Removal of nitrobenzene from water using activated carbon prepared from water hyacinth

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Abstract: The prevailing study is of the adsorption efficiency of nitrobenzene onto the activated carbon prepared from the water hyacinth by phosphoric acid activation under the considerations of effect of pH (2, 4, 6, 8, 10 and 12) of nitrobenzene sample and consequence of initial concentration (20, 100 and 200mg L\(^{-1}\)) and contact time. The samples were analysed in high performance liquid chromatography (HPLC). The outcome shows that the change in pH of the nitrobenzene sample does not impact the adsorption capacity or adsorption rate. But whereas, the increase in original concentration of nitrobenzene has shown that the adsorption of nitrobenzene was rapid at initial stages and gradually increased with time till the stability is reached with the adsorption values of 19.3, 84.7 and 158.3 for initial concentrations of 20, 100 and 200mg g\(^{-1}\) respectively. This study indicates that activated carbon formulated from water hyacinth is efficient for the removal of the nitrobenzene from the water.

Keywords: nitrobenzene, activated carbon, water hyacinth, adsorption

1. Introduction

During this contemporary age, industrial activities have a major impact on the environment [1]. Many industries such as: dyes manufacturing, plastics, pesticides, pharmaceuticals and chemical synthesis industries have been using nitrobenzene for years. The groundwater and other water bodies have been heavily contaminated due to this large-scale use of nitrobenzene [2,3]. In addition, Nitrobenzene (NB) can’t be easily debased by the microorganisms [4], which made the nitrobenzene a priority contaminant in most the countries [5]. Nitrobenzene also has adverse impacts on human health and natural ecosystems because of their high toxicity and carcinogenic quality. Nitrobenzene is well known to be highly damaging to the immune, circulatory, cardiovascular, nervous, respiratory, and reproductive systems in human beings. Even though, knowing the toxicity of nitroaromatic compounds, 9000 tons of nitrobenzene are being discharged annually into water bodies [6].

Many environmental protection agencies of numerous countries have categorized nitrobenzene as one of the main concerned pollutants. The consequences of nitrobenzene usage reduction [9], oxidation by ozone / ultraviolet processes [10], ozonation [11], biodegradation [12]. Adsorption with activated carbon is weighed as one of the most economical and efficient processes for removing the nitrobenzene from water [13,14]. A significant amount of
environment had raised many concerns for these agencies [7]. Various treatment methods were implemented to eliminate the nitrobenzene from water, which include adsorption [8], photochemical which are easily accessible in nature.

Activated carbon is a sort of porous carbon material, which is defined by its penetrable structure and surface chemical properties. It can be prepared by the chemical activation or physical activation methods [15]. Chemical activation process is the most typical method that is used these days because the activation of the pores on the carbon takes place at the lower temperatures than the physical activation process. The yield is also higher with the chemical activation process [16,17]. Moreover, chemical activation process helps in developing the good porous structure on the activated carbon. Meanwhile the type of activating agent used is also the important factor to be considered for the development of good porous structure on the activated carbon. [18,19].

2. Materials used and Methodology

2.1 Materials used

The chemicals that are utilized in this study are: Nitrobenzene, Phosphoric acid, NaHCO3, Na2CO3, HCL, NaOH, NaCl, Water hyacinth.

2.2 preparation of activated carbon

Grounded water hyacinth was used for preparing activated carbon. The water hyacinth was washed with distilled water and then dried at 110°C for overnight and later grounded into powder. Then the grounded water hyacinth is subjected to phosphoric acid activation.

For phosphoric acid activation, the grounded water hyacinth was impregnated for 24 hours with 85%(vol) phosphoric acid in the proportion of 1:1(1g of phosphoric acid:1g of grounded water hyacinth). And then the specimen has been carbonised in the furnace with nitrogen flow. The heating rate of furnace was adjusted to 5°C /min from the room temperature to 400°C for a period of two hours. Afterwards, when carbon has reached its room temperature, it was washed with the distilled water until it has reached neutral pH. Then the specimen was dried in the oven at 110°C for overnight. And sealed in an airtight package.

