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Treatability Study of Phenol by Using *Dracaena sanderiana* Based Activated Carbon from Synthetic Aqueous Solution

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Abstract. Phenols in industrial wastewater are a great threat to human and aquatic life. For removing such a hazardous pollutant, adsorption is one of the efficient techniques. The current study highlights the preparation of *Dracaena sanderiana* based activated carbon and its characterization, physical and chemical activation and application. At the lab scale variable doses of activated carbon (AC) and its modified forms such as acid treated and furnace treated were applied for the removal of phenol from synthetic solution. The highest removal efficiency was observed at a dose of 0.2 g, 120 rpm and neutral pH (7) with a contact time of 1 h for acid treated AC. For optimization of this process, the addition of anthracite coal to acid treated AC resulted in the enhancement of its adsorbability. The FT-IR spectrum has provided ample information regarding functional groups responsible for the adsorbent after treatment. This study concludes that the adsorption of phenol through AC in combination with anthracite coal is an effective treatment option.

Keywords: phenol removal, adsorption, activated carbon, *Dracaena sanderiana*, chemical activation

Introduction

Phenol and its derivatives are produced in petroleum, petrochemical, coal conversion and other phenol compounds generating industries (Liadi *et al*., 2021; Asmaly *et al*., 2016). These are known as the most common pollutants in wastewater with toxic and carcinogenic effects on the living organisms and ecosystem, even at the lowest concentration (Zhang *et al*., 2021; Wang *et al*., 2018; Hamdaoui *et al*., 2007). The recommended limit by U.S. Environmental Protection Agency Regulations for phenols in wastewater is 1mg/L (Nirmala *et al*., 2021; El-Ashtoukhy *et al*., 2013).

There is a variety of different techniques used for the removal of phenol for example, solvent extraction, chemical coagulation, membrane separation, electro-chemical oxidation, photocatalytic degradation and adsorption (Zhang *et al.,* 2021; Ingole *et al*., 2015). Among all these methods, adsorption is the most efficient, economical, conservative and widely used treatment for wastewater (Liadi *et al*., 2021; Nirmala *et al*., 2021). According to US Environmental Protection Agency Regulations (USEPAR) adsorptive treatment is the best technology for waste water treatment (Suresh *et al*., 2021).

Mostly used natural adsorbents are beet pulp (Dursun *et al*., 2005), rubber seed coat, fly ash, red mud, clay, natural zeolites and activated coconut shells (Din *et al*., 2009). Natural adsorbents are usually used in their original form or by preparing activated carbon by these agro solid-based adsorbents (Srihari and Das, 2008).

Activated carbon is considered the best adsorbent and is used widely because of its characteristically high adsorption capacity, developed pore structure, chemical stability and higher surface area (Gokce *et al*., 2021; Zhang *et al*., 2021; Cool *et al*., 2002).

Its properties highly depend on its precursor, pore structure, activating agent and production methods. Various starting materials can be used to produce activated carbon that includes biomass, agricultural or industrial wastes and carbonaceous substances based on fossils (Gokce *et al*., 2021; Heidarinejad *et al*., 2020). The most commonly utilized materials based on fossil

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fuels are coals, petroleum coke and tar. Coals are comparatively carbon-rich, low-cost and abundant. There are mainly two groups of coal i.e low rank sub-bituminous coal and lignite and high rank bituminous and anthracite coal.

Activated carbon can be produced by two methods i.e., physical and chemical activation.

In physical activation, high temperatures *i.e*., 750 to 900 ◦C or an oxidizing gas is used for activation of starting material and in chemical activation, any chemical activating agent like NaOH, KOH, K_2CO_3, $ZnCl_2$, H_3PO_4 or H_2SO_4 is used to impregnate the material and then infused precursor is activated or carbonized at the specific temperature (Gokce *et al*., 2021; Shokry *et al*., 2019).

The carbon structure of AC contains major functional groups like carbonyl, carboxyl, phenol, quinone and lactone which are the reason for contaminants' adsorption. Hydrogen, nitrogen, oxygen and sulfur are also found in the structure of AC in the form of chemical atoms or functional groups. The distinctive properties of adsorption depend on the functional groups, which are mainly derived from precursors, thermal purification and activation processes (Heidarinejad *et al*., 2020).

