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Adsorption efficiency of activated carbon prepared from Palm kernel shells in removal of dyes used in textile industry

Sabaridasan Arumugam [1], Harinath Vinu [2], Soranam Ramaiah [2, *]

[1] PG & Research Department of Biotechnology, Sri Vinayaga College of Arts and Science, Ulundurpet, Kallakurichi - 606107, Tamil Nadu, India

[2] Department of Environmental Sciences, Sri Paramakalyani Centre of Excellence in Environmental Sciences, (Manonmaniam Sundaranar University), Alwarkurichi-627412, Tamil Nadu, India

*Corresponding author Email: soranamr@gmail.com

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Abstract: Palm shell has been utilized to create an effective activated carbon adsorbent in this investigation. The adsorbent is being used to remove direct dyes from dyeing waste in textiles. Thermo Gravimetric Analysis, Scanning Electron Microscopy, Fourier Transform Infrared Spectroscopy and Atomic Absorption Spectroscopy were used to characterize the synthesized carbon. The particles are very porous and irregular in shape, based on the SEM analysis. This particle shape is effective at removing dye and toxic metals. TGA analysis has been shown to be highly stable under varied temperature circumstances. The FTIR data revealed the existence of functional groups that are responsible for dye and toxic metal elimination. The AAS analysis showed that dye degrading ability rises at a time interval and the adsorption ability of activated carbon. These findings suggest that Palm shell carbon could be used as a low cost alternative to commercial activated carbon in the removal of dyes from wastewater.

Keywords: Activated carbon, Adsorption, TGA, SEM, FTIR

1. Introduction

Industrial used water is one of the greatest contributions to aquatic contamination. The aquatic contaminants, toxic metals have gained increasing relevance on account of their persistence, biomagnification and toxicity [1, 2]. Among the toxic metals, such as cadmium (Cd), chromium (Cr) and lead ions (Pb), which are frequently found in the industrial waste of manufacturers of batteries, metallurgy, explosives, and other colourants, are among the wastes that harm the environment and cause serious water pollution today [3]. However, as a result of industrialization, water pollution by toxic metals has become a widespread threat [4], and this, combined with the use of pesticides, fungicides, and the production of paints, paper, and welding operations, can damage the environment [5]. As a consequence, the swift implementation of rules and regulations pertaining to the health of the natural environment as well as the health of the ecosystem's dependent must be considered [6]. Therefore, natural organic components, taste, odour, and manufactured organic substances are all removed with activated carbon [7]. The activated carbon generated from palm kernel shell is deployed in the toxic metal assessment to evaluate. Palm kernel shells have indeed been utilized generally in the manufacture of activated carbon due to their high carbon content (50.01%) and low organic content, as well as their availability in Southeast Asia [8, 9]. Nonetheless, the palm kernel shell has huge high applications are desired, and one of them is activated carbon, because of its extensive applicability in water treatment, pharmaceuticals, desalination, and gas storage due to its porosity [10, 11]. In this investigation, we used the palm kernel shell as an adsorbent for the treatment of toxic metal polluted water from the textile industrial dye, and the impact of activated carbon was assessed by physical activation of the solution, metal ion concentration, adsorbent dosage, and contact duration. The resulting palm kernel shell activated carbon was then evaluated for its capacity to absorb hazardous metals from industrial effluent as a model for the wastewater filtering process.

2. Materials and Methods

2.1. Carbonization of Palm Kernel Shell

The Palm Kernel Shell was obtained from Agrowaste products piled in Alwarkurichi's farmyard pit (8.7815° N, 77.3942° E). Palm Kernel shells were washed to remove fibre and dirt. Waste palm kernel shell were chopped into small pieces (range 0.370 - 0.840 mm), cleaned, and dried. They were carbonised differentially in a pyrolytic reactor at 400 - 500°C for roughly 2h before being allowed to cool to ambient temperature. The burned debris was sieved after being crushed with a mortar and pistol.

