

ADSORPTION STUDIES FOR THE REMOVAL OF AMMONIA BY THERMALLY ACTIVATED CARBON

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ABSTRACT: The efficiency of charcoal fraction activated at temperature ($^{\circ}\text{C}$) 50,100,150 and 200 $^{\circ}\text{C}$ for 24 hr duration was investigated in this study. The results demonstrate that the adsorption of ammonia increases with the increase of contact time and adsorption process gradually reaches to equilibrium. A thirty min contact time appears to be optimal. Adsorption of ammonia also increases with the increase of adsorbent dosage and a one gram of adsorbent quantity appears to be optimal, particularly in case of charcoal fractions activated at higher temperatures. It is also evident from the results that the adsorption of ammonia increases with the increase of activation temperature. The adsorption of ammonia is particularly higher in charcoal fractions prepared at activation temperature of 200 $^{\circ}\text{C}$. The adsorption of ammonia increases with the increases in ammonia concentration. The data from experiments was applied to Freundlich and Langmuir isotherms. The data was best fitted in Freundlich equation. Empirical formula obtained indicated that thermally activated charcoal had an excellent capacity of ammonia removal.

Key words: Activated carbon, Ammonia, Adsorption, Isotherms

1. INTRODUCTION

Ammonia is characterized as a colorless, pungent, and a corrosive gas in nature and is one of the abundantly found nitrogen containing compounds in the atmosphere after nitrogen and nitrous oxide [1,2]. The contents of ammonia in the atmosphere if exceed 50 ppm may cause breath problem [1]. Levels of 50-100 ppm of ammonia can causes irritation of eyes, throat, and nose [1,3].

Many techniques, including catalytic decomposition, reaction of ammonia with another gas, adsorption by solids, and staged combustion processes have been used to eliminate ammonia [3-4]. However, the adsorption process under certain conditions has a definite edge over other methods used for ammonia recovery because of its simplicity, selectivity and efficiency [1, 5]. Among the unit operations in water and wastewater treatment, adsorption occupies an important position. Adsorption operations exploit the ability of certain solids preferentially to concentrate specific substances from solution onto their surfaces [6].

In the field of gaseous separation the adsorption process is used to dehumidify air and other gases, to remove objectionable orders and impurities from industrial gases such as CO_2 and to recover valuable solvent vapors from dilute mixtures. Liquid separations include the removal of objectionable taste and odor [4]. Adsorption with charred wood is employed for centuries to improve the taste of water [6].

In this study, activated carbon preparation from wood charcoal at different temperatures was explored. The efficiency of a fraction of wood charcoal activated at temperatures ($^{\circ}\text{C}$) 50,100,150 and 200 $^{\circ}\text{C}$ for 24 hrs were investigated by the adsorption of ammonia. For this purpose adsorption parameters like contact times, adsorbent dosages and initial ammonia concentration was carried out. The Freundlich and Langmuir adsorption equilibrium isotherm were studied for adsorption phenomena principle.

2. EXPERIMENTAL

2.1 Chemicals and Materials

The chemicals used in this study were ammonia, sulphuric acid, methyl red, methylene blue, methyl orange, and ethyl alcohol. All the chemicals were used in their typical concentrations and normality according to the requirements. The coal used for activated carbon was collected from local market.

2.2 Activated Carbon Preparation

As received wood coal was dried, ground, and sieved to a particle size fraction of 300 μm to 150 μm (.012 in - 0059 in), which have adsorption efficiency of 99%. Thermal treatment was used to activate the charcoal, make different sample of adsorbents and activated at temperatures of 50 $^{\circ}\text{C}$, 100 $^{\circ}\text{C}$, 150 $^{\circ}\text{C}$ and 200 $^{\circ}\text{C}$ for a period of 24 hrs and then optimized each. Activation temperature of 200 $^{\circ}\text{C}$ has maximum adsorption efficiency [7-12].

2.3 Adsorption Studies

Adsorption of ammonia was calculated by titrating it against 0.02N H_2SO_4 . The instruments used for measuring different parameters are magnetic stirrer, electric balance, pH meter, stopwatch, electric furnace, thermometer and sieves.

Adsorption measurements were carried out via a batch technique at room temperature (30 ± 3 $^{\circ}\text{C}$), except where otherwise specified. Accordingly 10 ml of ammonia solution of known concentration were shaken on magnetic stirrer with about 1.0g (range 0.5 to 2 g) of dry activated charcoal at 200 $^{\circ}\text{C}$ in 250 ml reagent glass bottles for a given time period of 60 min (range 30 to 120 min). The solution was then filtered through Whatman filter paper No. 42 (circular, 14.0 cm). The first 2-3 ml portions of the filtrate were rejected because of adsorption of ammonia on the filter paper. The concentration of ammonia was determined by using titration method. The percentage adsorption was

$$\% \text{adsorption} = \frac{(C_o - C_e)}{C_o} \times 100$$

calculated using the following equations:

The quantity adsorbed q_e (mg/g) was calculated by the mass balance relationship:

$$q_e = (C_o - C_e) \times \frac{V}{m}$$

Where C_o and C_e are the initial and equilibrium liquid phase concentration of the dye (mg/dm³), V is the volume of the solution (dm³), and m is the mass (g) of the activated carbon used.