The main aim of the study is to evaluate the adsorption efficacy of phenol on AC prepared from low-cost bio-adsorbent from biomass i.e. leaves and stalks of *D. sanderiana*, analysis of the adsorbent characteristics based on proximate and FTIR analysis and optimization of phenol adsorption by using different dose rates of acid treated activated carbon and mixture of coal and acid treated activated carbon.

Materials and Methods

Chemical and standard solutions of phenol. The chemicals used in the study were of analytical grade. The reagents and solutions used for the detection ofphenol were 4-amino antipyrine, ammonium hydroxide solution, phosphate buffer solution and potassium ferricyanide solution. All of these solutions were prepared in CEPS, PCSIR lab by using the direct photometric method (Standard Methods Committee, 2000). Standard phenol (99.99%) was purchased from HACH Company. The standard stock solutions of phenol were prepared at concentrations of 100mg/L (Silva *et al*., 2006). Standard solutions with lower concentrations of phenol like 0.2, 0.4, 0.6, 0.8 and 1 mg/L and higher concentrations such as 5, 10, 15 and 20mg/L were prepared.

Raw material for preparing adsorbent. The plant *D. sanderiana* Sander ex Mast. was used for preparing powdered activated carbon. It was purchased from Nishat Nursery in the vicinity of Kalma chowk and the plants were identified from Government College University, Lahore.

Adsorbent. For preparing adsorbent, stalks and leaves of dried *D. sanderiana* were separated. The collecte draw materials were washed 5-6 times with the help of tap water for impurities removal. Then the stalks and leaves were dried at 108°C in a hot air oven before cutting and grinding them into a powdered form using a pestle and mortar (Evbuomwan *et al*., 2013).

Preparation of activated carbon. Two main processes were used for the preparation of activated carbon (AC), as follows:

Physical activation. Ash of ground leaves and stalks, 5 and 10g respectively were prepared by placing raw material in a carbolite furnace at 550°C for 2 h and then removed from the furnace and kept in a desiccator for 10-15 min (Mohtashami *et al*., 2018). Obtained ash was used for 1st batch experiment as furnace treated AC prepared by physical activation method.

Chemical activation. For chemical activation, the raw material was first impregnated with an activating agent like H_2SO_4 and heated in an electrical furnace maintaining the oven temperature range of 100-150 °C. This chemically activated carbon was cooled to room temperature and washed many times with deionized water for the removal of acid content in it. Finally,this activated sample was dried in the oven at 80 °C to remove moisture (Nurulain, 2007).

Types of activated carbon. Activated carbon was used in three different forms.

> The AC prepared in the furnace at 550 °C for 2 h (Mohtashami *et al*., 2018); acid (H_2SO_4) treated activated carbon; mixture of acid treated activated carbon and anthracite coal.

Characterization of the adsorbents. *FTIR Analysis*. For the identification of functional groups and chemical bonding of prepared activated carbon,TENSOR 27 was used for FTIR analysis. A spectrum was obtained that shows different bonding peaks where the adsorption maximizes.

Proximate analysis. American society for testing and materials (ASTM) standards methods were used for

proximate analysis (inherent moisture, ash, volatile matter and fixed carbon) of raw ground material of *D. sanderiana* and activated carbon prepared by *D. sanderiana.*

Determination of inherent moisture. The inherent moisture of raw material was calculated by using a crucible. Firstly, the crucible and a 1 g sample were weighed in the same crucible but its weight was tarred and only the weight of the sample was noted.The crucible was then placed in an air-drying oven drying oven 60 L for 2 h at 103±2 °C. After 2 h it was removed from the oven and placed in a desiccator for 10 to 15 min. The weight of the crucible was noted and then using values of the crucible before placing them in the oven and after removal from the oven,the inherent moisture of the sample was calculated as per standard.

Formula for (%) moisture:

$$M = \frac{S\text{-}U}{S\text{-}T} \times 100$$

where:

M= moisture content; T= crucible weight; S=crucible and sample weight before heating; U=crucible and sample weight after heating

Analysis of ash. For analysis of ash, a crucible was distincted with identification by a marker of porcelain and weighed by weighing balance (CYBER SCAN 500). This was the weight of the crucible without a sample. 1.0 g of raw material weighed into the tared crucible. It was placed in the thermolyne 1500 Furnace at 575±25°C for 3 h. After removing the crucible from the thermolyne furnace, it was placed in a desiccator to cool down at room temperature and re-weighed after 3 h. Then % ash in the sample was calculated.