2.2. Chemical activation of carbonised Palm Kernel Shell

The carbonised palm kernel was weighed and placed as well as transferred into separate beakers containing known amounts of dilute hydrochloric acid, phosphoric acid, trioxonitrate (v) acid, tetraoxosulphate (vi) acid, zinc-chloride, and sodium hydroxide. The components of the beakers were vigorously combined until each formed a paste. The sample pastes were then transferred to crucibles, which were set in a Muffle furnace and heated at 800°C for 2 hours. The activated samples were again allowed to cool at room temperature before being rinsed with distilled water to a pH of 6 -7 and dried in a 105°C oven for 3h. The finished products are sieved to the same particle size and stored in airtight polyethylene bags until used. It should be noted that different concentrations of granular PKSAC were minimized with size (0.420 mm) based activated carbon/charcoal and were afterwards employed as toxic metal adsorbents in industrial waste water.

2.3. Activated Carbon Characterization

The waste palm kernel shell utilised in this study had been characterised (moisture content, depolymerization, and acetyl and amine groups) using Thermogravimetric (TGA) analysis, as reported by Acosta-Ferreira et al. [12]. The morphological examination of the synthesised AC particles was done to evaluate particle size, shape, and form using SEM analysis [13].

2.4. Toxic metal adsorption on activated carbon in aqueous solution

For toxic metal adsorption, the textile industrial dye was treated with physically activated carbon. Lead (Pb), Chromium (Cr), and Cadmium (Cd) levels were determined in the samples. As concentration experiments, different dose rates of activated carbon are introduced to the industrial dye. The produced activated carbon was utilised to remove the colour from the effluent. In five test tunes, 10 ml of dye solution was collected and 0.05g, 0.1g, 0.15g, 0.2g, and 0.25g of adsorbent material were obtained was analyzed using Fourier transform infrared spectrometer [14]. The initial absorbance of the dye solution was measured using a UV-Vis spectrophotometer at 600 nm prior to addition. After adding the adsorbent material, readings were collected every 10 minutes for 1h. After one hour, readings were collected after 2h, 3h, 4h, and 24h.

To explore the impact of dye concentration, the following five samples were prepared: 1ml dye + 9ml water for sample 1, 3ml dye + 7ml water for sample 2, 5ml dye + 5ml water for sample 3, 7ml dye + 3ml water for sample 4, and 9ml dye + 1ml water for sample 5. The absorbance was measured at 600 nm before and after the addition of 0.1g of adsorbent material to each tube. After adding the adsorbent material, readings were collected every 10 minutes for 1h. After 1h, readings were obtained after 2h, 3h, 4h, and 24h. The dye solution containing the toxic metal was diluted with water in a 1:1 ratio and AAS analysis was performed [15].

3. Results and Discussion

The palm kernel shell has 44.74 %, 1.12% ash content, 0.07 % total N content, and up to 5.42 % moisture content. Based on its carbon content, the palm kernel shell can be utilised as a precursor of activated carbon. The selection of raw materials to make carbon porous is influenced by high carbon content, high density, and levels of substances evaporated. TGA was used to examine the thermal stability of activated carbon content. The TGA analysis of activated carbon indicated a sufficient decrease in moisture content in the sample, which was seen at 114 °C. The second loss was detected at around 182 °C as a result of functional group disintegration, depolymerization, and decomposition of palm shelled acetyl and amine groups. As shown in the (Figure.1), the nanoparticles are stable up to 500°C. After reaching 500°C, no significant loss was observed, and it shows that the nanocomposite samples are thermally stable.

At higher temperatures, the sample developed porosity, which was validated by SEM analysis. The porosity and surface area of activated carbon are significant factors in its adsorption characteristics. SEM examinations of these materials revealed an uneven distribution with a diverse surface shape (Figure.2A & Figure.2B). These analyses demonstrated the presence of porosity and cavities in all activated carbon samples. Activated carbon has been exhibit high porosity and irregularity. The increase in porosity and cavities for these materials results in an increase in adsorption capacity, allowing these materials to adsorb high concentrations of adsorbates and, as a result, it has high efficiency as adsorbent materials that can be used in a variety of environmental and industrial applications.

