Journal of Tropical Resources and Sustainable Science

journal homepage: jtrss.org

Dye Adsorbent by Activated Carbon

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Available online 27 May 2015

Keywords:
Pineapple waste, activated carbon, adsorption, methylene blue dye, malachite green dye.

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Abstract

Dyes are used extensively in many industries making the research on color production more important. Despite that, dyes are important class of pollutant in which it is disposed in water resources and causes major environmental problems due to toxicity and carcinogenic property of dye. However, the disposed dye into the environment can be treated by several alternatives. In this study, activated carbon derived from pineapple crown, core and peel were prepared by chemical activation using phosphoric acid (H_3PO_4). Laboratory prepared activated carbons were used to identify the suitability of its application to adsord methylene blue and malachite green. The results indicated that the activated carbon derived from pineapple crown shows maximum adsorption of methylene blue (38.6%) and malachite green. This study shows a benefit of transforming agriculture waste to value added product and also helps to solve over abundance pineapple waste problem.

1. Introduction

Water covers about 70% of the earth's surface and earth is the only planet that has water in abundance on its surface. Human being, animal and plants require water for survival and to carry out daily routines thus making water essential for all living forms to maintain continuity of their lives. Water on earth moves continually through water cycle via several processes such as evaporation, transpiration, condensation, precipitation and runoff. The amount of water on earth is immense and 97% consists of ocean which is unfit for human consumption, 2% is in the form of icecaps while the rest exists as fresh water. Above all, clean water supply is necessary but however, water sources and supplies are currently being tremendously polluted. This is due to increasing world population, unsustainable consumption of water and aggravated development [1]. Specifically, the following sectors namely agriculture, industrial and domestic respectively consumes 70%, 22% and 8% of available fresh water and thus results in generation of large quantity of wastewater [2].

Dye manufacturing, textile and other fabric finishing releases massive amount of dye into the wastewater [3]. Textile industry is a complex unit consisting of bleaching, dyeing, printing and stiffening of textile products and the entire process is well known to discharge pollutants especially wastewater. The textile waste water contains organic dyes, chemicals, auxiliaries, salts, surfactants, heavy metals, mineral, oil and others [4]. The dyes from textile wastewater are highly resistant to light, pH and microbial attack that makes them to remain in the environment for a longer period of time [5].

Commercially, there are more than 100 000 types of dyes such as acid, reactive, disperse, vat, metal complex, mordant, direct, basic and sulphur dyes in which their production exceeds 150 metric tons per year [5]. Among them azo dyes are the major group of synthetic dyes and makes up 70% of all commercial dyes [6].

ISSN Number: 2289-3946

As a result, major environmental issues arise due to the toxicity and carcinogenic property of the dyes. The carcinogenic property is caused by the presence of carcinogens such as benzidine, naphthalene and other aromatic compounds [7]. In addition, increasing demand for water supply had caused polluted water to be recovered and reused. Thus, several methods such as activated carbon, sorption, chemical coagulation, ion exchange, electrolysis and chemical treatment have been developed for removing dye from wastewater prior to release into the environment. [8]. According to Gecgel, Ozcan and Gurpmar (2013), the effective method to remove dyes and pigments is activated carbon sorption. Activated carbon sorption is regarded as a better option for adsorption due to its large surface area and pore volume. Coal based activated carbon has been used widely but cost and generation acts as a limitations. Therefore, non-conventional and low cost adsorbents from bottom ash, fly ash, coir pith, cassava peel, cotton, orange peel, bagasse fly ash, cellulose-based wastes, sewage sludge, kaolinite, zeolite, wheat straw, sawdust, char fines, and oil mill waste have been used [9]. Since commercial carbon activation method is expensive and thus production of activated carbon from agriculture waste can be less costly and environmental friendly as well.

Malaysia is one of the successful and potentially leading countries in pineapple industry. Pineapple (Ananas comosus) holds the third rank in the world tropical fruit production after banana and citrus [10]. Pineapple is the edible member of the family Bromeliaceae. Pineapple industry in Malaysia was started in1888 by a European in Singapore. It was then brought to Malaysia particularly Johor and later spread to Selangor and Perak. According the data provided by the Malaysia Pineapple Industry Board (1992), the species of pineapple that are found in Malaysia are Maspine, Sarawak, Yankee, Gandul, Moris Gajah, Josapine, N36, MD2 and Moris. Due to the massive production of pineapple, waste generated is not exception with the production of residual pulp, peels, stems and crowns.

