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CONVERSION OF DISPOSABLE BAMBOO CHOPSTICKS WASTE TO ADSORBENTS FOR LABORATORY WASTEWATER AND DYE WASTEWATER TREATMENT

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Abstract

Laboratory wastewater and dye wastewater cause damage to the environment if released without proper treatment. According to the Sustainable Development Goal (SDG), water recovery from wastewater treatment has been emphasized for decades. In this study, ecofriendly adsorbents were prepared from disposable bamboo chopsticks waste to remove contaminants from laboratory and dye wastewater. Disposable bamboo chopsticks waste was collected from one of the restaurants around University of Magway. The adsorbents were prepared at 300 ℃ and 500 ℃, respectively. For comparison, commercial activate carbon was used. The crystal structure of adsorbents was analyzed by X-ray diffractometer (XRD) and scanning electron microscopy (SEM) was used to observe morphology of the adsorbents. Energy dispersive X-ray fluorescence spectrometer (EDXRF) was used to study the elemental compositions of the adsorbents, initial and residual laboratory wastewater as well as dye wastewater. The dye removal percentages of prepared ecofriendly adsorbents were analyzed by ultraviolet-visible spectrophotometer (UV-vis). The results showed that the bamboo-based adsorbent prepared at 500 ℃ and commercial activated carbon performed higher removal in copper and zinc from laboratory wastewater, titanium, green and yellow colours from screen printing dye wastewater as well as methylene blue.

Keywords: adsorbent, bamboo, laboratory, dye, wastewater, adsorbent

Introduction

Laboratory wastewater derived from different types of laboratories including research, education, industrial, and agricultural institutions. The wastewater from laboratories was discharged from various laboratory activities such as washing of glass ware, chemical waste from research and student’s practicum as well as educational experimental activities. Although the quantity of wastewater produced by the laboratory is relatively small, it has a real impact on the living organism and environment around the laboratory because the discharged wastewater contains toxic chemicals, organic compounds and heavy metals (such as copper, zinc, cadmium, mercury, lead, chromium, iron, nickel, tin, arsenic, etc) depending on the research and module of the practicum. Therefore, the laboratory wastewater must be prevented from reaching directly to the environment (Susila Arita et al., 2022; Tamirat Dula Chaemiso and Tariku Nefo, 2019).

Methylene blue (MB) is a cationic dye that is used in paper colouring, cottons and wool dyeing, solar cells and as temporary hair colour. As result, it leads to the obtaining of large amounts of residual water (Bingbing Mi et al., 2019). Recent years, dye wastewater from screen printing services or industries is potential to pollute the environment since it flows into drainage channel without prior treatment. The most visible parameter is colour due to dye usage. Waste dyes are difficult to decompose, non-biodegradable, and toxic organic compounds. Untreated dye wastewater can be harmful to both aquatic and terrestrial life. Hence, it is necessary to treat dye wastewater before discharging to the environment (Nguyen Ngoc Tue et al., 2020).

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In order to remove toxic heavy metals and contaminants from wastewater, several techniques have been applied by advanced physical and chemical treatment. Some of these techniques include membrane separation, ion exchange, oxidation precipitation filtration process, advanced oxidation method, ultrafiltration, electrolysis. However, the major disadvantages of such techniques are a higher cost of production, high-cost equipment, expensive chemical requirements, and large-scale operation (Susila Arita et al., 2022; Junidah Lamaming et al., 2022).

Adsorption technique is widely used for the removal of various pollutants such as textile dyes, organic contaminants, inorganic anions, pesticides, and heavy metals. For adsorption technique, commercial activated carbon, a high surface area and a highly porous material, is a preferred adsorbent to remove impurities from liquid solutions. However, the high cost of activated carbon has inspired the researchers to search for suitable low-cost adsorbents. The alternative low-cost adsorbents have been investigated using various natural sources, agricultural wastes, forest wastes, municipal wastes and industrial wastes (S Fitriana et al., 2021; Kung-Yuh Chiang et al., 2012).

