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Removal of Phenol from Acqueous Solution by Adsorption on Senna Singueana and Santaloid Afzelli

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Abstract

Phenolic compounds are important industrial wastes, and are classified as hazardous substances contaminating ground-water resources. Therefore, the removal or diminish of these organics compounds in order to reach the permitted levels before discharging becomes a challenging.

Several processes have been developed to remove phenolic compounds from waters, including electrochemical oxidation, redox reactions, membrane separation and photocatalytic degradation. Recently, tendency of phenolic compounds removal involves adsorption and photocatalytic process, using synthetic or natural particles, such as carbon materials and clays. Actually, materials in micrometric scale play an important role in the processes previously mention due to their unique chemical and physical properties. In this research work, comparison is done between the adsorption of capacity of *Senna singueana* and *Santaloid afzelli*. These two plant leafs are use as absorbent for the absorption of phenol from already prepared phenol solution. The variables effect used for this study are absorbent dosage, temperature, pH, initial ion concentration and contact time. During this study various adsorption isotherms were used to obtain a perfect fit for the adsorption.

Keywords

Phenolic compounds, Senna singueana, Santaloid afzelli, Removal methods, Adsorption

Introduction

Phenols are organic compounds of great environmental interest. Their determination has been increasing in recent years because of their toxicity, even at low concentrations. Phenolic compounds are often derived from various manufacturing processes such as pharmaceutical, oil refineries, coke plants, and phenolic resin plants [1-4].

Phenolic compounds in portable water emit an unpleasant odor and flavor in concentration as low as 5 µg L^{-1} and are poisonous to aquatic life, plants and humans. Kumar, et al. [5] have reported that ingestion of phenols in concentrations from 10 to 240 mg L^{-1} for long periods causes mouth irritation, vision problems, diarrhoea, and excretion of dark urine. They are considered one of the priority pollutants by the US Environmental Protection Agency [1,6].

World Health Organisation (WHO) has established the maximum permissible concentration of phenol in drinking water as 1 mg L^{-1} [7,8]. As a result, various studies have been conducted for the removal of phenolic compounds before being discharged to receiving sink. Water pollution is one of the most important problems in the world, which represents a risk to the human and environment. The increasing industrial and human activities have caused an increase on the discharge of wastewater into the water resources [9-13].

Phenolic compounds from different industrial activities such as refineries, pesticides, insecticides, pharmaceutical, etc., are found among the main pollutants of water. These compounds are toxic and their degradation is difficult; thus, it is important the development of materials and effective methods that allow the removal of these pollutants from water. Different methods have been used to assist with this problem [14-18]. The use of cheap, renewable and readily available absorbents like *Senna singueana* and *Santaloid afzelli* has shown to be quite efficient and promising.

Materials and Methods

Senna singuena and *Santaloid afzelli* leafs were removed, wash, dried, grinded and sieve to obtain absorbent of large surface area. NaOH was prepared, also H_2SO_4 was also prepared. Distill water was obtained.

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Determination of effect of contact time

The effect of contact time was studied using an initial concentration of 60 mg/l. The time intervals chosen for this experiment were 30, 60, 90, 120, 150 minutes.

Procedure

A 0.5g of *senna singueana* and *Santalloid afzelli* was weighed properly and mixed with 100 mls solution of initial concentration 60 mg/l. the mixture was shaken constantly for a period of 30 mins. At the end of the contact time period, the mixture was filtered. The procedure was then repeated for 60, 90, 120 and 150 minutes. The concentration of the filtrate was determined using the UV-visible photo spectrometer.

The difference between the initial and final concentration of the solution was recorded as the amount absorbed for each contact time.

Determination of effect of initial ion concentration

The effect of initial ion concentration on adsorption was studied using 0.5g of the adsorbent. The concentrations chosen for this experiment are 20, 30, 40, 50 and 60 mg/l.

Procedure

A 0.5g of Senna singueana and Santaloid afzelli was mixed with 100 mls solution of initial phenol concentration of 20 mg/l. The mixture was shaken constantly for 30 mins. At the end of the equilibrium time, the mixture was filtered. The procedure was repeated for 30, 40, 50 and 60 mg/l. The concentration of the filtrate was determine using UV-visible photo spectrometer.

The difference between the initial and final concentration was recorded as the amount of phenol absorbed for each concentration.

Determination of effect of absorbent dosage

The effect of absorbent dosage on adsorption was studied using initial concentration of 60 mg/l. The absorbent dosage chosen for this experiment were 1g, 1.5g, 2.0g 2.5g and 3.0g respectively.