Pineapple wastes are generally disposed in the open environment due to costly proper disposal method. This eventually causes serious environmental problems as pineapple waste requires high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) to degrade. To overcome the disposal problem, currently pineapple waste is utilized in various manners namely as bromelain, ethanol, antioxidant, organic acid, acids, anti-dyeing agent, fiber, removal of heavy metal, animal feed, and energy and carbon source [11].

Besides that, pineapple waste can be used in the removal of dye because adsorbent produced from pineapple waste is of low cost, prevents disposal cost and off-site burning issues [4]. Based on these reasons, pineapple waste namely pineapple crown, peel and core were chosen for this study to produce activated carbon for the adsorbent of dyes. The objective of this study is to investigate the most suitable waste of pineapple that will produce the best activated carbon for dye adsorption.

2. Materials and Methods

2.1. Preparation of Raw Material

The materials that are used in this research are pineapple crown, pineapple peel and pineapple core. These parts of pineapple were subjected to acid activation using phosphoric acid (H3PO4). Pineapples were bought at local markets in Jeli, Kelantan. The pineapple peel, crown and core were cut into small pieces and washed thoroughly with deionized water and dried in oven for 2 to 3 hours at 105°C [4]. The dried pineapple crown, peel and core are then grinded and sieved using 300 µm siever.

2.2. Preparation of Adsorbate

About 0.5 g of dye was weighed using a weighing balance and pour into 250 ml beaker. Then, 20 ml deionized water is pour into the beaker and was stirred using glass rod to ensure complete dissolve of the dye. Next, the dye solution was poured into 100 ml volumetric flask and make up to the mark with deionized water. The dye solution is then filtered using 0.45 µm Whatman filter paper. Later, 5 ml of the dye solution was pipette into 50 ml volumetric flask and was made up to the mark with deionized water. The dye sample was stored in 50 ml polypropylene bottle and labeled before analysis [12].

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2.3. Preparation of Adsorbent

Oven dried pineapple crown, peel and core were soaked in a boiling solution of 40% phosphoric acid for 1 hour [13]. Later, the pineapple crown, peel and core are subjected to oven at 100°C for 24 hours to dry the raw materials [8]. Then, the pineapple peel, crown and core were kept at room temperature for 24 hours [13]. The air dried pineapple peel, crown and core is then carbonized in furnace at 500C for 1 hour [8]. Later, the pineapple peel, crown and core were washed with of hot deionized water, cold deionized water and dried at 120°C for 2 hours [14] and stored in tight lid container [13].

2.4. Testing Pure Adsorbate in Spectrophotometer

The prepared pure dye, methylene blue and malachite green were placed in spectrophotometer HACH DR 5000 to identify their initial optical density prior to treatment with activated carbon from pineapple peel, crown and core. The initial optical density was determined at the wavelength of 668nm for methylene blue and 659nm for malachite green [5]. Spectrophotometer HACH DR 5000 operates on principles of UV light absorption by dye being tested. Untreated methylene blue and malachite green contains higher percentage of color pigments that absorbs the UV light produced in the Spectrophotometer HACH DR 5000. Thus, the absorber detects higher optical density as the color pigments in the dye absorb the UV radiation indicating the concentration of color is high. However, vice versa should occur in which lower optical density or zero optical density value should be recorded for treated methylene blue and malachite green indicating lower percentage or absence of color pigments after treatment with activated carbon.

