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Bentonite Clay as Effective Adsorbent in Natural Rubber Industry Wastewater Treatment

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Abstract

The natural rubber processing industry's wastewater is typically highly concentrated in organic compounds, suspended solid, colour, ammonia, nitrogen and other pollutants. Any excessive amount of ammonia and nitrogen discharged, eutrophication and the death of various aquatic creatures will take place in every water bodies. The goal of this experiment was to investigate the effectiveness of bentonite as an adsorbent for removal of chemical oxygen demand (COD), ammoniacal nitrogen, and colour from natural rubber processing industry's wastewater. The samples of wastewater from natural rubber processing industry for this study were acquired directly from the discharging point of a manufacturer in Kluang, Malaysia. The effects of optimum adsorbent pH, dosage, shaking speed, and contact time, were determined based on removal of COD, ammoniacal nitrogen and colour, where obtained result reveals that the best batch was achieved at pH 7, 4g, 150 rpm and 120 minutes respectively. For all batch of experiments, the best removal efficiency of all three aspects; COD, ammoniacal nitrogen and colour was typically found in the range of 85%. Bentonite is expected to have great potential and demand for wastewater treatment in the near future. Various challenges and potentials in using bentonite and its composites highlighted and some future prospects for Bentonite-based adsorbents are proposed.

1. Introduction

In South-east Asian countries, natural rubber processing is still one of the most valuable and significant agricultural products despite its numerous impacts on the environment such as pollution of air, water and smells [1-2]. A large quantity of effluent was produced from the processing of raw natural rubber as its operation required a titanic amount of water [3]. This effluent usually contains high level concentration of ammoniacal nitrogen, organic constituent, BOD, nitrate, phosphorus and total suspended solid (TSS)[1-2]. The direct discharge of influent into water bodies like streams, drains and rivers affects the aquatic life's ecosystem thus may contribute to eutrophication [4-5]. A number of systems have been developed such as anaerobic-cum-facultative lagoon system, anaerobic-cum-aerated lagoon system, aerated lagoon system and oxidation ditch system for the treatment of natural rubber industry wastewater [5]. These systems possess few drawbacks such as requiring a longer period of influent treatment, commanding a considerable larger area, causing odor problem, and many more. and also, high operating and maintenance cost [3,5].

Adsorption method has shown effectiveness and was widely used for removal of contaminants from aqueous solution [6]. Activated carbon (AC) was the most commonly and widely used as adsorbent for the treatment of wastewater because it has high surface area capability to adsorbed organic matter but due to high price its usage is limited [7]. In fact, AC is famous for its properties, the better the quality the higher the price [8-9]. Thus, a cost-effective material has led to a search. Over the past 20-years, many researchers have explored the feasibility of cost effectiveness and commercially obtainable materials which are easier to reproduce and reuse as every so often [10].

Bentonite is one of the clay minerals which become popular and was widely used as an adsorbent for wastewater treatment [11]. Bentonite, sometimes referred to as sedimentary clay is derived from volcanic ash and possesses the unique ability to retain water [12]. Among its several notable properties are those of montmorillonite, which has high surface charge, high cation exchange capacity, high surface area, and porosity. Bentonite was thought to be an essential component, particularly in the adsorption process [13-14]. Abundance in nature, bentonite become low cost and ecofriendly adsorbent material compared to other material which creates environment problem [15-16]. Due to Bentonite's strong absorption and complexation capabilities, studies have been conducted on natural rubber wastewater to remove contaminants such as COD, ammonia nitrogen and colour using adsorption method.

2. Methodology

2.1 Preparation of Adsorbent

A natural bentonite known as Delta 500 was supplied by Delta Corp Sdn Bhd from Klang Selangor. The bentonite was sieved to obtained specific particle size of between 106 µm to 150 µm. Obtained samples were then placed in the oven and dried at 105°C for 24 hours to eliminate excess content of moisture, and subsequently placed in a desiccator to exclude atmospheric moisture until it is tested.

2.2 Sampling of Wastewater

In this research study, natural rubber processing industry influent samples were directly collected from the point of discharge at Kluang, Malaysia. The collected samples were immediately transported to laboratory and preserved in a cold room at 4°C prior to minimize further reactions. The characterization of the samples was performed and analyzed according to the Standard Methods for Examination of Water and Wastewater (APHA, 2012) [17].