2.3 batch adsorption experiments

Batch equilibrium method was adopted for the adsorption of nitrobenzene onto the activated carbon. 25mg of activated carbon is added to conical flasks with 25ml of nitrobenzene solution with the concentrations of 20mg L⁻¹, 100mg L⁻¹ and 200mg L⁻¹. The mixtures were shaken at a constant temperature of 25°C, using the temperature-controlled water bath shaker for 24 hours. Later, all the specimens were collected and filtered by a micropore membrane with a pore size of 0.45lm, and 1-2mL of filtrate was discarded. The residual concentrations of nitrobenzene solution were determined by using High Performance Liquid Chromatography (HPLC) “Jasco PU-2080Plus”. The mobile stage used for the determination of nitrobenzene is a mixture of acetonitrile, water and phosphoric acid in a ratio 20:1:79 respectively. For this mobile stage and flow rate of 1mL/min the retention time was found to be 6.47min.

The impact of the pH of the solution was determined by performing the adsorption process at various pH values ranging from 2 to 12, with a nitrobenzene concentration of 100 mg/L and a time period of 24 hours at 25°C. Drops of 0.1N HCl or NaOH were used to adjust the pH of the solutions.
3. Results and discussion

3.1 Effect of pH

The impact of pH on nitrobenzene removal by prepared activated carbon was studied. Diluted solutions of HCL and NaOH were used to adjust the pH of the solutions. The values are shown in the Figure 1, with an adsorption temperature of 25°C and the nitrobenzene concentration of 100 mg L\(^{-1}\). As it is seen in the figure, the adsorption of nitrobenzene at different pH levels has brought into light that the values are between 81.8 to 83.5 mg g\(^{-1}\). Hence, we can say that the pH value has very little influence on adsorption of nitrobenzene from the solution.

| pH  | 2   | 4   | 6   | 8   | 10  | 12  |
|-----|-----|-----|-----|-----|-----|-----|
| Q\(_{\text{eq}}\) | 81.8 | 82.1 | 82.4 | 82.7 | 83.1 | 83.5 |

**Figure 1:** Adsorption of activated carbon for different pH levels (conditions C\(_0\)= 100 mg L\(^{-1}\), agitation speed= 150rpm, contact time= 24hrs)
3.2 Effect of initial concentration and contact time

To create a cost-efficient process, the time taken to reach equilibrium is the important factor for adsorption methods. The removal time is heavily influenced by the properties of the AC surface. Therapid uptake and quick establishment of equilibrium reveal the potency of a particular adsorbent in wastewater treatment. Nitrobenzene’s adsorption onto activated carbon was investigated over a various interval of time to the nitrobenzene concentrations of 20mg/L, 100mg/L, and 200 mg/L. The changes in nitrobenzene concentration are plotted as qt along time. The figure 2 implies that the adsorption was very quick at first and then gradually increased with time till the equilibrium was reached.

As it is seen in the figure 2, the adsorption capacity elevated significantly with the increase in nitrobenzene concentrations, with maximum values of 19.3, 84.7, and 158.3 for the initial concentrations of 20mg/L, 100mg/L, and 200 mg/L. At low initial concentrations, nitrobenzene was found to rapidly reach equilibrium, which means it requires more time to reach the equilibrium with increasing initial concentration.

| Time (min) | 20mg L⁻¹ | 100mg L⁻¹ | 200mg L⁻¹ |
|------------|----------|-----------|-----------|
| 0          | 0        | 0         | 0         |
| 15         | 10.6     | 43.4      | 78.6      |
| 30         | 16.3     | 67.7      | 122.8     |
| 60         | 18.7     | 73.9      | 135.1     |
| 90         | 19.1     | 78.3      | 142.2     |
| 120        | 19.3     | 81.9      | 150.6     |
| 150        | 19.3     | 84.7      | 158.3     |
| 180        | 19.3     | 84.7      | 158.3     |
| 210        | 19.3     | 84.7      | 158.3     |
| 240        | 19.3     | 84.7      | 158.3     |
| 270        | 19.3     | 84.7      | 158.3     |
| 300        | 19.3     | 84.7      | 158.3     |

Figure 2. Adsorption capacity of activated carbon for different concentrations and time intervals
4. Conclusion
This analysis shows that the activated carbon formulated from water hyacinth is effective for the adsorption of nitrobenzene from the water. It has been come to light that the variation in the pH of the sample containing nitrobenzene does not have any considerable effect on the adsorption efficiency or the rate of adsorption by the activated carbon. But in the case of initial concentration of the sample with nitrobenzene shows that there was a major variation in adsorption by the activated carbon. The adsorption was rapid at the beginning and gradually increased after few minutes until the maximum adsorption value of activate carbon is reached. As the initial concentration increased the contact time also increased to reach the ultimate adsorption of the nitrobenzene by activated carbon.