2.5 Adsorption Process

50ml of methylene blue and malachite green was treated with 1g of activated carbon. The mixture was placed in shaker and stirred for 2 hours at 150 rpm [1]. Then, the supernatant liquid (treated dye) was filtered using 0.45μm Whatman filter paper [1]. The treated dye was then tested with spectrophotometer HACH DR 5000 at the wavelength for maximum absorbance of 668nm and 650nm for methylene blue and malachite green respectively to identify the optical density of adsorbed dye by the activated carbon [5]. The percentage removal of dye is defined as the difference in dye concentration before and after adsorption and was calculated using the equation:

$$\% \text{ Uptake} = (\text{Initial Concentration} - \text{Treated Concentration}) \times 100\%$$

3. Results and Discussion

Within the scope of our research, an attempt to identify the best activated carbon produced from pineapple waste was investigated and Figure 1-6 shows the illustrations of results obtained from the treatment of methylene blue and malachite green using activated carbons produced from pineapple crown, peel and core. Three different activations (replications) were carried and the adsorption was recorded using spectrophotometer HACH DR 5000.

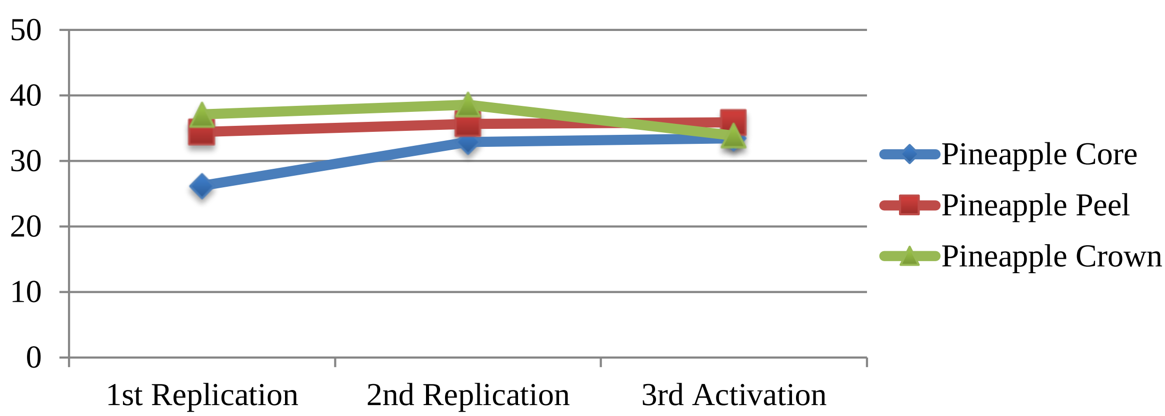

Figure 1: Comparison between Different Pineapple Wastes Activated Carbon in Methylene Blue Adsorption (%)

ISSN Number: 2289-3946

3.1. Treatment of Methylene Blue Dye

Figure 1 indicates the treatment of methylene blue by different activated carbon produced from pineapple crown, pineapple peel and pineapple core. The maximum adsorption of methylene blue dye is by activated carbon produced from pineapple crown at 2nd replication (38.6%), maximum adsorption for activated carbon produced from pineapple peel was at 3rd replication (35.9%) and for activated carbon produced from pineapple core, the maximum adsorption as at 3rd replication (33.5%). However, comparing the entire adsorption of methylene blue dye in Figure 1, it can be observed that the best activated carbon that shows maximum adsorption capacity (38.6%) is activated carbon produced from pineapple crown.