Procedure

1g of Senna singueana and Santaloid afzelli was mixed with 100 mls solution of initial concentration of 60 mg/l. The mixture was shaken constantly for 30 mins. The mixture was filtered. The procedure was repeated for 1.5g, 2g, 2.5g and 3.0g. The concentration of the filtrate was determined using UV-visible photo spectrometer.

The difference between the initial and final concentration was recorded as the amount absorbed for each absorbent dosage.

Determination of effect of temperature

The effect of temperature on adsorption was studied using 0.5g of the absorbent and initial concentration of 60 mg/l, the temperature chosen for this experiment are 30, 35, 40, 45 and 50 °C.

Procedure

0.5g of Senna singueana and Santaloid afzelli was mixed with 100 mls solution of initial ion concentration of 60 mg/l. The mixture was shaken constantly for 30 mins after which it was placed in water bath at a temperature of 30 °C for about 30 mins. The mixture was then removed from the water bath and filtered. The procedure was repeated for temperature of 35, 40, 45 and 50 °C. The concentration of the filtrate was determined using UV-visible photo spectrometer.

The difference between the initial concentration and final concentration was recorded as the amount absorbed for each temperature.

Determination of effect of pH

The effect of pH on adsorption was studied using 0.5g of the absorbent and an initial ion concentration of 60 mg/l. The pH values chosen for this experiment are pH, 3, 5, 7, 9 and 11.

Procedure

Phenol solutions of 60 mg/l were prepared. 1M nitric acid or 1M of sodium hydroxide was added drop wise until the desired pH of 3, 5, 7, 9 and 11 was obtained. 0.5g of Senna singueana and Santaloid afzelli was measured accurately and mixed with the phenol solutions of varying pH. The mixture was shaken constantly for 30 mins. The mixture was then filtered and the concentration of the filtrate was determined using UV-visible photo spectrometer.

The difference between the initial and final concentration was recorded as the amount of absorbed for each pH.

Calculation of the Percentage of Phenol Absorbed

The percentage adsorption of phenol was calculated for each experiment using the formula

$$R = \frac{Ci - Ce}{Ci} \times 100$$

Where R = percentage adsorption of phenol

Ci = initial phenol concentration in mg/l

Ce = final phenol concentration in mg/l

Calculation of amount absorbed

The amount of phenol absorbed was also calculated for each experiment performed using the formula.