2.3 Batch Adsorption Experiment

The batch adsorption experiment was conducted to investigate the optimum range of variables which include optimum dosage, shaking speed, contact time, and pH respectively. Every variable process that required optimization was examined and monitored individually. The batch experiment was carried out with bentonite as the media and 100mL of rubber industry effluent sample in 250mL titration flask. The top cover of flask wrapped with parafilm, laboratory film to ensure satisfactory agitation process. The prepared sample flask was agitated with orbital shaker (Sartorius, Germany). The sample flask then was removed from the shaker and allowed to settle before the supernatant was collected for ammoniacal nitrogen analysis.

2.4 Natural Rubber Industry Wastewater Characteristics

COD and Ammoniacal nitrogen were determined both by reactor digestion closed reflux colorimetric method (5220-D) and Nesslerization method respectively. The Platinum Cobalt (Pt-Co) method was used to measure colour using true colour test at 455nm using HACH/DR6000 spectrophotometer. Using a new filter paper with a pore of 0.45 µm, each sample was filtered before measured. All procedures and analysis were extracted from Standard Methods for the Examination of Water and Wastewater [17]. All experiments were performed in triplicate for a consistent result a at room temperature 25±2°C.

3. Results

3.1 Bentonite Characteristics

Table 1 shows the chemical characterization concentration of bentonite in percentage using X-ray Fluorescence (XRF) analyser. Considerably, silicon dioxide (SiO_2) and aluminium oxide (Al_2O_3) are the main compound in bentonite thus were found with a high percentage of 59.5% and 15.8% respectively [18-21]. A relatively poor percentage of 0.71 % and 1.03% was discovered for phosphorus pentoxide (P_2O_5) and titanium dioxide (TiO_2) correspondingly while a slightly higher percentage of Iron (III) oxide (Fe_2O_3) and Sodium oxide (Na_2O) were

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discovered, each at 7.75% and 3.62% respectively. Bentonite characterization resulting has rough surface with open cavities and 3D structural compose of octahedra (Al_2O_3) and/or aluminium tetrahedra (SiO_2) of the framework [12,16].

Table 1 *XRF analysis data of bentonite*

Formula	Chemical characterization (%)
SiO_2	59.5
Al_2O_3	15.8
Fe_2O_3	7.75
Na_2O	3.62
MgO	2.72
CaO	1.82
K_2O	1.76
TiO_2	1.03
P_2O_5	0.71
Other	5.29

3.2 Characteristic of Natural Rubber Wastewater

The natural rubber processing industry effluent samples were analysed and examined to identify the effluent's initial characterization concentration namely COD, BOD_5, pH, TSS, ammoniacal nitrogen and colour. This characterization is illustrated in Table 2. The concentration values of these parameters were 5260mg/L, 3350mg/L, 9.3, 500mg/L, 55mg/L and 345 Pt.Co, respectively. These initial characterization values are higher compared to the acceptable condition of natural rubber effluent regulation 1978. Thus, it must be treated before being release into another body of surface water.

Table 2 *Characteristics of natural rubber effluent*

Parameters	Unit	Value	Discharge of Natural Rubber Effluent Standards
Chemical Oxygen Demand (COD)	mg/L	5260	250
Biological Oxygen Demand (BOD)	mg/L	3350	100
Ammoniacal Nitrogen	mg/L	55	55
Total Suspended Solids	mg/L	500	150
Colour	Pt.Co	345	100
pH	-	9.3	6.0-9.0

3.3 Effect of Different Optimum Parameters

3.3.1 Effect of Different pH

The initial pH concentration of rubber industry effluent is a vital key parameter, as it controls adsorption process, mainly the adsorption capacity. The effect of different optimum pH varying from 3 to 13 towards the removal percentage of COD, ammoniacal nitrogen and colour using bentonite adsorbent is shown in Fig 1. These removal percentage efficiencies increase along with the increment of pH concentration from 3 to 7 respectively. The best optimum result was considered at pH 7 with its removal percentage of COD, ammoniacal nitrogen and colour at 79.3%, 74.3% and 76.5% respectively. After that, the removal percentage begins to decline with further increases in pH solution up until concentration of 9 and this finding result correlate with other researchers [22].