Nowadays, the managing disposable bamboo chopsticks waste is challenging. Because bamboo chopsticks are widely used not only in Asian countries but also throughout the world as Asian cuisine is popular around the world and an essential component of Asian cuisine culture is the use of chopsticks. Disposable bamboo chopsticks are discharged daily from street food, trunks, canteens, food deliveries, and restaurants. The service life of one pair of chopsticks is just one meal, and most end up in a landfill (Saowanee Wijitkosum, 2023; Jian Jiang et al., 2014). Uncontrollable amounts of bamboo chopsticks waste contribute to the environmental problem. Thus, more research is required to be carried out to investigate other potential uses of bamboo chopsticks waste.

Therefore, this research aims to convert disposable bamboo chopsticks waste (low-value waste materials) to high-value ecofriendly adsorbents for laboratory and dye wastewater treatment do develop the circular economy. For this purpose, firstly, disposable bamboo chopsticks waste was collected from one of the restaurants around University of Magway. Then, the collected disposable bamboo chopsticks waste was prepared as adsorbents by carbonization at 300 ℃ and 500 ℃ and the prepared adsorbents were characterized by XRD, SEM and EDXRF, respectively. Finally, the laboratory and dye wastewater as well as methylene blue removal percentage of prepared ecofriendly adsorbents were investigated by EDXRF and UV-vis, respectively.

Materials and Method

In order to prepare ecofriendly adsorbent, disposable bamboo chopsticks waste was used as raw materials. Laboratory wastewater was collected from sample preparation laboratory, University Research Center, University of Magway. Dye wastewater (yellow and green) was collected from a screen-printing service from Taunggyi city. Methylene blue ($C_{16}H_{18}ClN_3S$, MB) was also used as dye. Distilled water was used as solvent.

First, disposable bamboo chopsticks waste was collected from one of the restaurants around University of Magway. Second, the collected bamboo chopsticks waste was washed thoroughly with the boiled water for three times to remove impurities. Then, the washed bamboo chopsticks waste was cut into small pieces and dried under sunlight for two days. Finally, the dried bamboo chopsticks waste was carbonized in muffle furnace at 300 ℃ and 500 ℃ to obtain the desired ecofriendly adsorbents. The flow chart and the photographic illustration of preparation of adsorbents are shown in Figure 1 and Figure 2. X-ray diffractometer (XRD) and scanning electron microscope (SEM) were used to study the crystal structure and morphology of the adsorbents. The elemental compositions of prepared adsorbents were analyzed by energy dispersive x-ray fluorescence spectrometer (EDXRF).

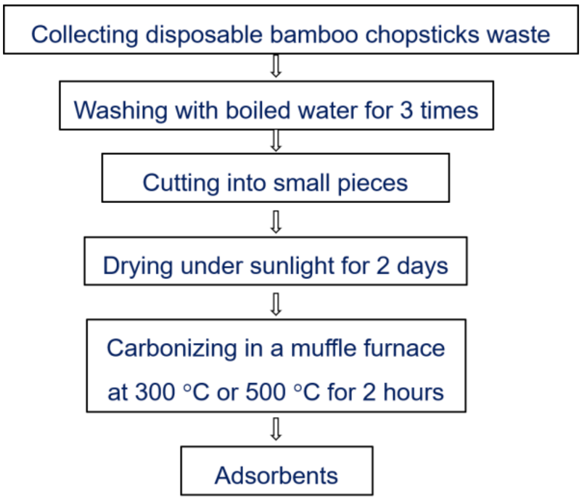

Figure 1. Flow chart of the preparation of adsorbents derived from disposable bamboo chopsticks waste

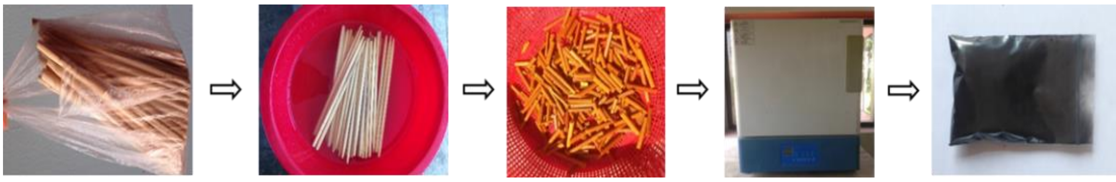

Figure 2. Photographic illustration of the preparation of adsorbents derived from disposable bamboo chopsticks waste

