

MODIFICATION OF THE SURFACE PHYSICOCHEMICAL PROPERTIES OF ACTIVATED CARBON FOR WATER FILTRATION

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ABSTRACT

The purpose of this work was to study the effect of chemical surface properties of activated carbons for their use in water purification. To achieve this objective, activated carbon in both granular and powdered forms namely: as received and devolatilized carbons were prepared. Proximate analysis of the carbon materials was performed. Mass titration experiments were carried out to determine the point of zero charge of the activated carbon materials. Again, using an ultraviolet spectrophotometer, the adsorption of phenol on as-received and devolatilized activated carbon was investigated. Adsorption isotherms were acquired from which the monolayer adsorption capacities were calculated.

Keywords: Activated carbon, Adsorption isotherms, ultraviolet spectrophotometer, devolatilized carbons and Proximate analysis

1. INTRODUCTION

1.1 ORIGIN AND NATURE OF ACTIVATED CARBON

Carbon is the fifteenth most abundant element in the earth's crust and the fourth most abundant element in the universe by mass after hydrogen, helium and oxygen. Scientists, industries, and consumers use different forms of carbon and carbon containing compounds in many ways such as activated carbon or carbon in its active form which can be used to purify water, among others. Activated carbon is a form of carbon that has been produced to make it extremely porous and thus have a very large surface area available for adsorption or chemical reactions. It can be defined as a microcrystalline non-graphitic amorphous form of carbon which has been processed to develop a high internal porosity due to its network of inter- connecting pores.

The history of activated carbon is dated since the fifteenth century, during the time of Columbus when sailors used to blacken the inside of wooden water barrels with fire, since they observed that the water would stay fresh much longer. It is likely that people at that time proceeded by intuition only without having any insight into the mechanism of the effect. The mechanism was recognized beginning from the eighteenth century.

In 1862, Lipscombe prepared a carbon material for purifying portable water. This development paved the way for the commercial application of activated carbon first for portable water and then in waste water sector.

1.2 METHODS OF MANUFACTURE OF ACTIVATED CARBON

The methods employed in the industrial manufacture of activated carbons are numerous but consist of three main methods namely; Chemical activation, Steam activation and thermal processing techniques.

The raw materials or precursors used in the manufacture of activated carbon are as follows; Softwood, coconut shell, lignite, hardwood, grain and agro products, bituminous coal, anthracite, etc.

Chemical activation is generally used for the production of activated carbon from sawdust, wood or peat and uses chemicals for activation. Chemical activation technique involves mixing an inorganic chemical compound with the carbonaceous raw materials and the most widely used activating agents are Phosphoric acid and Zinc Chloride.

Steam activation technique is generally used for coal-based, coconut shell and grain- based activated carbons and uses gases, vapors or a mixture of both for its activation.

Thermal processing technique is a separation process that removes unwanted materials from the carbonaceous precursor used under varying heat applications. This technique is at a lower cost compared to the two techniques above and meets all environmental standards, while others need expensive solutions to achieve the same results.

1.3 NEED FOR PRESENT INVESTIGATION

The need for present investigation of this material cannot be over emphasized. This is as a result of the pressing need for treatment of waste water emanating from domestic and industrial concerns. Activated carbon plays an important role in the purification of fluids (water), including vegetable oils used in domestic cooking and as a precursor in industrial

manufacture of food products. The slow pace of technological development in the country has resulted to the expenditure of the nation's resources on importation of activated carbons to meet the demand for local chemical and process industries, as well as the demand for municipal and industrial water treatment plants.

Rapid industrialization, together with the increase in modern methods of agriculture and the increase in population, has contributed to the pollution of the ecosystem. Most of the pollutants are toxic to living organisms. It is therefore imperative that waste water has to be treated to remove the toxic materials before disposal to the environment. Most methods of treating water have some inherent shortfalls. Activated carbon treatment was therefore developed because of its effectiveness in pollutants removal, especially in water purification.

1.4 OBJECTIVES AND SCOPE OF THE STUDY

- The primary objectives and scope of the present investigation include the following:
- Acquisition of the different types of activated carbons available to the nation's chemical industry.
- Modification of the surface physical and chemical properties of the carbon material, for their use in liquid phase applications.
- Determination of the physical properties of the as-received and modified activated carbon materials.
- Testing the adsorption capacity of the carbon materials in adsorption processes.
- Evaluation of the fractional surface coverage for each carbon material.
- Proposal of a scheme for the optimal modification of activated carbon material for optimal application in liquid phase adsorption.

2. METHODOLOGY

2.1 MODIFICATION OF THE ACTIVATED CARBON

2.1.1 DEVOLATILIZATION OF THE COCONUT SHELL BASED ACTIVATED CARBON

The coconut shell based activated carbon was placed in an air tight oven and heated at 6000C for 6 hours. The sample was left to cool in the oven after which it was placed in a desiccator to preserve its integrity.