3. RESULTS AND DISCUSSIONS

3.1 Influence of contact time on the removal Efficiency of Charcoal

Fig 3.1 represents the influence of contact time on the performance of charcoal fractions activated at various temperatures ranging between 50 to 200°C at an interval of 50°C. The adsorption of ammonia increase with the increase of contact time and the adsorption gradually reach to equilibrium. The removal efficiency of size fraction charcoal activated at temperature 200°C appears to be exceptionally high that is nearly 98.1 % at 90 min contact time. The 30 min contact time appears to be optimal in the senses that beyond which the removal efficiency is not appreciable.

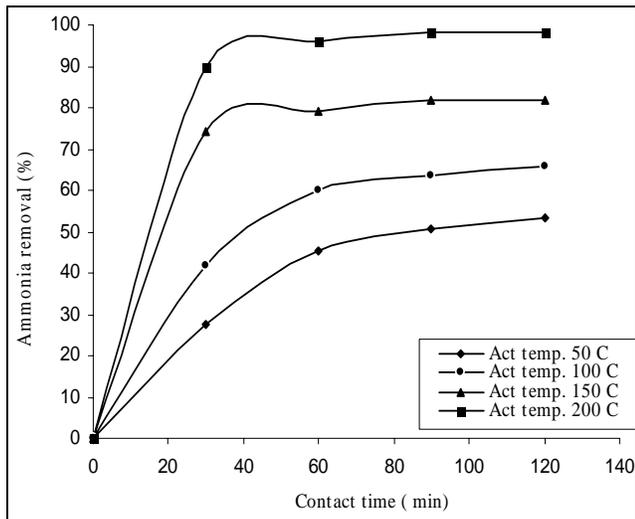


Figure 3.1 Effect of contact time (min) on the removal of ammonia (%) at different activation temperatures (°C) such as 50, 100, 150 and 200°C.

It is evident from the figure that adsorption of ammonia takes place in two distinct stages; a relatively fast followed by a slower one. In the fast stage, the rate of adsorption is substantially high, particularly in charcoal fraction prepared at higher temperature (200°C). Higher percentage and rate of adsorption can be explained because of the availability of higher surface area and active sites. However, active sites are gradually declined; the reaction rate becomes slower and reaches equilibrium when the surface area becomes almost saturated [13-14].

3.2 Effect of Quantity of Adsorbent

Fig. 3.2 represents the influence of activated charcoal dose (g) such as 0.5, 1.0, 1.5 and 2 g on the removal of ammonia (%). It can be seen from the results that percent removal of ammonia increases with increasing amount of the adsorbent. This is due the greater availability of the active sites or surface area, when the adsorbent quantity is increased. Although two gram dose of adsorbent shows ammonia removal more than 98% but it may be concluded that by increasing the adsorbent dose, the removal efficiency (%) beyond a dose of one gram adsorbent is not striking. Therefore, the value of 1.0 g of charcoal dose appears to be optimal, particularly for the charcoal fractions activated at higher temperatures such as 150°C and 200°C respectively. It is also evident that below a dose of one gram, the removal

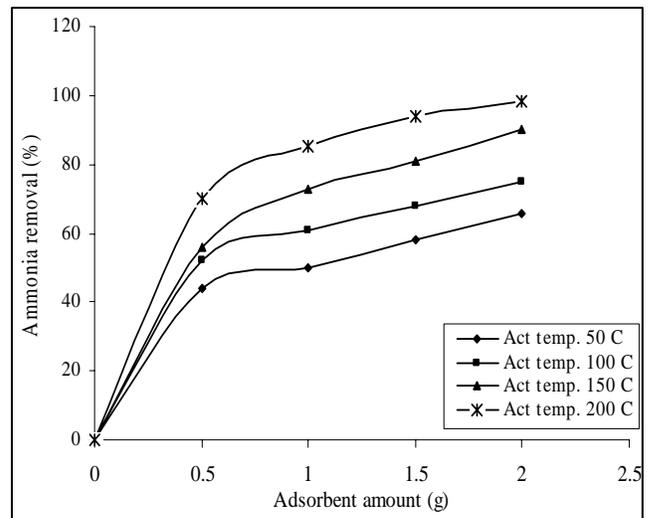


Figure 3.2 Effect of adsorbent dosages (g) on the removal of ammonia (%) at different activation temperatures (°C) such as 50, 100, 150 and 200°C.

rate is exceptionally high. Beyond that, the percentage removal reaches almost a constant value. Very slow increase in removal of ammonia beyond an optimum dose may be attributed to the attainment of equilibrium between adsorbate and adsorbent at the operating conditions.