Therefore, the activated carbon formulated from water hyacinth by phosphoric acid activation can be considered an efficient adsorbent for removal nitrobenzene from water.

5. References
[1] Sadeghalvad B, Khosravi S and Azadmehr A R 2016, Nonlinear isotherm and kinetics of adsorption of copper from aqueous solutions on bentonite, Russian Journal of Physical Chemistry, A 90 2285–91
[2] Liu J, Xin X and Zhou Q, Phytoremediation of Contaminated Soils Using Ornamental Plants Environmental Reviews, 26 (2018) 43-54.
[3] Liu G, Dong B, Zhou J, Wang J, Jin R and Li J 2017, Enhanced bioreduction of nitrobenzene by reduced graphene oxide materials: effects of surface modification and coexisting soluble electron shuttles, Environmental Science and Pollution Research 24 26874–80
[4] Yan Z G, Zhang Z S, Wang H, Liang F, Li J, Liu H L, Sun C, Liang L J and Liu Z T 2012, Development of aquatic life criteria for nitrobenzene in China, Environmental Pollution 162 86–90
[5] Pan J and Guan B 2010, Adsorption of nitrobenzene from aqueous solution on activated sludge modified by cetyltrimethylammonium bromide, Journal of Hazardous Materials 183 341–6
[6] US-EPA https://www3.epa.gov/airtoxics/pollsour.html
[7] Pan J, Guan B, Adsorption of nitrobenzene from aqueous solution on activated sludge modified by cetyltrimethylammonium bromide, Journal of Hazardous Materials, 183 (2010) 341-346.
[8] Boyd S A, Sheng G, Teppen B J and Johnston C T 2001, Mechanisms for the adsorption of substituted nitrobenzenes by smectite clays, Environmental Science and Technology, 35 4227–34
[9] Zhang L, He X, Xu X, Liu C, Duan Y, Hou L, Zhou Q, Ma C, Yang X, Liu R, Yang F, Cui L, Xu C and Li Y 2017, Highly active TiO2/g-C3N4/G photocatalyst with extended spectral response towards selective reduction of nitrobenzene, Applied Catalysis B: Environmental, 203 1–8
[10] Liu X-B, Lu H-Y, Huang W-M, Kong H-S, Ren X-B and Lin H-B 2012, Electrochemical Degradation of Nitrobenzene vol 16
[11] Chen C, Yan X, Yoza B A, Zhou T, Li Y, Zhan Y, Wang Q and Li Q X 2018, Efficiencies and mechanisms of ZSM5 zeolites loaded with cerium, iron, or manganese oxides for catalytic ozonation of nitrobenzene in water, Science of the Total Environment, 612 1424–32

[12] Li T, Deng X, Wang J, Chen Y, He L, Sun Y, Song C and Zhou Z 2014, Biodegradation of nitrobenzene in a lysogeny broth medium by a novel halophilic bacterium Bacillus licheniformis, Marine Pollution Bulletin, 89 384–9

[13] Jadhav A J and Srivastava V C 2013, Adsorbed solution theory based modeling of binary adsorption of nitrobenzene, aniline and phenol onto granulated activated carbon, Chemical Engineering Journal, 229 450–9

[14] Rauthula M S and Srivastava V C 2011, Studies on adsorption/desorption of nitrobenzene and humic acid onto/from activated carbon, Chemical Engineering Journal, 168 35–43

[15] Watson V J, Nieto Delgado C and Logan B E 2013, Influence of chemical and physical properties of activated carbon powders on oxygen reduction and microbial fuel cell performance, Environmental Science and Technology, 47 6704–10

[16] Arami-Niya A, Wan Daud W M A, S. Mjalli F, Abnisa F and Shafeeyan M S 2012, Production of microporous palm shell based activated carbon for methane adsorption: Modeling and optimization using response surface methodology, Chemical Engineering Research and Design, 90 776–84

[17] Daoud M, Benturki O, Fontana S, Rogaume Y and Girods P 2019, Energy and matter balance of process of activated carbon production from Algerian agricultural wastes: date palm rachis and jujube stones, Biomass Conversion and Biorefinery, (2019) 1-18.

[18] Ahmadpour A, Do D D, The preparation of active carbons from coal by chemical and physical activation, Carbon, 34 (1996) 471-479

[19] Daoud M, Benturki O, Girods P, Donnot A and Fontana S 2019, Adsorption ability of activated carbons from Phoenix dactylifera rachis and Ziziphus jujube stones for the removal of commercial dye and the treatment of dyestuff wastewater, Microchemical Journal, 148 493–502