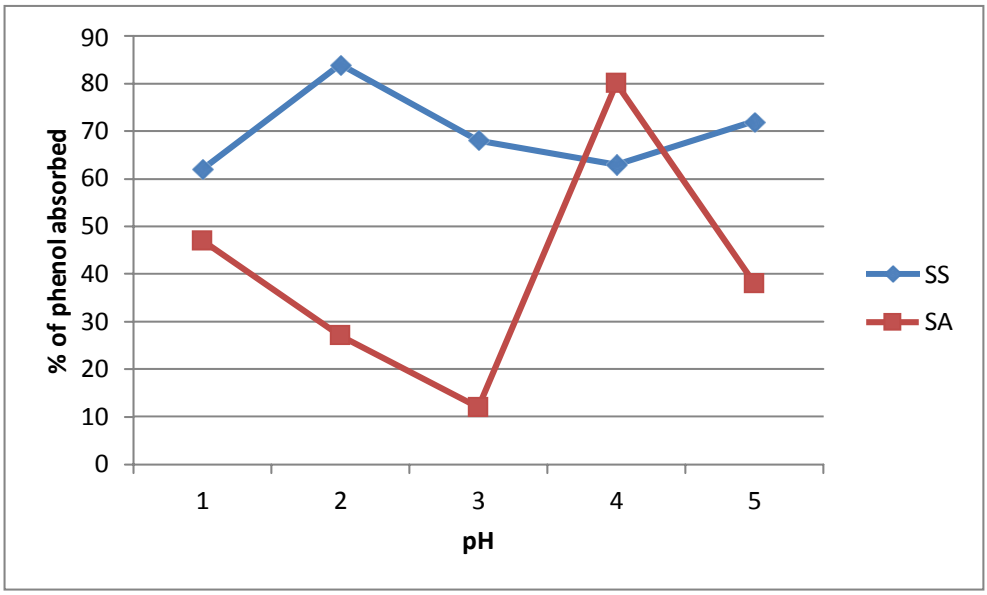
Amount absorbed = Ci-Ce

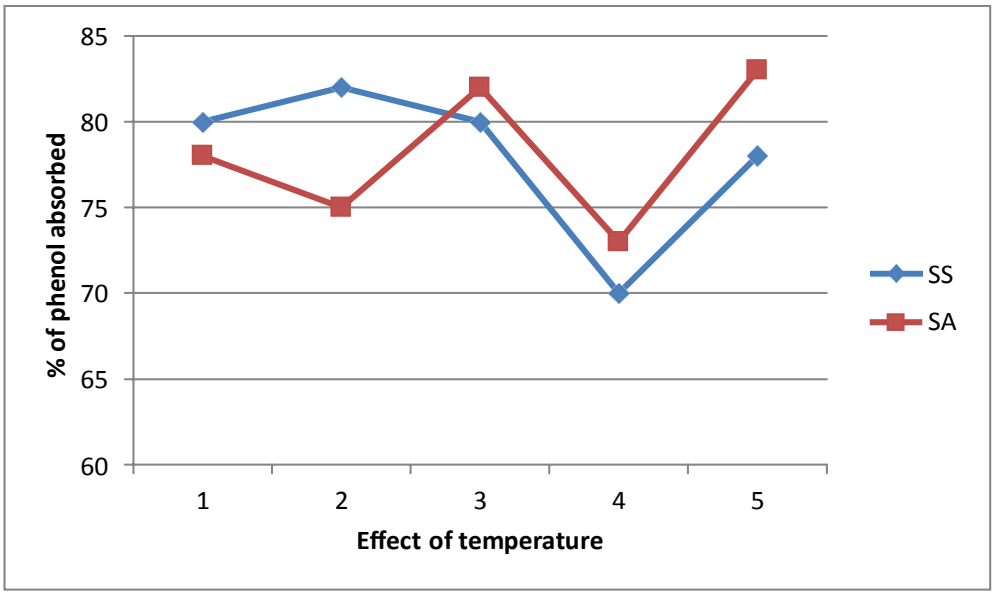
Where Ci = initial phenol concentration in mg/l