Formula of ash %:

$$A\ (\%) = \frac{G-C}{F-C} \times 100$$

where:

A= ash content; C= weight of the crucible; G= weight of crucible and sample after heating; F= weight of crucible and sample before heating.

Volatile matter. To determine the volatile matter,the empty crucible and its lid were weighed first. The covered crucible was placed with the sample in a furnace chamber, which was maintained at a temperature of 950±20 °C. After heating for 7 min, the crucible was removed from the furnace and without disturbing the cover; cooled in a desiccator. The crucible was weighed with the sample as soon as cold to the nearest 0.1 mg and recorded as the final weight. (ASTM E 897 – 88).

Formula of volatile matter %

$$\left(= \frac{H-F}{F-G} \times 100 \right) - M$$

where:

H= weight of sample plus crucible and lid; F= weight of crucible and lid; G= weigh of the sample before heating, g; M= moisture (%)

Fixed carbon. The values of fixed carbon in samples were calculated by using values of inherent moisture, ash content and volatile matter.

Fixed carbon = 100- (ash %+ volatile matter % +moisture)

Analytical measurement of phenol. Analytical measurement of phenol was conducted by constructing the calibration curve of known concentrations of phenol standard. The λ max of phenol is 500 nm as mentioned in standard method for phenol determination in water and wastewater samples (Rice *et al*., 2012). A spectrophotometer (SPECORD 200, Analytic Jena) was used for the determination of absorbance.

Adsorption test. For adsorption experiments,an orbital shaker used at 120 rpm in conical flasks of 250 mL containing 100 mL of each phenol solution and a blank having 100 mL of distilled water instead of phenol solution. Experiments were performed at room temperature (25°C). After an hour of shaking, these solutions were treated with reagents *i.e*., 2.5 mL ammonium hydroxide, 1 mL buffer solution, 1 mL potassium ferricyanide and 1 mL 4-amino antipyrine, within 15min samples were placed in UV visible double beam at the wavelength of 500 nm for readings of phenol. The readings of the original sample of phenol were noted and a calibration curve was constructed.

Phenol solutions. Phenol solutions of different concentrations ranging from 0.2 to 20mg/L were prepared by taking 2, 4, 6, 8 and 10mL of phenol solution from 100 mg/L stock solution of phenol. Phenol solutions

of 5, 10, 15 and 20 mg/L standard solutions were also prepared by taking 5, 10, 15 and 20 mL of phenol solutions from 200 mg/L stock solution of phenol. These two types of phenol stock solutions were used one is of the minimum concentration of phenol (100 ml/L) and the second is of a higher concentration of phenol (200 mg/L). The reason was to detect the adsorbance ability of different adsorbents on lower and higher concentrations of phenol and because the increase in phenol concentration is an impact that increases the capacity of the fixed amount of adsorbent.

Calibration curve. Phenol solutions with different concentrations were prepared and calibration curves were constructed. The calibration curve in Fig. 1 shows the standard solutions of phenol having different concentrations such as 0.2, 0.4, 0.6, 0.8 and 1 mg/L. Fig. 2 shows the calibration curve of the standard solutions which have more concentration of phenol *i.e*., 5, 10, 15 and 20 mg/L.

Experimental design. Experimental solutions were prepared by mixing different doses ranging from 0.2 to 1.6 mg/L of different types of AC in standard solutions of phenols having 2 to 20 mL concentrations of phenol solutions. After an hour the mixing was stopped and the mixed solution was filtered. The Millipore Whatman (0.45μ m) filter paper was used to filter the sample after treatment.AC used in treatment was removed and dried at 40 °C in drying oven for an hour and used for FTIR. Filtered samples were treated with reagents.

The phenol adsorbtion was calculated by using the following equation, (Ma *et al*., 2013)

$$qe = (Ci - Cf)V/m$$

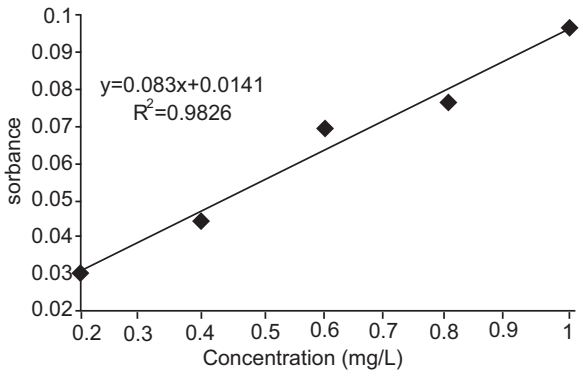

Fig. 1. Calibration curve for phenol solutions ranging from 0.2 to 1 mg/L.