Based on FTIR spectra, the surface functional group of palm kernel shell activated carbon revealed three absorption bands at 2100, 1439, and 980 cm^{-1} (Table. 1). The narrow band at 2100 cm^{-1} was indeed attributed to the -CC- stretching of alkynes, the peak at 1439 cm^{-1} corresponds to aliphatic and aromatic -CH bending, and the band at 980 cm^{-1} has been related to trans =C–H out-of-plane (oop) bending of alkenes (Figure.3).

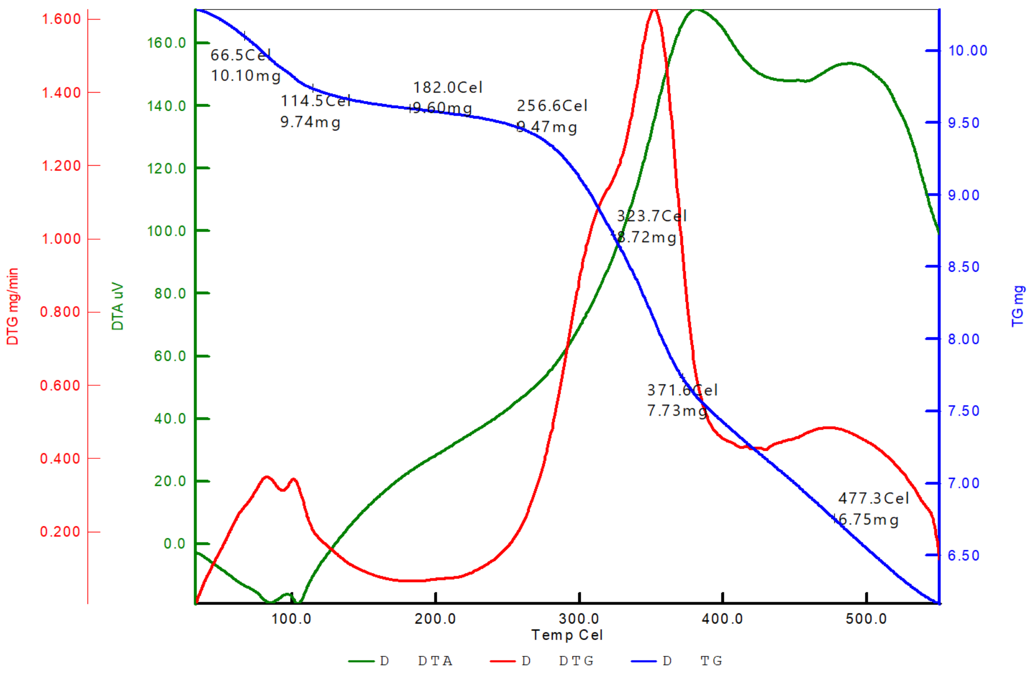

Figure 1. TG/DTA Thermogravimetric analysis of Palm shell powder.