2.2.2 TREATMENT OF THE ACTIVATED CARBON WITH NITRIC ACID

The treatment with nitric acid was done in two phases thus:

- **TREATMENT WITH CONCENTRATED NITRIC ACID-** Both the granular and the powdered coconut shell based activated carbon were treated with concentrated nitric acid. 5g of the activated carbon was mixed with 50ml of concentrated nitric acid and heated in a fume cupboard for 2 hours. After the treatment, the activated carbon was filtered out, rinsed with distilled water repeatedly to remove all traces of acid and dried at 1100 C in an oven.
- **TREATMENT WITH DILUTE NITRIC ACID-** A molar solution of nitric acid was prepared with distilled water. 5g of the activated carbon was mixed with 50ml of dilute nitric acid heated in a fume cupboard for 2 hours. After the treatment, the activated carbon was filtered out, rinsed with distilled water repeatedly to remove all traces of acid and dried at 1100C in an oven.

2.2 MASS TITRATION

This has to do with point of zero charge of the absorbent. Point of zero charge of an adsorbent is the value of the pH required to give zero net surface charge using American Society for Testing and Materials (ASTM) method.

2g, 4g, 6g, 8g, and 10g of as-received carbon sample were mixed with 50ml of distilled water, allowed to equilibrate and the pH of the mixture was measured and recorded. The same procedure was repeated for devolatilized activated carbon, activated carbon treated with concentrated nitric acid and activated carbon treated with dilute nitric acid and reported as well for both granular and powdered activated carbon.

2.3 PROXIMATE ANALYSIS OF THE ACTIVATED CARBON MATERIAL

The proximate analysis of the coconut shell based activated carbon material was carried out to determine the percentage by mass of moisture, volatile matter, ash and fixed carbon. This was done at varying temperature.

2.3.1 MOISTURE CONTENT

This was determined by heating at a temperature of 1050C for an hour. The difference in weight was recorded accordingly on percentage basis.

2.3.2 VOLATILE MATTER CONTENT

Volatile matter content was determined by heating the moisture-free activated carbon at a temperature of 6000C for ten minutes in the absence of air. The corresponding weight difference was reported on percentage basis.

2.3.3 ASH CONTENT

The sample is further heated for thirty minutes at a temperature of 6000C in the presence of air. The difference in weight was reported as ash content in percentage basis.

2.3.4 FIXED CARBON

This is the residue left after the moisture, volatile matter and ash is given up. It is deduced by subtracting from 100, the percentage of moisture, volatile matter and ash content. Thus,

Fixed Carbon (FC) = 100 – (%moisture + %volatile matter + %ash)

2.4 ADSORPTION EXPERIMENT

The effect of such parameters as absorbance and phenol concentration was put into consideration. The procedure taken is as follows:

Various amount of the adsorbent (0 – 5.0g) was mixed with a fixed weight of the adsorbate (25m) in stoppered flasks and the mixture was shaken intermittently for six hours. The adsorbate was subsequently separated by filtration and the filtrate analyzed by UV spectrophotometer to determine the concentration of residual adsorbate and recorded accordingly.

3. RESULTS AND DISCUSSION

3.1 Mass Titration

The mass titration results of the four grades of coconut shell based activated carbonare shown in Tables 1.1 – 1.3.

Table 1.1: Mass titration result for as-receivedactivated carbon

SOLID FRACTION(Wt %)	EQUILIBRIUM pH	
	GRANULAR ACTIVATED CARBON	POWDERED ACTIVATED CARBON
2	4.25	3.50
4	4.27	3.46
6	4.30	3.41
8	4.33	3.38
10	4.35	3.35

Table 4.2: Mass titration resu

SOLID FRACTION(Wt %)	EQUILIBRIUM pH	
	GRANULAR ACTIVATED CARBON	POWDERED ACTIVATED CARBON
2	4.70	3.95
4	4.75	3.92
6	4.78	3.88
8	4.81	3.85
10	4.85	3.82

It for devolatilized activated carbon

Table 1.3: Mass titration result for concentratednitric acid treated activated carbo

SOLID FRACTION(Wt %)	EQUILIBRIUM pH	
	GRANULAR ACTIVATED CARBON	POWDEREDACTIVATED CARBON
2	4.52	3.80
4	4.60	3.78
6	4.66	3.74
8	4.72	3.71
10	4.80	3.68

Figures 1.1 – 1.3 shows mass titration plot for as-received activated carbons, devolatilized activated carbons, concentrated nitric acid treated activated carbons and dilute nitric acid treated activated carbons.