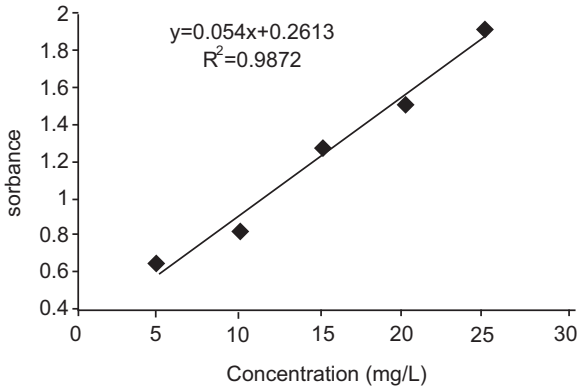

Fig. 2. Calibration curve for phenol solutions ranging from 5 to 20 mg/L.

where:

qe is the amount of adsorbed phenol at equilibrium (μg/mg); Ci and Cf are the initial and final concentrations of phenol; V is the solution volume m is the mass of the adsorbent(mg) (Ma *et al*., 2013).

The removal percentage of phenol was determined by the following equation (Nedjai *et al.*, 2021).

$$(\%)R = \frac{Ci - Cf}{Ci} \times 100$$

where:

R is the removal efficiency of adsorbent (%)

Results and Discussion

In this study, the elimination of phenol in synthetic standard solution was performed by adsorption. The adsorbent used for this purpose was *D. sanderiana* based activated carbon. The characterization of adsorbent was performed by using different characterization techniques like proximate analysis and FT-IR analysis.

Proximate analysis. The moisture content,the fixed carbon, ash contents and volatile matter of ground raw material of plant as well as acid treated activated carbon which calculated by using ASTM methods. The volatile matter and ash content of acid treated AC was decreased but the inherent moisture and fixed carbon were increased in acid treated activated carbon as shown in Table 1.

Study of various forms of activated carbon and their effects on adsorption of phenol. The results in

Table 2 show the effect of furnace treated activated carbon on adsorption**.** 100 mL of 0.2 to 1 mg/L phenol synthetic solutions were treated with 0.2 g of furnace treated AC. At lower concentration *i.e*., 0.2 - 1.0 mg/L adsorbed phenol was 0.01, 0.0105, 0.0325, 0.008 and 0.038 mg/L respectively, whereas the removal efficiency of adsorbent was 10, 5.25, 10.83, 2 and 7.6% respectively. Maximum phenol was adsorbed at 0.6 mg/L and lower at 0.8 mg/L as shown in Fig. 3.

The results in Table 3 show the effect of 0.2 g of acid treated activated carbon on adsorption by using different concentrations of phenol solutions. The higher removal efficiency of adsorbent was observed in 0.6 mg/L phenol solution which was 98.33% while the lower was in 0.2 mg/L phenol solution i.e., 69.5% as shown in Fig. 4a. The increased removal efficiency of adsorbent represents the increase in carbon yield, development of better pore structure and presence of more adsorbent sites than furnace treated activated carbon developed high adsorption capacity as described by (Nirmala *et al*., 2021; Eletta *et al*., 2020; Pak *et al*., 2016). After successful removal of phenol in lower concentration phenol solutions, higher concentration phenol solutions were prepared because the increase in phenol concentration is an impact that increases the capacity of the fixed amount of adsorbent. Furthermore, an increase in the initial concentration of phenol causes adsorbate-adsorbent interaction to increase more. A further increase in the initial concentration of phenol causes the adsorbent to reach saturation and thus the capacity of the adsorbent is determined (Srivastava *et al*., 2006). The 0.2 g/100 mL dose of acid treated activated carbon was used for treating phenol solutions ranging from 5 mg/L to 20 mg/L. In this experiment,the removal efficiency of adsorbent was decreased as shown in Fig. 4b because the phenol concentration in solutions was so high as compared to the adsorbent dose that they filled all the adsorption sites of activated carbon and decreased the adsorption capacity of acid treated activated carbon. Also described by (Sahu *et al*., 2017) that the percentage adsorption decreased with an increase in the concentration of the pollutant.