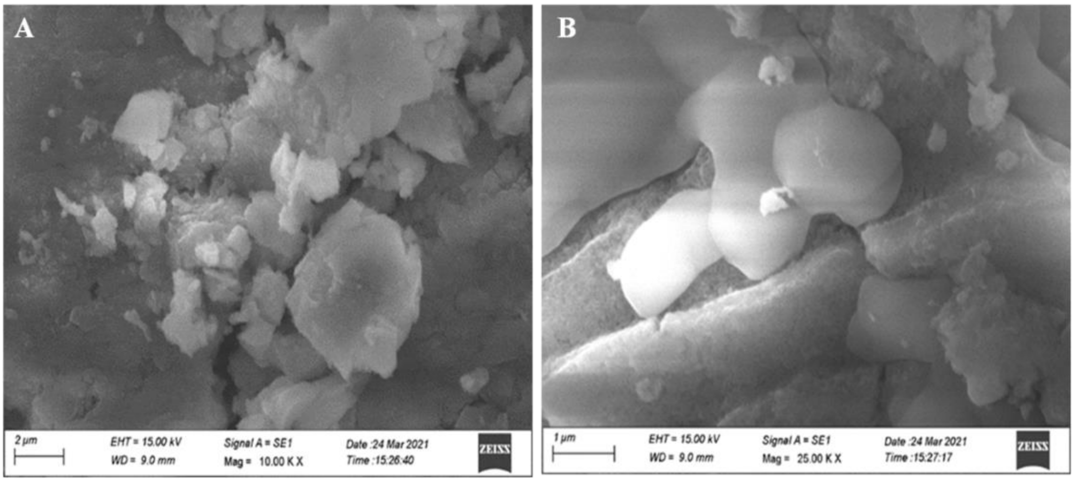

Figure 2. SEM micrograph of Palm shell powder (A-x1000; B-x5000).

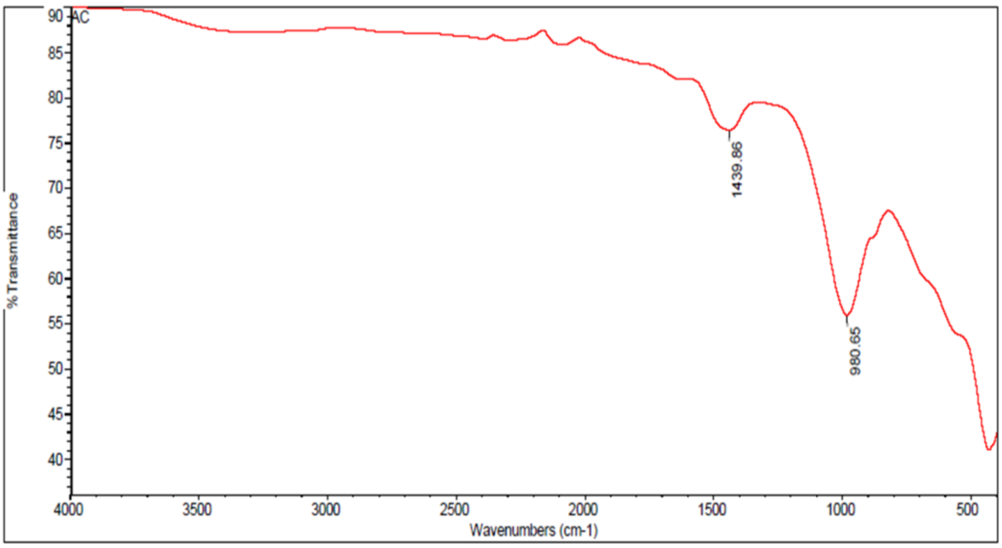

Figure 3. FTIR spectrum of activated carbon from palm shell powder.

Table 1. Concentration rates of Toxic metals in palm shell activated carbon.

Toxic metals	Pre-treatment (ppm)	Post-treatment (ppm)	Wavelength (nm)	Slit Width (nm)
Lead (Pb)	0.3379	0.2681	283.3	0.7
Cadmium (Cd)	0.124	0.075	228.8	0.7
Chromium (Cr)	0.1818	0.0276	357.9	0.7