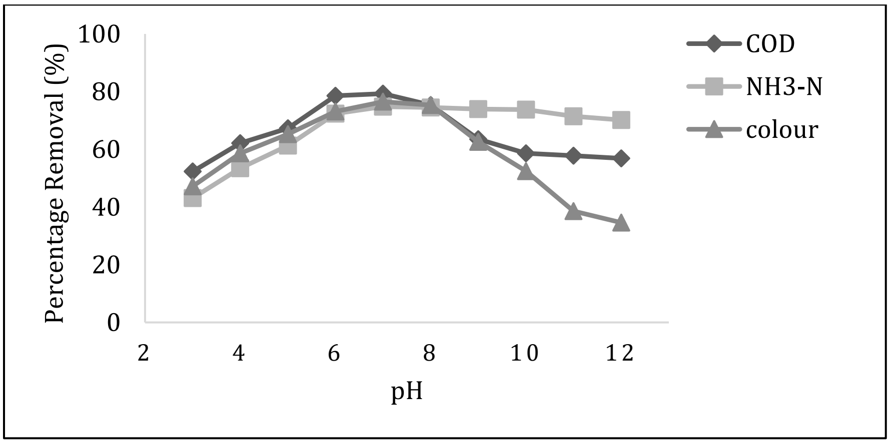

Fig. 1 *Removal percentage of COD, ammoniacal nitrogen and colour against different pH*

3.3.2 Effect of Different Dosage

The investigation of optimum dosage is considered an important key factor in quantitative uptake of contaminants. The effect of different optimum dosage varying from 0g to 8g towards the removal percentage of COD, ammoniacal nitrogen and colour was shown in Fig 2. The removal percentage efficiencies of COD, ammoniacal nitrogen, and colour increase with an increase in bentonite adsorbent dosage from 0.5g to 4g, respectively. The best optimum result was considered at 4g with its removal percentage of COD, ammoniacal nitrogen and colour at 74.9%, 70.8% and 76.8% respectively. Subsequently, further increments in the bentonite dosage at 4.5g and above does not increase the removal percentage because the maximum amount of COD, ammoniacal nitrogen and colour are adsorbed in the rubber effluent. Due to a greater surface area and accessibility of more adsorption sites, adsorption increases more quickly as adsorbent was added [23,24].

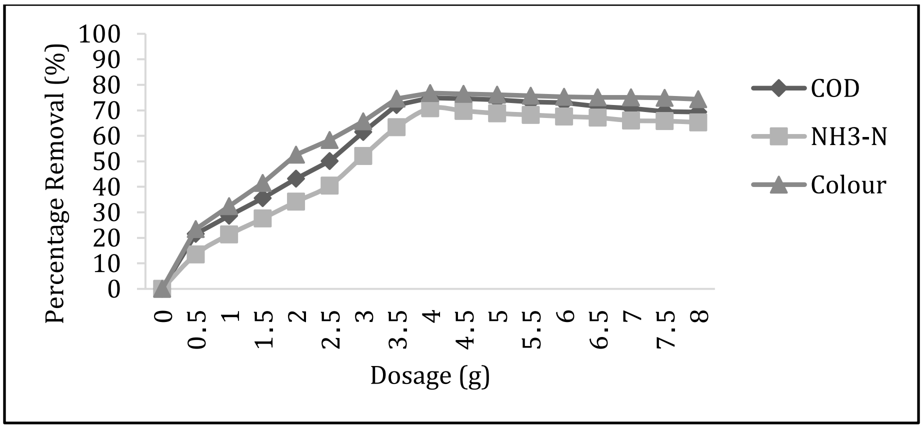

Fig. 2 *Removal percentage of COD, ammoniacal nitrogen, and colour against different bentonite dosages*

3.3.3 Effect of Different Shaking Speed

The effect of stirring rate is considered crucial in the adsorption phenomenon, as it affects the solute distribution in the bulk solution and the formation rate of the outer boundary film [23,24]. The effect of different optimum shaking speeds was varied from 00rpm, 50rpm, 100rpm, 125rpm, 150rpm, 175rpm, and 200rpm towards the removal percentage of COD, ammoniacal nitrogen, and colour as shown in Fig 3. The removal percentage efficiencies of COD, ammoniacal nitrogen, and colour increase with increasing shaking speed from 50rpm to 150rpm, respectively. In fact, it was at 150rpm that the best optimum result was achieved, where the removal percentages of COD, ammoniacal nitrogen, and colour were 83%, 77.97%, and 87.2%, respectively. Ultimately, further increasing the shaking speed to 200rpm does not result in an increase in the removal percentage for COD, ammoniacal nitrogen, and colour, as the majority of these compounds have already been adsorbed in the rubber effluent. Rapidly rising adsorption rates combined with faster speeds reduces boundary layers of surrounding particle, increasing the external film transfer coefficient and, ultimately increases the removal percentage of ammoniacal nitrogen [25].