The ecofriendly adsorbents derived from disposable bamboo chopsticks waste prepared at 300 ℃ and 500 ℃ as well as commercial activated carbon were denoted as B-300, B-500 and CAC, respectively. For adsorption processes, 0.5 g of B-300, B-500 and CAC adsorbents were separately added to the 50 ml of laboratory wastewater, 50 ml of methylene blue (MB), 50 ml of yellow and green dye wastewater in 250 ml conical flasks. As shown in Figure 3, the adsorption process was carried out by shaking with 110 rpm in the water bath shaker (BT-150RD) for 1 hour. Then, the adsorbed laboratory wastewater, methylene blue, yellow and green dye wastewater solutions were filtered by filtered paper and the residual solutions were kept in laboratory glass bottles.

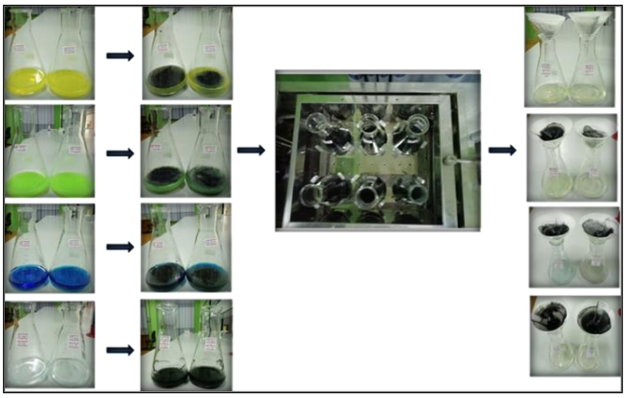

Figure 3. Photographic illustration of laboratory wastewater, methylene blue as well as yellow and green dye wastewater adsorption process using B-300 and B-500 adsorbents

In practical applications, the adsorption process is dealt with the regeneration of the spent adsorbents. Therefore, the regeneration process was conducted in this study. The Laboratory wastewater, MB, yellow and green dye wastewater loaded B-500 adsorbents were mixed with 1 M of hydrochloric acid (HCl). The mixed solution was stirred with 150 rpm at 60 °C for 1 hour followed by filtering and drying in oven at 80°C for 2 hours. Then, 0.5 g of regenerated B-500 adsorbent denoted as 2B and 50 ml of MB were used to conduct second time adsorption. The adsorption process was the same procedure as mention above.

Energy dispersive x-ray fluorescence spectrometer (Xenemetrix, EDXRF spectrometer X-Calibur) and UV-visible spectrophotometer (UV-2600) were used to study the removal efficiency of prepared adsorbents. The removal percentages of the prepared adsorbents were calculated from the following equation:

$$\text{Removal \%} = \frac{C_i - C_f}{C_i} \times 100\% \qquad (1)$$

where C_i and C_f are the initial and final (residual) concentration of wastewater (or MB).

Results and Discussion

Figure 4(a) shows XRD patterns of B-300 and B-500 adsorbents while Figure 4(b) expresses the XRD pattern of CAC adsorbent. The broad peak between 15° and 30° showed the amorphous structure of the adsorbents due to the conversion of hemicellulose and lignin to a more carbonaceous structure during carbonization. XRD patterns in this study match well to previously reported pattern (Qian Liu et al., 2023). In Figure 4(b), the sharp peak at around 43° implied the existence of graphite in CAC adsorbent.