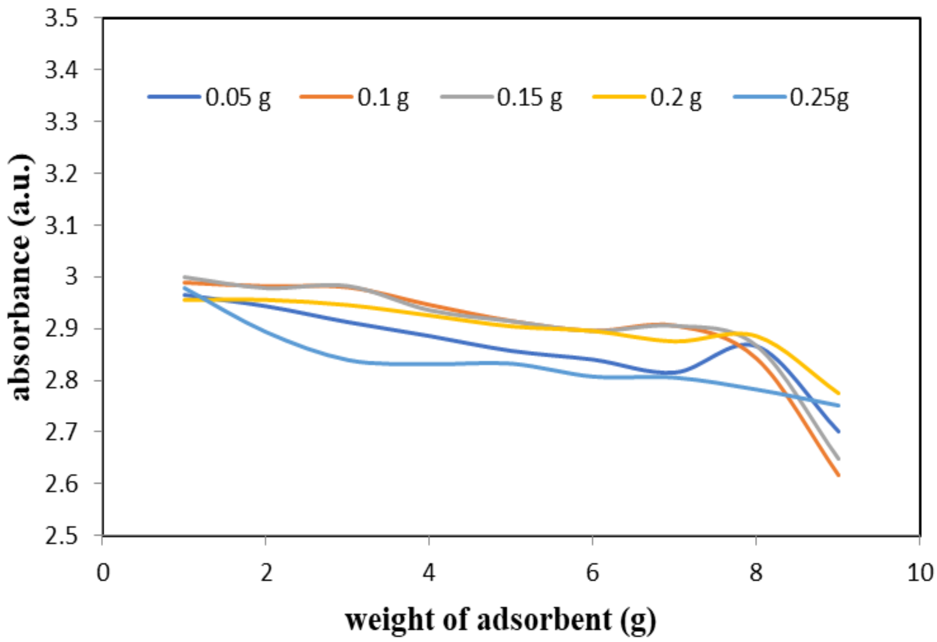

Figure 4. Adsorption dosage of the industrial dye treated with palm shell activated carbon

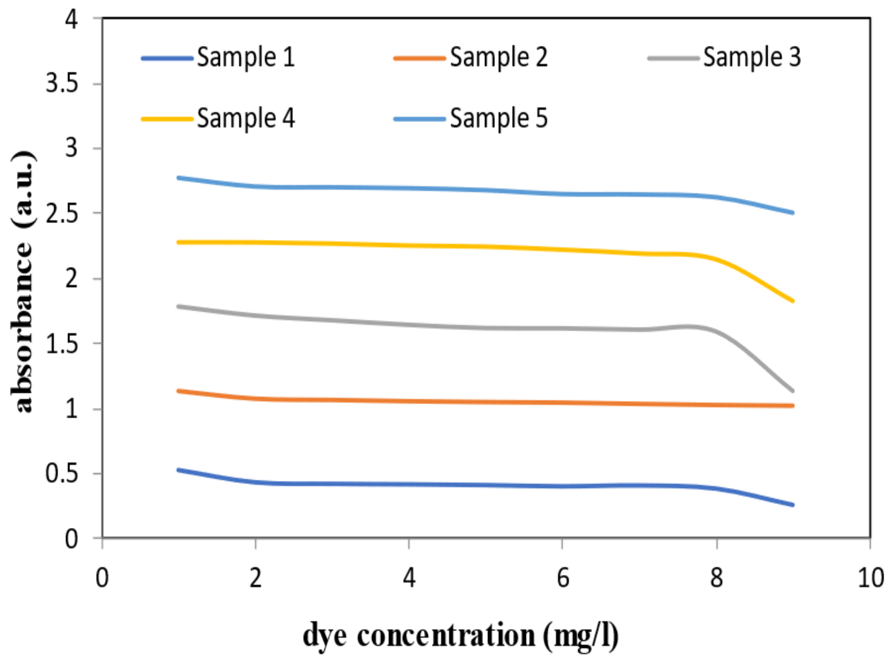

Figure 5. Adsorbent at different dye concentration using palm shell activated carbon

The concentrations of lead, cadmium, and chromium in the dye solution were determined by AAS to be 0.3379, 0.124, and 0.181 ppm, respectively. The particles were treated with activated carbon for 24 hours before being filtered and analysed by AAS. The concentrations of lead, cadmium, and chromium in the activated carbon treated sample were 0.2681, 0.075, and 0.0276 ppm, respectively. This showed that the toxic metals in the dye solution had been eliminated by the activated carbon (Table. 1).

4. Discussion

In recent decades, dye contaminants have become a major hazard to the worldwide, spreading severe illnesses mostly as a result of dye discharges [16]. The discharge of enormous amounts of dye-bearing industrial effluents into waterbodies has long been recognised as a major cause of pollution [17]. There have been several methods available for pollutant removal, which may be generally classified into three groups, namely, physical (including adsorption), chemical, and biological processes. These procedures have been utilised to remove hazardous contaminated industrial effluents [18]. According to the present investigation, physical activation of the solution, metal ion concentration, adsorbent dosage, and contact duration were used to assess the efficacy of the palm kernel shell as an adsorbent for the treatment of toxic metal polluted water from textile industrial dye. The adsorption capacity of activated carbon is related to its internal surface area, pore volume, pore size distribution, and, most importantly, surface characteristics. More organic adsorption has been reported in pores that are almost strong enough to accommodate the adsorbate molecule [19].