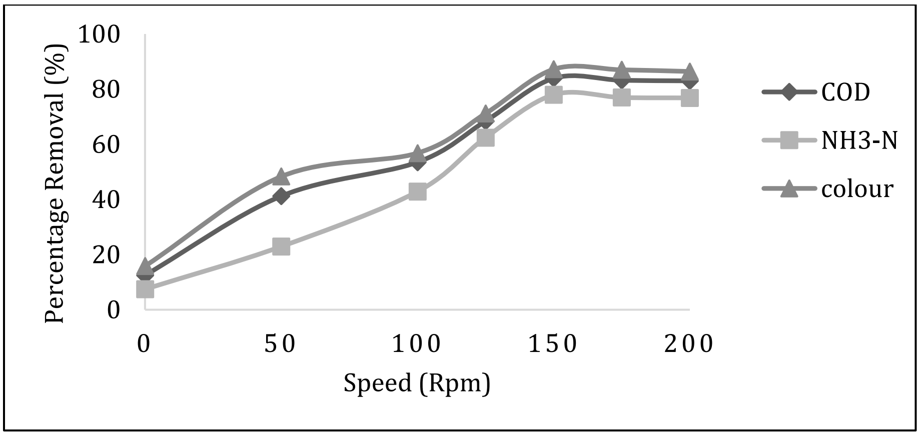

Fig. 3 *Removal percentage of COD, ammoniacal nitrogen and colour against different shaking speed*

3.3.4 Effect of Different Contact Time

The investigation of optimum contact time is considered prominent in quantitative uptake of contaminants. In this study, contact time was altered from 5 minutes to 300 minutes to influence the removal percentage of COD, ammoniacal nitrogen and colour as shown in Fig 4. The removal percentage efficiencies of COD, ammoniacal nitrogen and colour increases with increasing time from 5 minutes to 120 minutes respectively. The best optimum result was considered at 120 minutes with its removal percentage of COD, ammoniacal nitrogen and colour at 82.5%, 76.8% and 86.2% respectively. Subsequently, further increments in the contact time does not increase removal percentage of parameters because utmost all COD, ammoniacal nitrogen and colour was adsorbed in rubber effluent when further increment in time was 150 minutes [26].

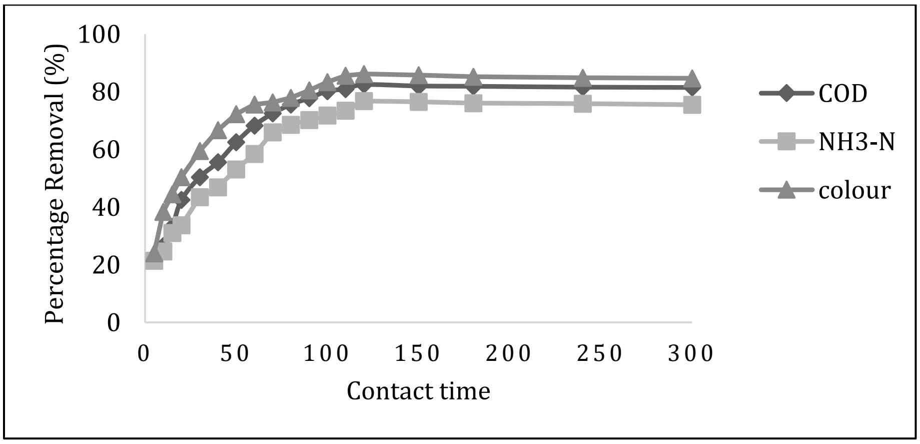

Fig. 4 *Removal percentage of COD, ammoniacal nitrogen and colour against different contact time*

4. Conclusions

This research study shows that the utilization of bentonite as an adsorbent is an economical and environmentally acceptable material that can remove over 70% of pollutants from rubber industry effluent, including CD, ammoniacal nitrogen and colour. cost effective. The best batch adsorption experiment optimum dosage was conclude at 4g with its removal percentage of COD, ammoniacal nitrogen and colour at 74.9%, 70.8% and 76.8% respectively. The best optimum pH was valued at pH 7 with its removal percentage of COD, ammoniacal nitrogen and colour at 79.3%, 74.8% and 76.5% respectively. The best optimum shaking speed was noted at 150rpm with its removal percentage of COD, ammoniacal nitrogen, and colour at 83%, 77.97% and 87.2% respectively. The best optimum contact time was monitored at 120 minutes with its removal percentage of COD, ammoniacal nitrogen and colour at 82.5%, 76.8% and 86.2% respectively. However, more research works should be conducted to determine the effectiveness of bentonite in removing other pollutants from rubber industry effluent namely Total Suspended Solids, Zinc, Iron (Fe), Copper (Cu) and many others.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

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