laterite soil adsorbent, which is almost 99.6%. The last batch experiment for colour removal to find the best contact time can be seen in Figure 4. From the result, activated carbon can remove almost 100% of colour in the water sample at minute 5 like acid wash 40%.

The capability of natural adsorbents was increased with acid modification. This is because activating the soil can improve the adsorption properties of the soil and modify the pore of the soil. A bottom-up synthesis method for active clay preparation with uniform pores might offer an alternative way to optimise the sorption properties further.

The different acid concentrations used in acid treatment will give different adsorption capacities. Not only that, the structure of the dyes and the soil properties also affect the adsorption capacity. Soil modification did involve the changes of soil texture, such as the amount and size of pores, the surface area, and in some cases, the modification of soil might change the structural properties of soil by introducing new elements on it. This modification will strengthen the raw soil, hence enhancing the adsorption capability.

From all the results, acid wash 40% adsorbent is the best adsorbent to remove colour in water sample compared to activated carbon and other laterite soil adsorbents. Only a small amount of dosage is needed when using acid wash 40% adsorbent with the best pH of 6, which is almost natural pH and able to remove almost 100% colour concentration. Not only that, acid wash 40% adsorbent just required short contact time and is environmentally friendly as its plus point. This is because acid washing treatment enhances the capabilities of the media as adsorbent by increasing its pores volume (Lee et al., 2010). A higher volume of pores will increase the adsorption capabilities by increasing its capacity (Fathy et al., 2013).

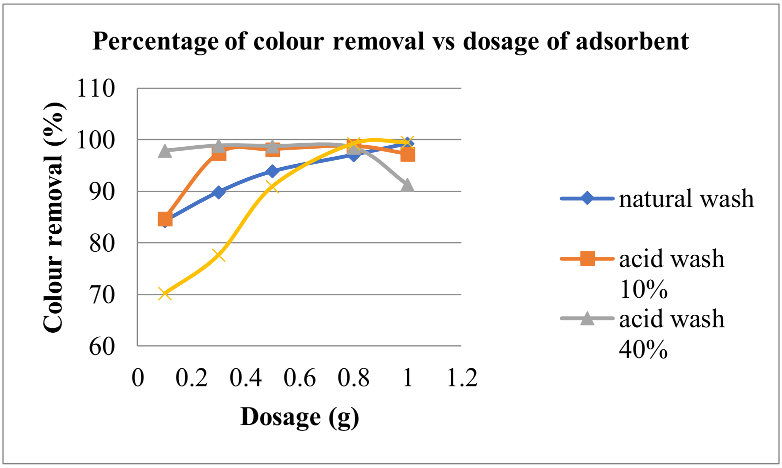

Figure 2: Percentage of colours removal vs Dosage of adsorbent

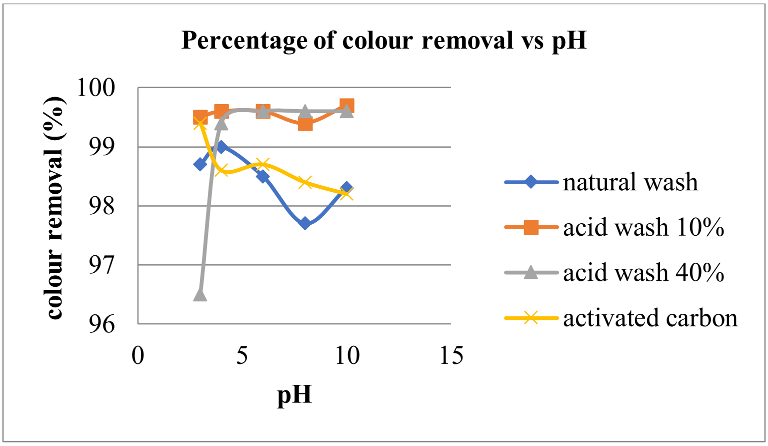

Figure 3: Percentage of colours removal vs pH

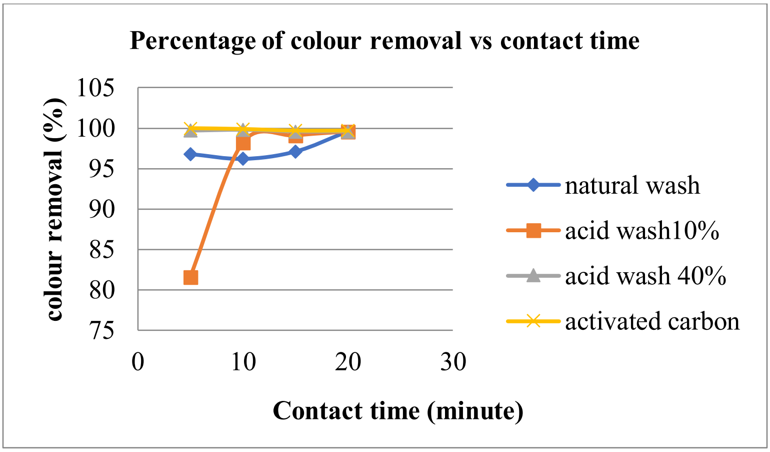

Figure 4: Percentage of colours removal vs Contact time

Conclusion

The objective of this study has been achieved. This study proves that laterite soil could become one of the natural adsorbents that can remove colour in the wastewater. The capability of soil as an adsorbent was increased by modifying it using the acid wash method with colour percentage removal up to 100%. A higher concentration of acid enhances the capability of laterite soil as natural adsorbent, since acid increases the pores in soil structures, hence increasing the adsorption capability. Comparison between laterite soil as natural adsorbent with commercial adsorbent shows that natural adsorbent can stand the same level as the commercial adsorbent but much better respected to environmentally friendly aspects.

This research can be carried out for further study by adding more characteristic studies such as FTIR and SEM, and more parameters can be included such as temperature. Last but not least, this study can be run on other wastewater impurities such as heavy metals.

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