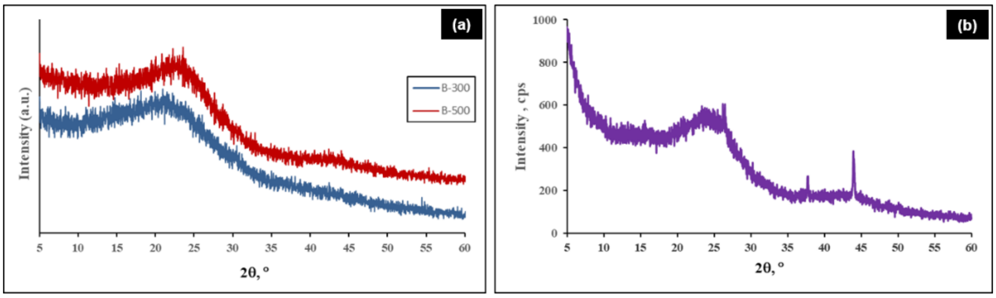

Figure 4. XRD patterns of (a) B-300, B-500 and (b) CAC adsorbents

Figure 5(a-c) shows SEM images of B-300, B-500 and CAC adsorbents. Bamboo is composed of vascular bundles and these are the origin of the large pores (Arachaporn Wilamas et al., 2023). Porous structure was observed in SEM images of B-300 and B-500 adsorbents (Figure 5(a-b)). In comparison with B-300 adsorbent, B-500 adsorbent possessed larger longitudinal pores which were suitable for removal of pollutants in liquid phase The irregular shape and size of CAC adsorbent was seen in the SEM image shown in Figure 5(c).

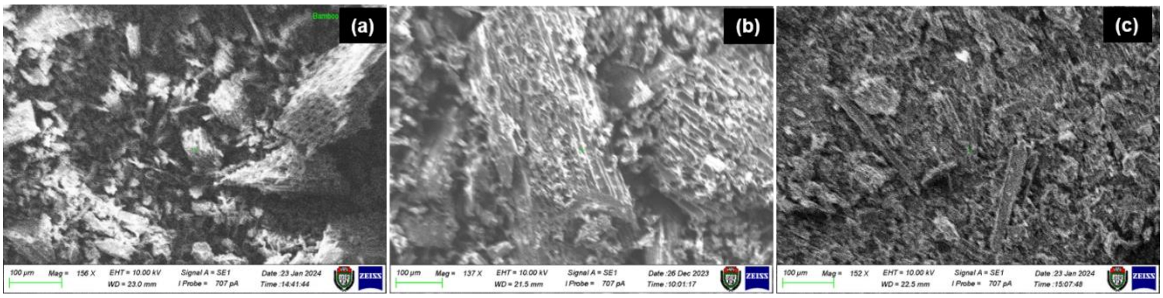

Figure 5. SEM images of (a) B-300, (b) B-500 and (b) CAC adsorbents

Figure 6(a-b) shows the elemental composition of B-300 and B-500 as well as CAC adsorbents studied by EDXRF. Generally, 9 elements such as Al (aluminum), Si (silicon), P (phosphate), S (sulphur), K (potassium), Mn (manganese), Fe (iron), Cu (copper), Zn (zinc) were found in B-300 and B-500 adsorbents (Figure 6(a)). In the B-500 adsorbent, Ca (calcium), and Pb (lead) were observed whereas Ca and Pb were not detected in the B-300 adsorbent. K was the main component of B-300 and B-500. B-500 had higher content of K (63.34%), and Ca (10.24%), and the results were comparable to the reported values of K (64.5%) and Ca (7.78%) (Arachaporn Wilamas et al., 2023). In the EDXRF result shown in Figure 6(b), 12 elements including Al, Si, P, S, K, Ca, Ti (titanium), Cr (chromium), Mn, Fe, Cu and Zn were observed. The higher levels of metals (Ca, Fe, Cu, Zn, Ti) and S were present in the CAC adsorbent compared to B-300 and B-500 adsorbents.