Table 4 represents the effect of two types of dosage, one acid treated activated carbon and the other one is

Table 1. Proximate analysis of raw grinded material of *D. sanderiana* and activated carbon prepared by *D. sanderiana*

Proximate analysis (%)	Raw ground material (%)	Activated carbon (%)
Moisture content	6.62	8.66
Volatile matter	21.37	13.35
Ash content	14.82	12.99
Fixed carbon	57.73	65

Table 2. Effect of 0.2 g furnace treated AC on adsorption

Adsorbent dose (g)	Standard solution (mg/L)	Adsorbed phenol Qe	Removal efficiency (%)
0.2 g/100 mL	0.2	0.01	10%
	0.4	0.0105	5.25%
	0.6	0.0325	10.83%
	0.8	0.008	2%
	01	0.038	7.6%

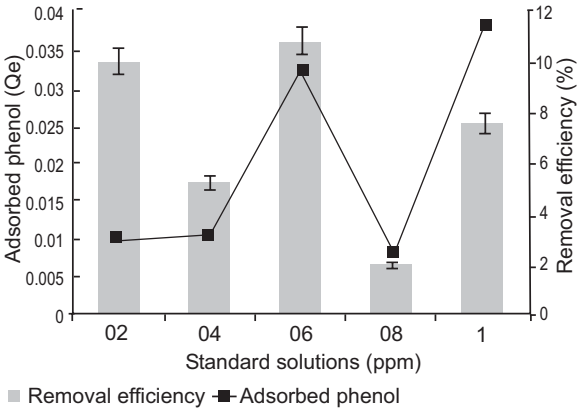

Fig. 3. Effect of 0.2 g of furnace treated activated carbon on adsorption of phenol.

Table 3. Effects of 0.2g acid treated AC on adsorption

Adsorbent / dose (g)	Standard solutions (mg/L)	Adsorbed phenol (Qe)	Removal efficiency (%)
0.2 g/100 mL	0.2	0.0695	69.5
	0.4	0.1945	97.25
	0.6	0.295	98.33
	0.8	0.365	91.25
	1.0	0.473	94.01
Treatment of higher concentration of phenol synthetic solutions			
	5	0.545	21.8
	10	1.0655	21.31
	15	1.4765	16.69
	20	2.025	20.25

the mixture of acid treated activated carbon and anthracite coal. In the first treatment, 0.8 g of acid treated activated carbon was used and the results are represented in Fig. 5a. These results showed more removal efficiency of the adsorbent in 10 mg/L standard solution of phenol and lesser in 15 mg/L standard solutions of phenol. The increased removal of phenol was due to the increased adsorbent surface area and the availability of more vacant surfaced sites. (Ren *et al*., 2016) illustrates the phenomenon of such adsorption by stating that the increase in uptake is due to the phenol availability in solution for adsorption. It is also noted that the higher initial adsorbate concentration provided a higher driving force to overcome all mass transfer resistances of the ions from the aqueous to the solid phase resulting in a higher probability of collision between ions and the active sites.

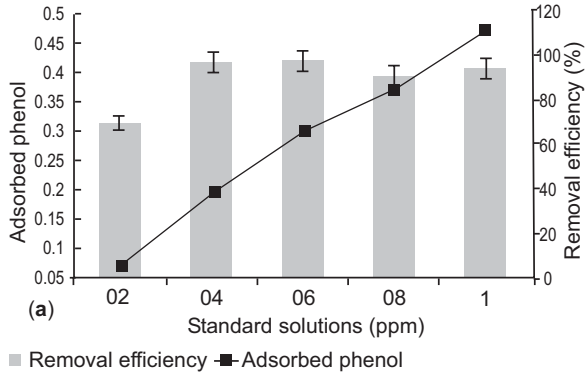

Fig. 4a. Effect of 0.2 g acid treated activated carbon on adsorption of phenol.

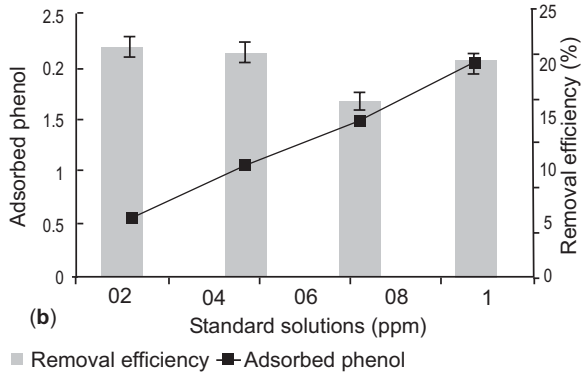

Fig. 4b. Effect of 0.2 g acid treated activated carbon on adsorption in higher concentration phenol solutions