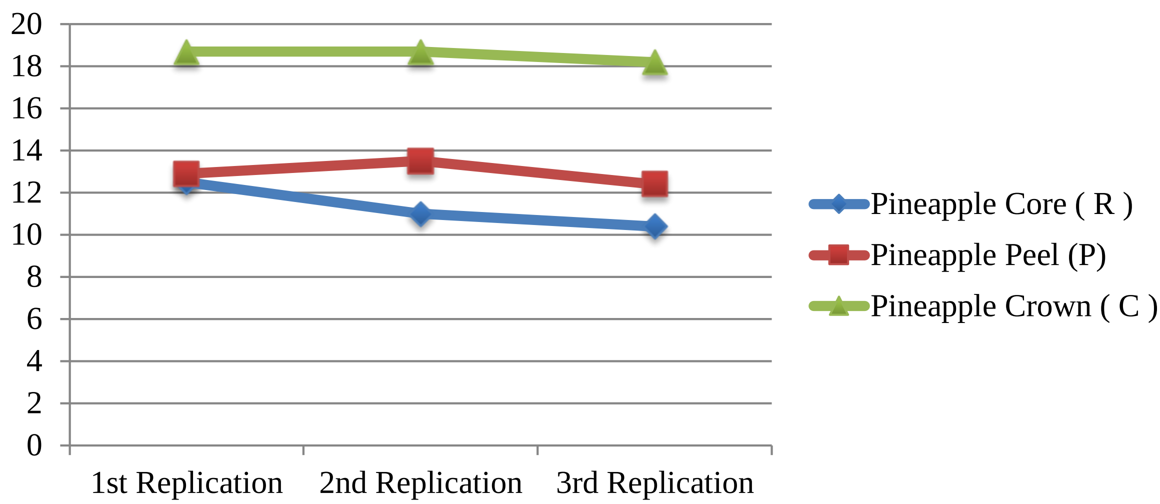

Figure 2: Comparison between Different Pineapple Wastes Activated Carbon in Malachite Green Adsorption (%)

3.2. Treatment of Malachite Green Dye

As for malachite green dye, the adsorption is shown by Figure 2 using different activated carbon produced from pineapple waste. Maximum adsorption of malachite green dye treated with activated carbon from pineapple crown was at 1st and 2nd replication (18.7%), activated carbon produced from pineapple peel shows maximum adsorption at 2nd replication (13.5%) while activated carbon from pineapple core was at 1st replication (12.5%). The entire adsorption capacity of activated carbon for malachite green dye as illustrated in Figure 2 indicates pineapple crown serves as the best activated carbon for adsorption of malachite green with 18.7% of dye adsorption.

3.3. Best Activated Carbon for Methylene Blue and Malachite Green Dye Treatment

Pineapple crown, peel and core composed of cellulose, hemicelluloses and lignin being plant waste in nature [7]. Large number of hydroxyl groups (-OH) are present in cellulose, hemicelluloses and lignin that gives the gives the adsorptive property to the pineapple waste. Besides hydroxyl groups, it also consists of carbonyl groups (>C=O) that plays a vital role in adsorption process [6]. The hydroxyl and carbonyl group are negatively charged in nature. Methylene blue and malachite green are cationic dyes which are positively charged. Thus, strong electrostatic attraction exists between negatively charged pineapple crown, peel, core and positively charged dye. The cationic dye molecules dissociates and adsorb on the binding sites of pineapple waste activated carbon such as the hydroxyl and carbonyl groups. As a result, adsorption takes place as adsorbent favors adsorption of dye molecules [6].

In this case, activated carbon produced from pineapple crown shows maximum adsorption (38.6%-methylene blue & 18.7%-malacite green)) because the number of hydroxyl and carbonyl group present in pineapple crown is more compared to pineapple peel (35.9% methylene blue & 13.5%- malacite green) and pineapple core (33.5% methylene blue & 12.5%-

ISSN Number: 2289-3946

malacite green). Pineapple peel contains lower percentage of cellulose and hemicelluloses [15]. Thus, the number active sites for binding are also lower causing reduced adsorption of cationic dyes. As for pineapple core, it is mainly composed of sugar and water that degrades during drying process. The presence of large content of sugar and water replaces the cellulose and hemicelluloses with active sites which eventually reduces the capability of pineapple core to adsorp cationic dye molecules.

4. Conclusions

The adsorption of methylene blue and malachite green dyes using acid treated pineapple wastes namely pineapple crown, peel and core were investigated. From this study, it shows that the removal of methylene blue and malachite green dye by adsorption utilizing activated carbon derived from pineapple waste to be useful in controlling water pollution. It can be concluded that acid treated pineapple crown activated carbon is an effective adsorbent for adsorption of methylene blue and malachite green dyes. Pineapple waste is easily available has the potential to be used for small industries that releases dye as effluent. The information collected from this study may be informative to design economically inexpensive treatment process for removal of dye effluent.

Acknowledgment

A word of appreciation to the Faculty of Earth Science, University Malaysia Kelantan for providing all the equipments and laboratory devices to conduct the experiment. Cordial appreciation also goes to all staff from Environmental Lab. This research was supported by SGJP grant, R/SGJP/A08.00/00880A/001/2014/000167.

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ISSN Number: 2289-3946