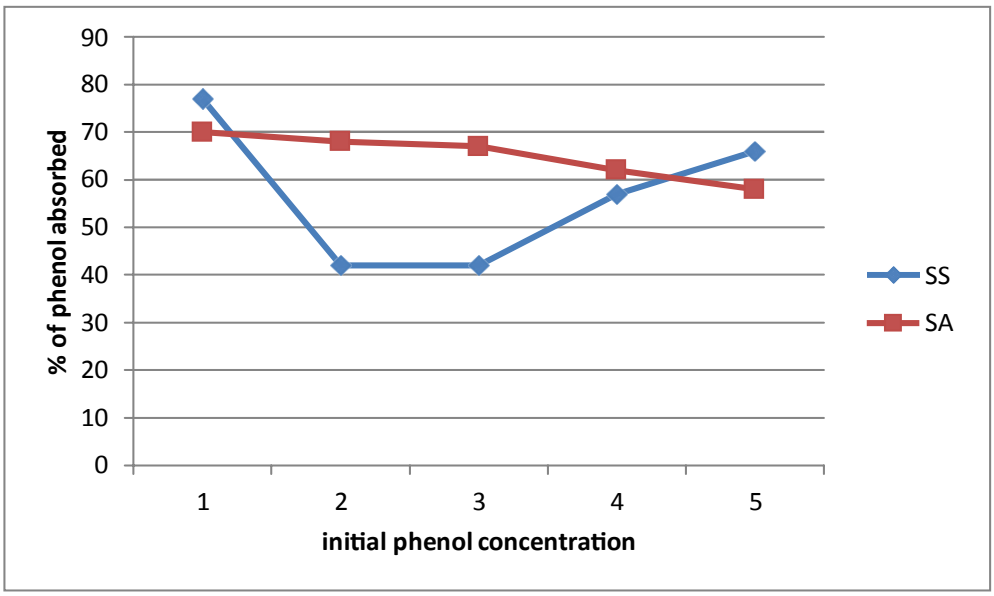
Ce = final phenol concentration in mg/l

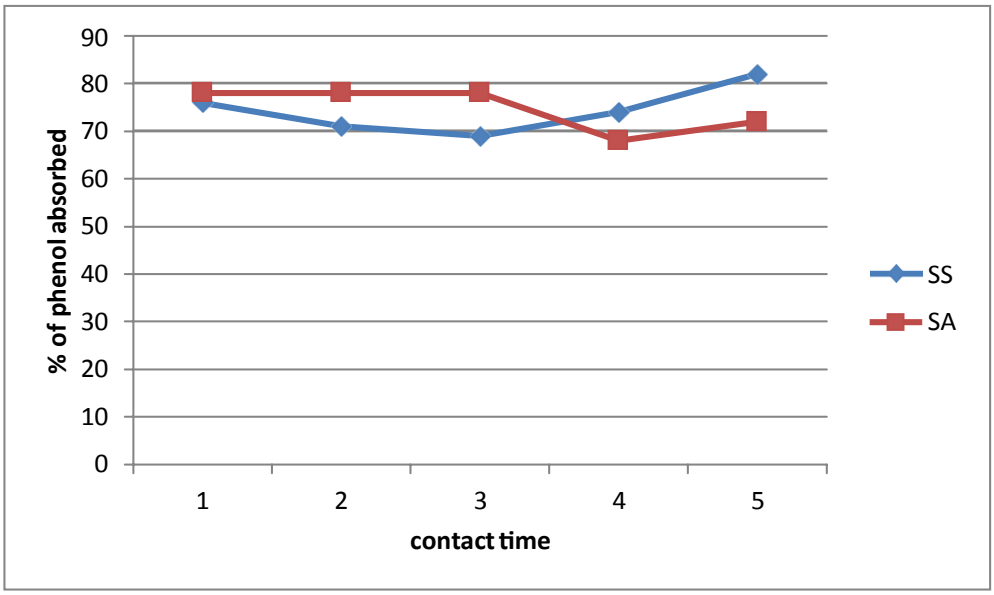
Thermodynamic treatment of sorption

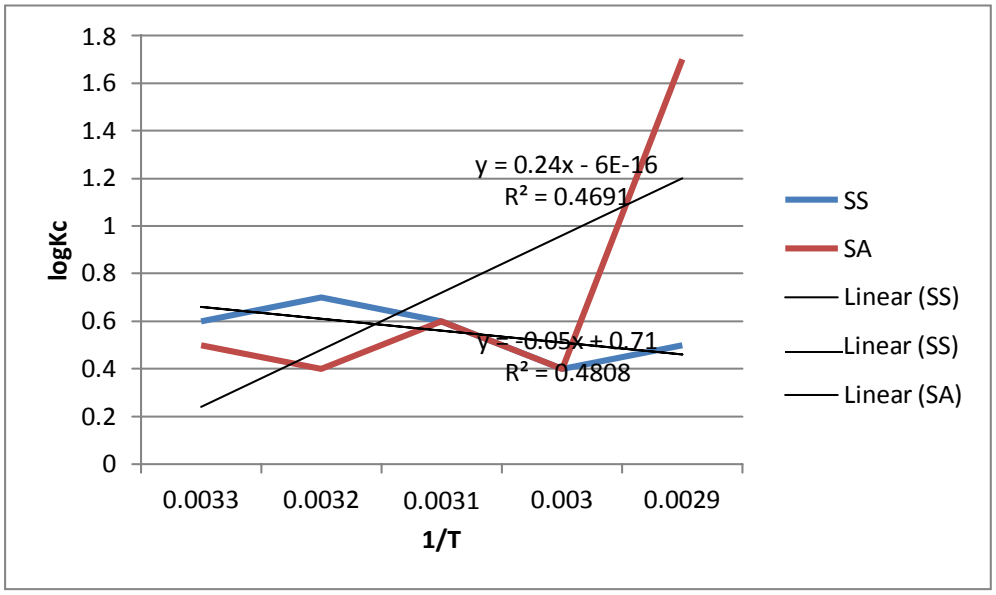
Thermodynamic considerations of an adsorption process are necessary to conclude whether the process is spontaneous or not. Gibb's free change, ΔG°, is the fundamental criterion of spontaneity. Reactions occur spontaneously at a given temperature if ΔG° is negative. The thermodynamic parameter Gibb's free energy, ΔG° for the adsorption


90
80
70
60
50
40
30
20
10
0
% of phenol absorbed
1
2
3
4
5
pH
SS
SA


85
80
75
70
65
60
% of phenol absorbed
1
2
3
4
5
Effect of temperature
SS
SA


90
80
70
60
50
40
30
20
10
0
% of phenol absorbed
1
2
3
4
5
initial phenol concentration
SS
SA


90
80
70
60
50
40
30
20
10
0
% of phenol absorbed
1
2
3
4
5
contact time
SS
SA


1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
logKc
y = 0.24x - 6E-16
R² = 0.4691
y = -0.05x + 0.71
R² = 0.4808
0.0033
0.0032
0.0031
0.003
0.0029
1/T
SS
SA
Linear (SS)
Linear (SS)
Linear (SA)