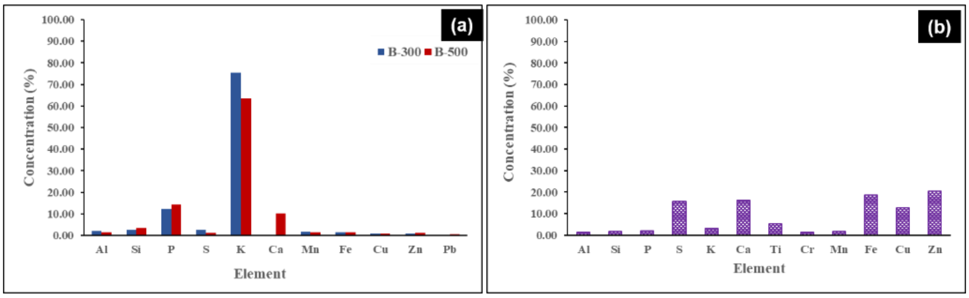

Figure 6. EDXRF results of (a) B-300 and B-500 and (b) CAC adsorbents

EDXRF analysis was also conducted to observe the elemental contents in the laboratory and dye wastewater and to study the removal percentages of B-300 and B-500 adsorbents. Figure 7 shows the elemental compositions of the initial laboratory wastewater. Al, Si, Ca, Cu and Zn were observed in the laboratory wastewater. The laboratory wastewater was collected during the synthesis of copper oxide and zinc oxide nanoparticles. As a result, the presence of higher amount of copper (50.58 wt%) and zinc (39.90 wt%) were observed.

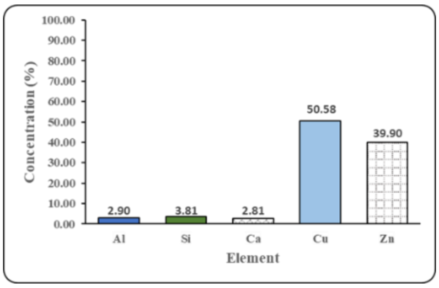

Figure 7. Elemental compositions of initial laboratory wastewater

After adsorption with B-300, B-500 and CAC adsorbents, the decrease in Cu and Zn concentration in comparison with the initial laboratory wastewater were observed obviously in Figure 8(a-c). Figure 9(a-b) show Cu and Zn removal percentages of B-300, B-500 and CAC adsorbents. As seen, Zn removal percentages of B-300, B-500 and CAC adsorbents were about 93%, 97% and 98%, respectively which were higher than the Cu removal percentages, about 71%, 77% and 82%, respectively.

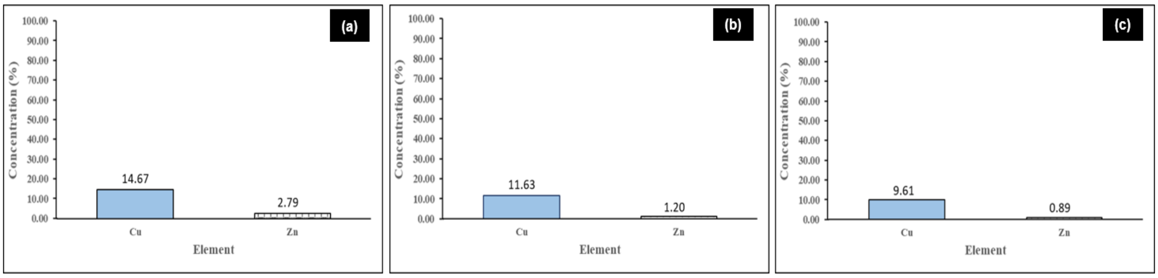

Figure 8. Cu and Zn concentration of residual laboratory wastewater after adsorption with (a) B-300, (b) B-500 and (c) CAC adsorbents

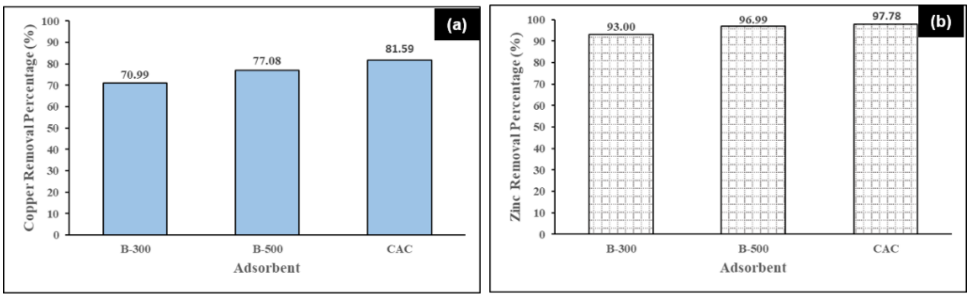

Figure 9. (a) Cu and (b) Zn removal percentages of B-300, B-500 and CAC adsorbents