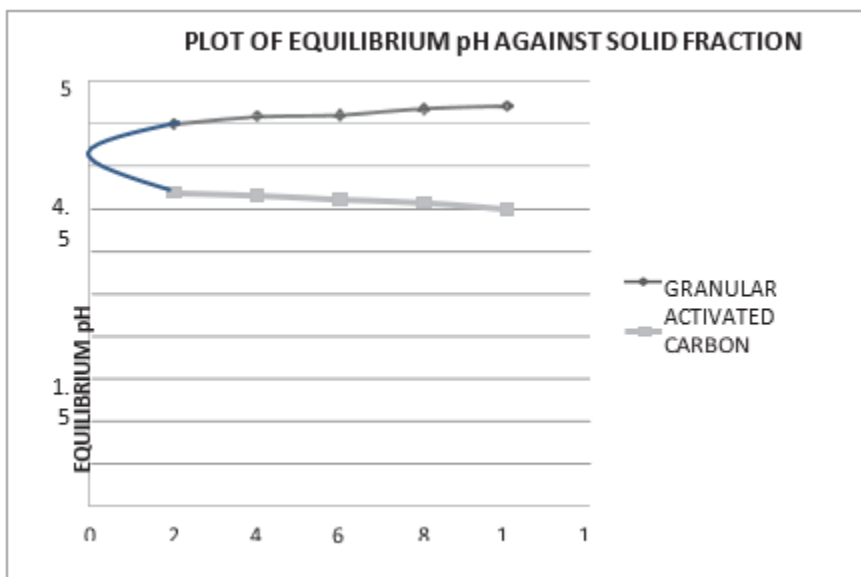


Figure 1.1 Mass titration plots for as-received activated carbons

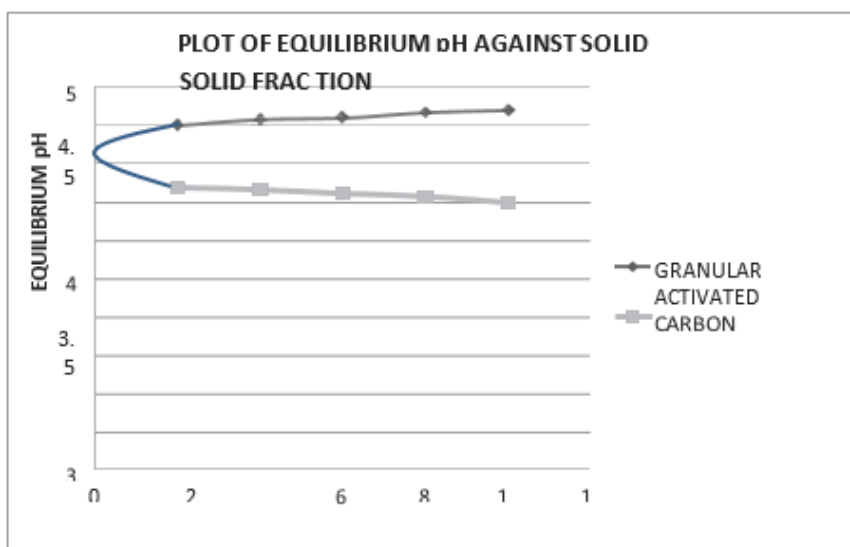


Figure 1.2: Mass titration plot for devolatilized activated carbons

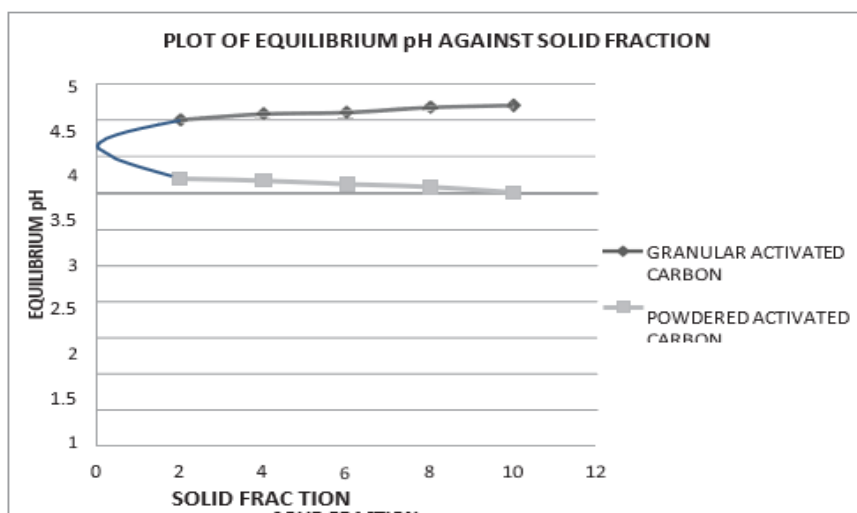


Figure 1.3: Mass titration plot for activated carbon treated with concentrated nitric acid.

4. CONCLUSION

As a result of their internal and external surface areas as well as developed pore structure, activated carbons are good adsorbents and are therefore used to remove a broad spectrum of dissolved organic and inorganic from the gas and aqueous phases.

Coconut shell based activated carbon at its initial stage has little internal surface area and hence need further modification to enhance their surface area and pore structures.

Devolatilization of the coconut shell based activated carbon was shown to enhance the monolayer capacity and surface coverage of the adsorbent.

On the other hand, treatment with nitric acid attaches oxygen functional groups and adsorbent and hence lowers the adsorption capacity, monolayer capacity as well as surface coverage of the carbon material. Agriculturally based activated carbon as coconut shell provides room for productive use of agricultural waste.

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