Then acid treated activated carbon was modified for increasing adsorbance and thus mixed with anthracite coal and 0.8 g dose of this mixture used to treat standard solutions of phenol ranging from 5 mg/L to 20 mg/L and results are shown in Table 4 describes the amount of adsorbed phenol i.e 0.378, 0.622, 0.908 and 1.165 which denotes higher adsorbance in 5 mg/L standard solution of phenol and lower adsorbence in 20 mg/L standard solution of phenol. The removal efficiency of the adsorbent was 60.42, 49.79, 48.41 and 46.62 % as shown in Fig. 5b. These results state that the increased AC dosage from 0.2 to 0.8 g which is increased the removal of phenol with decreasing adsorption capacity of AC (Ma *et al*., 2013).

The third treatment in Table 4 indicates the treatment of phenol solutions with 1.6 g of a mixture of adsorbents i.e. anthracite coal and powdered activated carbon. Referring to these results removal efficiency of adsorbent was the highest in 5mg/L standard solution of phenol, while the lowest as shown in 20mg/L standard solution of phenol.

The removal efficiency of adsorbent in 5, 10, 15 and 20 mg/L solutions was 79.52, 72.85, 68.56 and 69.95 % respectively (Fig. 5c). The increased removal efficiency of adsorbent was due to the well developed

Table 4. Effects of 0.8g acid treated AC on adsorption

Adsorbent dose (g)	Standard solutions (mg/L)	Adsorbed phenol (Qe)	Removal efficiency (%)
0.8g/100 mL	5	0.351	56.18
	10	0.721	57.65
	15	1.004	53.55
	20	1.373	54.93
Effect of 0.8 g of a mixture of acid treated activated carbon and anthracite coal			
	5	0.378	60.42
	10	0.622	49.79
	15	0.908	48.41
	20	1.165	46.62
1.6 g/100 mL	Effects of 1.6g acid treated AC+Coal on adsorption		
	5	0.2485	79.52
	10	0.4553	72.85
	15	0.6427	68.56
	20	0.8744	69.95

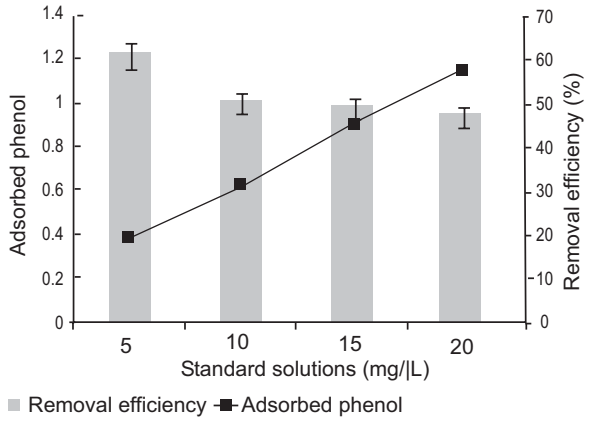

Fig. 5a. Effect of 0.8 g of acid treated activated carbon on adsorption of phenol.

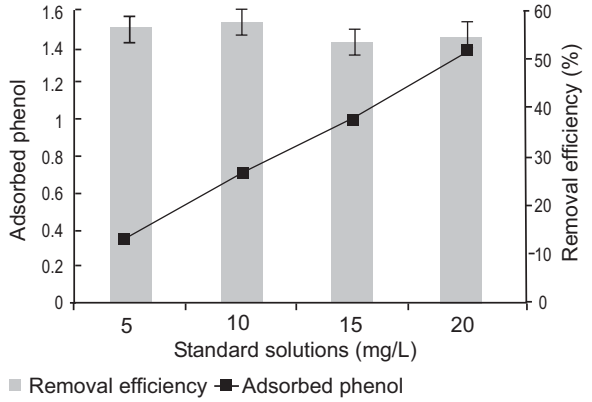

Fig. 5b. Effect of 0.8 g of mixture of acid treated activated carbon and coal on adsorption of phenol.

pore morphology and abundance of functional groups of activated carbon and anthracite coal. In these treatments,the removal efficiency of adsorbent was gradually decreased by increasing the dose of adsorbent (Tan *et al*., 2017).