Figure 10(a) shows Ti concentration in initial and residual yellow and green dye wastewater solutions (adsorbed by B-300, B-500, and CAC adsorbents). Before the adsorption process, the higher concentration Ti about 61% and 80% were found in the EDXRF results of yellow and green dye wastewater. After adsorption with B-300 adsorbent, about 5% and 8% of the Ti concentration were left. When initial yellow and green dye wastewater were adsorbed by B-500 and CAC adsorbents, the presence of Ti was not observed in the EDXRF results of residual yellow and green dye wastewater. Figure 10(b) shows the Ti removal percentages of B-300, B-500, and CAC adsorbents. The results proved that the highest Ti removal percentage of B-500 adsorbent was comparable with the CAC adsorbent.

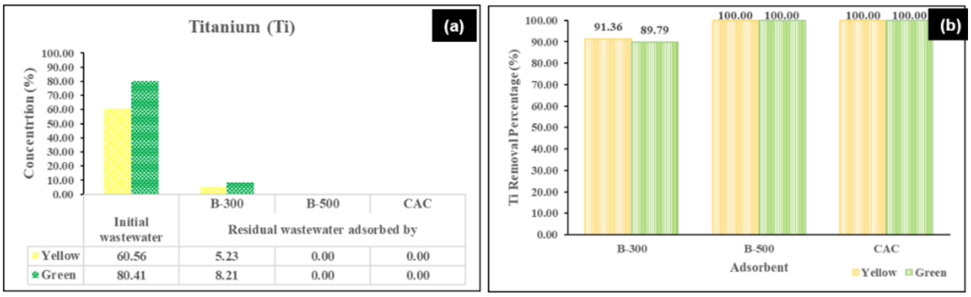

Figure 10. (a) Ti concentration in initial and residual yellow and green dye wastewater solutions (adsorbed by B-300, B-500, and CAC adsorbents) and (b) Ti removal percentages of B-300, B-500, and CAC adsorbents

Figure 11(a-c) and Figure 12(a-c) show the photographic illustration of the comparison of initial and residual MB, yellow and green dye wastewater solutions. As seen in Figure 11(a-c) and Figure 12(a-c), the significant decrease in MB, yellow and green colours were observed after adsorption with B-300, B-500 and CAC adsorbents for 1 hour, indicating that bamboo-based adsorbents were comparable with the commercial activated carbon.

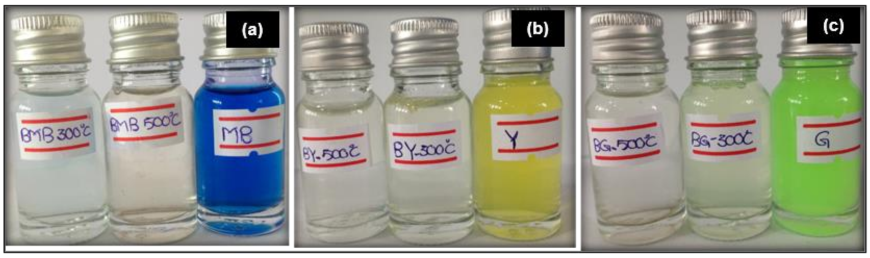

Figure 11. Initial and residual (a) MB, (b) yellow and (c) green dye wastewater solutions

(B-300 and B-500 adsorbents were used for the adsorption process)

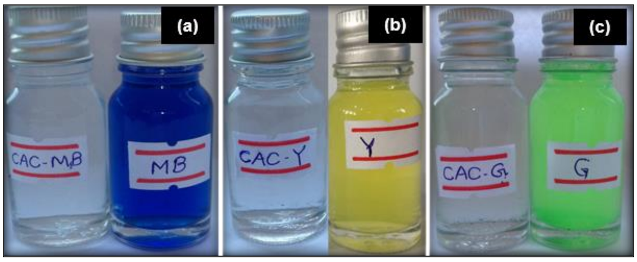

Figure 12. Initial and residual (a) MB, (b) yellow and (c) green dye wastewater solutions