A number of researches have been conducted in order to convert carbonaceous and other wastes into activated carbons or other adsorbing materials. Vehicle tyres, plastic trash, and textiles are examples of carbon-containing waste [20–23]. Adsorption by activated carbon provides a higher capability for dye removal without the emergence of contaminants. Nevertheless, these procedures are only successful and cost-efficient when the concentration of the substance is quite significant [24]. Activated carbon, on the other hand, is very efficient at removing pollutants from textile colours using adsorption technology. The issue of recirculating adsorbent surfaces must be prioritised if they have a high manufacturing cost, which impacts their economic viability, necessitating a continual investigation for low-cost sources of activated carbon [25]. Furthermore, at high temperatures, the lignocellulosic components of OPW begin to decompose, resulting in the generation of condensable hydrocarbons [26].

Thermal-chemical activation resulted in a larger and more complex pore structure and increased surface area [27]. It further means that when the temperature rises, so does the quantity of adsorption. This might be owing to a greater number of available adsorption sites or enhanced mobility of dye molecules and the probability of reaching the adsorption surface at higher temperatures [28]. However, since the adsorption process emits heat, this indicates that the adsorption capacity diminishes with rising temperature. In this case, increasing the temperature weakens the binding forces between the adsorbent and the adsorbate [29].

The prevalence of hydrogen bonded host guest interactions was indicated by the envelope at 3339 cm^{-1} [30]. Because of the direct relationship between the amount of concentration and the amount available for adsorption on the adsorption surface, which decreases as the adsorption sites reach saturation and the number available for adsorption decreases, maximum absorbance has a significant impact on dye removal efficiency [31]. The adsorption efficiency is significant in deciding the adsorbent's capability to absorb a specific amount of adsorbent under specific laboratory conditions in which the desirable quantity of the adsorbent surface is assessed because once the maximum appropriate amount of the adsorbent is adsorbed at the time of equilibration [32]. Indeed, as the amount of adsorbent surface increases, so does the amount of dye adsorbed, owing to a rise in the number of vacant adsorption sites on the adsorption surface, and therefore the rate of removal efficiency from the solution [33]. We reveal information on the dye absorption capacity by exploring the influence of the amount of adsorbent, which helps to evaluate the effectiveness of the adsorbent materials, which is essential from an environmental perspective. According to the study, raising the adsorbent dose provides a greater surface area, which allows higher binding sites for target pollutant adsorption on industrial waste water.

5. Conclusion

The physical activation approach was used to successfully create palm shell-based activated carbon. The results revealed that the highest capacity of activated carbon is influenced by pore size, surface area, and micropore volume. According to the SEM observations, the particles are extremely porous and irregular in form. This particle shape is effective in removing dyes and toxic metals. TGA was used to assess thermal stability, and the sample was extremely stable under a range of different temperature conditions. The presence of functional groups responsible for dye and toxic metal removal was revealed by the FTIR findings. Despite this, the AAS analysis concludes that activated carbon derived from palm shell kernel might be a promising adsorbent for removing lead (Pb), cadmium (Cd), and chromium (Cr) from textile industry effluent.

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Conflict of interest

The Authors have no conflicts of interest to declare that they are relevant to the content of this article.

Author Contribution Statement

Sabaridasan Arumugam: Conceptualization; methodology; investigation; formal analysis; visualization; writing - review and editing; and paper administration. **Harinath Vinu**: Investigation; formal analysis; writing - review and editing. **Soranam Ramaiah**: Conceptualization; visualization; drafting and editing the manuscript. All the authors read and approved the final version of the manuscript.

Does the Article Screened for Similarity?

Yes.

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