Fourier transform infrared analysis. FTIR analysis technique was employed for the identification of the functional groups present on the surface of the adsorbent by identifying the chemical bonds in a molecule using an infrared absorption spectrum. In this research work, FTIR analysis was employed on controlled and experimental samples of activated carbon. The resulted spectrum of this analysis showed different peaks that represent the possible mechanism of adsorption of phenol, owing to the appears and disappearance of functional groups and chemical reactions with sites of

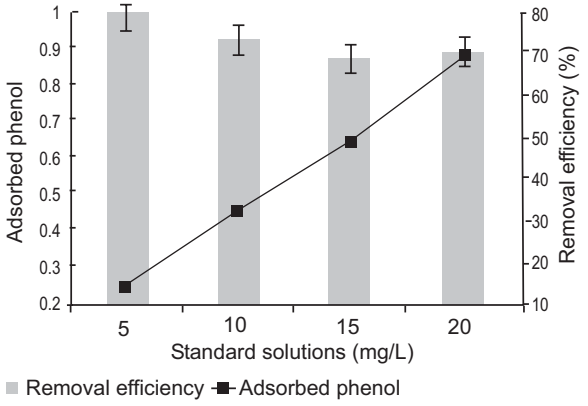

Fig. 5c. Effect of 1.6 g of mixture of acid treated activated carbon and coal on adsorption of phenol.

adsorbent surface and also due to physical adsorption (Sahu *et al*., 2017). This obtained spectrum represents the FT-IR analysis of *D. sanderiana* based AC both with treatment and without treatment of phenol (Fig. 6 a-b). These spectrums were made in the range of 1000-3500/cm region and the transmittance in percentage (%T) versus wave number/cm region plot. The difference in peaks of both spectrums is attributed to the reason for phenol adsorption onto AC. Several peaks were obtained in the spectrums. The characteristic absorptions upto 1000/cm represent strong, alkene (=C-H-) bonds with bending vibrations. Peak around the section 2357.92/cm and 3675.25/cm indicate nitrile (C=N) and –OH functional groups.The peak around 2855.48 and 29.26.34 relates to owing to the aromatic groups with C-H bonds of medium strength.

It is clear from FTIR's analysis that the potential for phenol sorption is due to the appearance and disappearance of active functional groups as well as chemical interactions with adsorbent surface areas and due to physical adsorption. Absorption in 3500-3700/cm regions should be C-O bonded alcohol with streatched vibrations and are strong in nature. Absorption near 4000/cm indicates that of the N-H bond of amide groups with extended movement and strong nature.

The result in Fig. 6 showed the plot of Qe and % removal for all treatments were plotted on the same axis against the adsorbent dose. It describes the effect of adsorbent doses ranging from 0.2 g/100 mL to 1.6 g/100 mL showing the gradual increase in also adsorption of phenol on activated carbon. The adsorbance of phenol

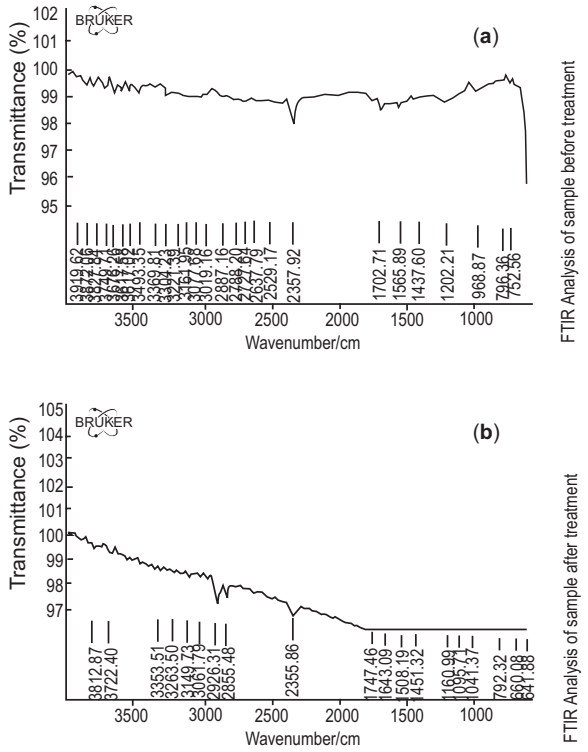

Fig. 6. FTIR analysis of sample before (**a**) and after (**b**) treatment.