(CAC adsorbent was used for the adsorption process)

UV-vis analysis was conducted to study the MB, yellow and green dye wastewater removal percentages of B-300, B-500 and CAC adsorbents. As shown in Figure 13, MB, yellow and green dye removal percentages of B-500 adsorbent (about 97%, 95% and 94%) and CAC adsorbent (about 100%, 99% and 99%) were higher when compared to those of B-300 adsorbent (about 67%, 82% and 61%). The results proved that removal efficiency of B-500 adsorbent was greater than that of B-300 adsorbent due to the larger longitudinal porous structure.

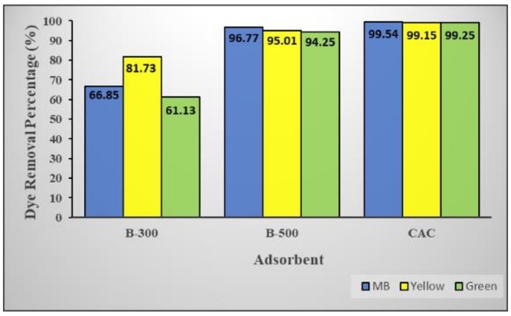

Figure 13. Methylene blue, yellow and green dye removal percentages of B-300, B-500 and CAC adsorbents

From economy and environmental point of view, the reuse of adsorbent is important. Therefore, the regeneration of wastewater loaded B-500 adsorbents was carried out. The regenerated B-500 adsorbent (denoted as 2B) was conducted for MB adsorption to test the reusability of 2B. UV-vis spectra were detected the wavelength range between 500 nm and 750 nm. As reported, the UV-vis spectrum of the initial MB solution exhibited a characteristic absorption peak at 664 nm (Idrees Khan et al., 2022). Figure 14(a-b) shows the photographic illustration and UV-vis spectra of initial and residual MB solution. The absorbance values obtained from the highest peaks in UV-vis spectra of initial and residual MB solution were 2.75 and 0.25, respectively. The calculated removal percentage about 91% showed that 2B adsorbent had a strong potential to adsorb significant amount of MB molecules, implying the reusability of the prepared adsorbent.

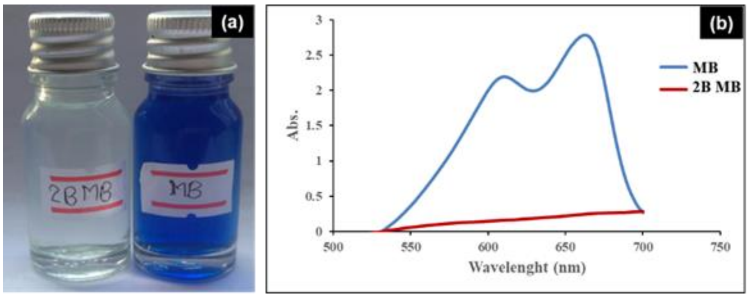

Figure 14. (a) Photographic illustration and (b) UV-vis spectra of initial and residual MB solution

Conclusion

In this study, disposable bamboo chopsticks waste, a widespread and easily available raw material was used to convert ecofriendly adsorbents at 300 °C and 500 °C, respectively. The obtained adsorbents and commercial activated carbon were analyzed by XRD, SEM, EDXRF and UV-vis. The EDXRF and UV-vis results showed that B-500 adsorbent possessed high removal percentages for Laboratory wastewater (about 77 % of Cu and 97 % of Zn) as well as for methylene blue, MB (about 97 %), for screen printing dye wastewater (about 100% of Ti, 94 % of green and 95 % of yellow colours). These removal percentages of B-500 adsorbent were comparable with the removal percentages of commercial activated carbon (about 82% of Cu, 98% of Zn, 100% of MB, 100% of Ti, 99% of green and 99% of yellow colours). The reusability study of the B-500 adsorbent showed higher removal percentage about 91%. The results indicated that the conversion of bamboo waste as a local adsorbent might be an alternative choice for the adsorption process to remove the contaminants from Laboratory and dye wastewater.

Acknowledgements

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