3.3 Effect of Adsorbate Concentrations

Fig. 3.3 presents the effects of ammonia concentrations such as 320, 450, 550 and 600 ppm on the removal efficiency (%) of activated charcoal. It is seen from the figure that the removal of ammonia increases with the increase ammonia concentration. The removal efficiency of size fraction appears to 98 % at ammonia concentration of 450 ppm.

It can be concluded that adsorption process is highly dependent on initial concentration of ammonia because at lower concentration, the ratio of the initial concentration of ammonia to the available surface area is low (concentration / surface area) and subsequently the fraction adsorption of ammonia increases. However, at higher concentration the availability of active sites for adsorption becomes less and hence the percentage removal of ammonia decreases.

3.4 Adsorption Isotherms

To facilitate estimation of the adsorption capacities, the two well-known equilibrium models, Freundlich and Langmuir are most frequently employed. The Freundlich equation is an

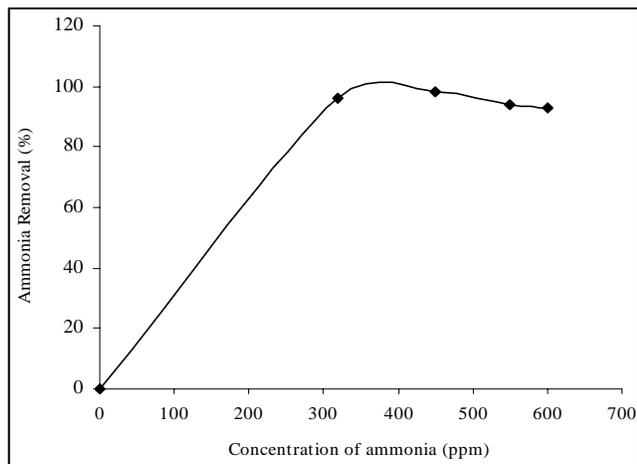


Figure 3.3 Effect of ammonia concentration (ppm) on the removal efficiency of the activated carbon at contact time, 30 min and activation temperature 200°C.

empirical one and Langmuir equation assumes the maximum adsorption occurs when the surface is covered by the adsorbate. In the present work Freundlich and Langmuir isotherm models are used.

The Freundlich model is an indication of the surface heterogeneity of the sorbent. The relationship between the ammonia uptake capacity q_e (mg/g) of the adsorbent and the residual ammonia concentration C_e (mg/l) at equilibrium is given by:

$$q_e = kC_e^{1/n}$$

The linearized form of the Freundlich equation is given by

$$\log q_e = \log k + \frac{1}{n} \log C_e$$

Where the interception $\log k$ is a measure of adsorbent capacity, and the slope $1/n$ is the sorption intensity. The ammonia adsorption isotherm followed the linearized Freundlich models as shown in the Fig 3.4, which indicate that the isotherm data fit the Freundlich model well.

The values of the constant k and $1/n$ were calculated to be

$$\begin{aligned} K &= 22 \text{ g/g} \\ 1/n &= 0.776 \end{aligned}$$

The value of Freundlich exponent, n is greater than unity, indicating that ammonia ions are favorably adsorbed.

4. CONCLUSIONS

The present study indicates that the locally available wood charcoal can be utilized for the production of activated carbon. It also appears that by using only thermal treatment a high surface area and economically viable activated carbon can be produced. The results show that the adsorption of ammonia by activated carbon increase with the increase of contact time, amount of adsorbent and initial dye concentration. The maximum removal of ammonia is achieved with in short contact time and by using only one

gram of adsorbent. The Freundlich isotherm is best fitted as proofed by the correlation coefficient R^2 greater than 99.9 %. The value of Freundlich exponent, n is greater than unity, indicating that ammonia ions are favorably

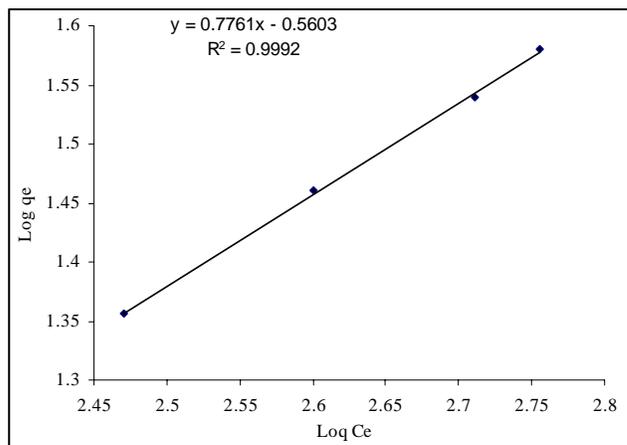


Figure 3.4 Freundlich plot for the adsorption of ammonia by activated carbon.

adsorbed.

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