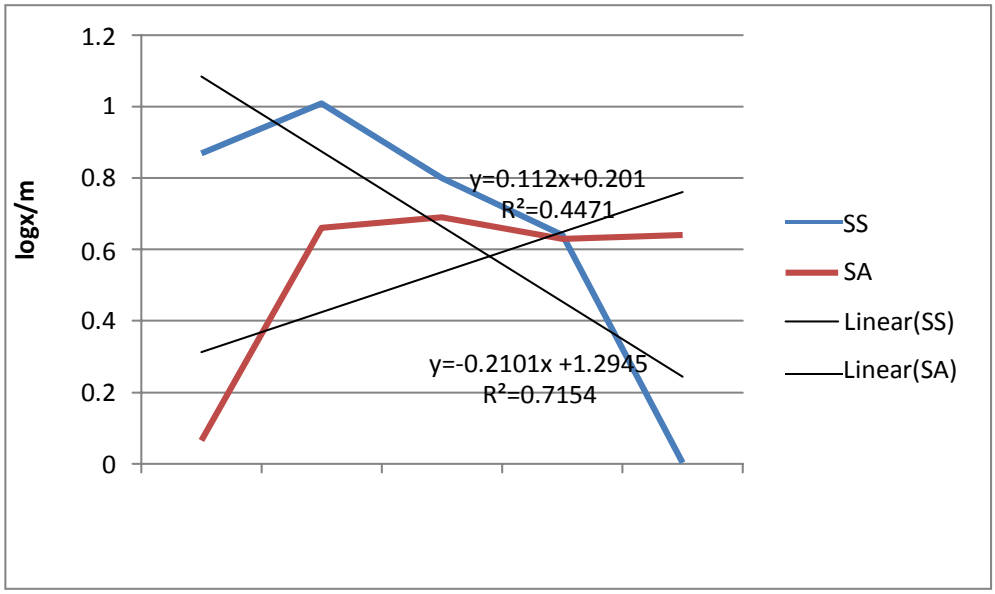

1.2
1
0.8
0.6
0.4
0.2
0
logx/m
y=0.112x+0.201
R²=0.4471
y=-0.2101x +1.2945
R²=0.7154
SS
SA
Linear(SS)
Linear(SA)

Table 1

Isotherms	Parameters	Senna singuena	Santaloid afzelli
Langmuir	$Q_{max.}$(mg/g)	10.2	4.9
	K_L	0.24	0.05
	R^2	0.4808	0.4691
Freundlich	K_f	0.819	
	n	-0.210	0.112
	R^2	0.715	0.447

process is calculated using the following equations:

$$\Delta G° = -RT \ln K_C$$

Where R is the universal gas constant (8.314 j/mol/k) and T is the absolute temperature in K. Kc is calculated using the formula below:

$$Kc = \frac{C_{AE}}{C_e}$$

Where CAE is the amount of phenol absorbed in mg/l,

Ce is the equilibrium concentration in solution in mg/l and Kc is the thermodynamic equilibrium constant (Table 1 and Figure 1).

Results and Conclusion

In this study, Senna singueana and Santaloid afzelli were used as absorbent for the removal of phenol from distilled water solution. Batch experiments were carried out to study the effect of variables on the rate of adsorption. Such as contact time, pH, temperature, Initial ion, concentration and absorbent dosage. It was found from the study to be effective in the removal of phenol [19,20].

For the effect of pH, it was observed that as the pH, moves to weakly acidic medium, the adsorption increases. Therefore it can be imply that he adsorption of phenol unto Senna singueana and Santaloid afzelli is favored at low pH.

It was also observed from the effect of contact time that a minimum contact time of 120 minutes is required for the removal of 81.5% of phenol from the solution.

For the effect of temperature, the adsorption decreased as the temperature increased. This implied that the adsorption of phenol onto Senna singueana and Santaloid afzelli is favored at low temperatures.

For the effect of initial ion concentration, it was observed that the adsorption decreased as the initial ion concentration increased from 20-60 mg/l with maximum adsorption of 77% at concentration of 20 mg/l.

It was observed from the effect of absorbent dosage that as the adsorbent dose increased the adsorption increased. This implied that an increase in adsorbent dose has effect on the adsorption. Also a minimum of 6g of the adsorbent will be enough to obtained 100% adsorption of phenol from the solution.

Adsorption equilibrium data fitted well into Langmuir and Freundlich isotherms. Although Langmuir isotherm provided the best fit. This implied that the adsorption of phenol was more of a mono layer adsorption and the adsorbed molecules do not interact with each other.

Recommendation

This study showed that Senna singueana and Santaloid afzelli is readily available and it also has the potential for removing industrial waste from aqueous solution. Also the process is environment friendly and may also provide an affordable technology for small and medium scale industry in Nigeria.

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