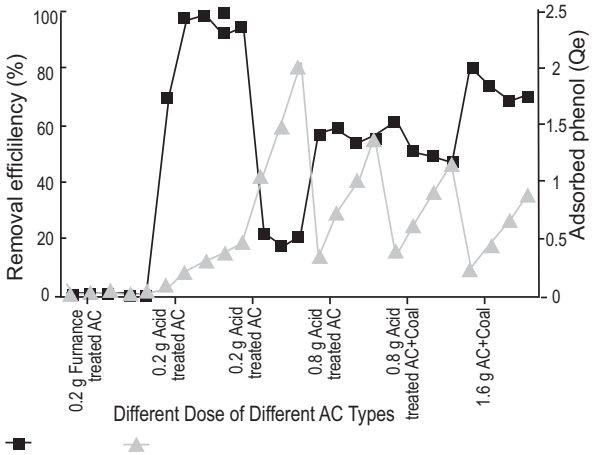

Fig. 7. Effect of different doses of different types of AC on adsorption of phenol.

increased from 2 to 98.33% by modifying furnace treated AC with sulfuric acid. The adsorbent ability of acid treated AC was enhanced by mixing anthracite coal which showed adsorbance of phenol from 19.69% to 79.52%.

Referring to Fig. 7, it was found that with the increase in the adsorbent dose, the percentage removal increased because a larger number of adsorption sites were found and in contrast the phenol intake gradually decreased. This may be due to two reasons firstly by the same amount of phenol a large number of attractions found, while secondly a large number of adsorbents in the small available space that accumulate together thus preventing the distribution process and thus adsorption (Singh *et al*., 2008).

Our results are in close agrement as reported by (Dakhil *et al*., 2013) that phenol removal was 91.6% at 130 mg/L of initial concentration, natural pH 6.7, 120 min of contact time and 0.82 g of adsorbent dose (Dakhil, 2013) and at pH 6, 83% of phenol at an initial concentration of 50 mg/L and adsorption 60 min at room temperature (Ingole and Dilip, 2015). As compared to all the above study present experiment results shows 98.33% and 79.52% adsorption of phenol at the minimum operating condition of initial concentration 0.2 mg/L and 5 mg/L, contact time 1 h, adsorbent dose 0.2 g of acid treated AC and 1.6 g mixture acid treated AC and anthracite coal at natural pH. The maximum result of absorptions of phenol can be achived by increasing the amount of modified adsorbent and experimental time. The difference between values of proximate analysis of furnace treated AC and acid treated AC indicates the increased fixed carbon content, while decreasing in moisture content, volatile matter and ash content as compared to furnace treated AC (Nedjai *et al*., 2021). The FTIR analysis of samples before and after treatment was performed by using a controlled adsorbent i.e. without treatment and the experimental adsorbent i.e. treated one. The spectrum of adsorbent without treatment showed more peaks and functional groups and the spectrum of treated adsorbent showed a significant decrease in functional groups of treated adsorbent and an increase in adsorption peaks which denotes the higher adsorption of phenol by adsorbent which was acid treated AC. The same results are also described by (Sahu *et al*., 2017). The results indicated that the phenol removal efficiencies of all three AC were significant and followed the order of a mixture of acid treated AC and anthracite coal > under acid treated AC > furnace treated AC. This can be explained as a mixture of adsorbents had a maximum specific surface area which exposed the most active sites for the binding of phenol.

Conclusion

The current study was conducted for the elimination of phenols from synthetic standard solutions by adsorption method using AC produced from the *D. sanderiana*. Characterization of adsorbent was studied by using proximate analysis and FTIR analysis. Removal of phenol was increased with increasing adsorbent concentration and by modifying the adsorbent dose. The maximum removal efficiency of 0.2 g dose of furnace treated AC was 10.83%, while acid treated AC showed 98.33% removal efficiency at a contact time of one hour and 120 rpm at natural pH. In 5 to 20 mg/L standard solutions of phenol the removal efficiency was decreased (21.31%). Thus for optimizing the process, and adsorption anthracite coal was added to acid treated AC that enhanced its adsorbent ability to 79.52%. FTIR analysis demonstrated that the removal of phenol by activated carbon was highly significant. The FTIR spectrum gave information about the disappearance of functional groups on the surface of the adsorbent. From the result of study it is concluded that anthracite coal and chemically modifies activated carbon is an effective treatment methodfor the adsorption of phenol in aquous solution.

Conflict of Interest. The authors declare that they have no conflict of interest.

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