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The Application of Activated Carbon in The Removal of Organic Compounds from Wastewater

Jihang Xue[1, a]

[1]Queen Mary University of London Engineering School, Northwestern Polytechnical University, Xi'an, 710129, China
[a]chri030718@gmail.com

Abstract: Removing organic compounds from wastewater is a crucial process to protect the environment and human health. It's high for activated carbon to adsorb capacity and efficiency due to it has been proved that it is a promising option which is powerful for the removal of organic compounds. This paper explores the performance of activated carbon in various wastewater treatment processes, including case studies and experimental data on the use of activated carbon in how to remove specific organic compounds. The discoveries in this review article offer the insights for further research into the potential for improving the effectiveness and efficiency of activated carbon based the processes of wastewater treatment.

Keywords: Activated carbon, Wastewater treatment, Organic compounds, Adsorption mechanisms, Performance evaluation.

1. Introduction

The rampant release of organic pollutants from industries has taken a severe toll on the quality of water, creating an alarming threat to the ecosystem and human health alike. However, there is a glimmer of hope in the form of activated carbon(AC), which promises to be a highly efficient and economical method for purging these pollutants from wastewater. With its exceptional adsorption capacity, activated carbon acts as a magnet to attract and eliminate organic compounds from wastewater, making it a popular and reliable tool in water treatment processes.[1] The paper endeavors to delve deeper into the myriad benefits of utilizing activated carbon to rid wastewater of these harmful contaminants, highlighting its potential to revolutionize the way we tackle water pollution.

2. Case Studies on The Removal of Specific Organic Compounds by Activated Carbon

2.1. Removal of pharmaceuticals

Pharmaceuticals are the most difficult class of organic compounds to remove from wastewater because of their low biodegradability and potential negative effects on health of human and the our environment. Activated carbon, shown as an effective solution in removing different kinds of pharmaceuticals from wastewater, including antibiotics, hormones and painkillers.

For example, a study by Wang J, et al. investigated the removal of four common antibiotics (tetracycline, sulfamethoxazole, erythromycin, and ciprofloxacin) from synthetic wastewater using powdered activated carbon (PAC). The results showed that PAC had the ability to remove antibiotics up to 99%, with one of the highest productivity of removal for tetracycline[2] .

2.2. Dye removal

There are many industries that require the use of dyestuffs, such as textiles, paper and leather, which's presence in the waste water can have a negative impact on the environment. Activated carbon has been cosidered to be effective in removing various dyes, including acidic, reactive and basic dyes, from wastewater.

For example, Aksakal O et al. (2010) investigated how to use granular activated carbon (GAC) to remove reactive dyes (reactive red 195) from waste-water. The results were GAC was able to remove as high as 99.7% of the dye, with the highest removal efficiency at a pH of 7.0[3] .

Similarly, another study by Vargas A M M et al. (2012)came to an investigation about the use of powdered activated carbon (PAC) for the dye acid yellow ascription the from waste-water, which was found it was tend to be effective. The results showed that PAC had an effective influence in removing the dye, which's maximum removal efficiency is 97.7% at an initial concentration of dye is 50 mg/l. [4]

2.3. Removal of pesticides

Pesticides are extensively used in agriculture which is tend to control pests and improve crop yields, but their presence in wastewater can have a negative impact on the environment. Activated carbon, known as an effective material in treating with a variety of pesticides from wastewater, including atrazine, simazine and imidacloprid.

For example, a study by Xiao Y,et al. (2017) was investigating the use of granular activated carbon (GAC) in the area of removal about atrazine from synthetic wastewater. The results appeared that GAC was able to remove as much as 98% of atrazine, with the highest removal efficiency at an initial concentration of atrazine is 5 mg/l.[5]

2.4. Removal of phenols

Activated carbon is widely used for the reduction of phenols which is included in the wastewater as it had a high ability of adsorbing capacity for phenolic compounds. The removal efficiencies depend on several factors including the type of activated carbon used, the concentration that in initial of phenols in the wastewater and the time of contacting of the activated carbon with the wastewater. Studies have shown that powdered activated carbon (PAC) along with granular activated carbon (GAC) are effective in the reduction of phenols from wastewater. [6] Moreover, activated carbon fibre (ACF) has also been found effective in removing phenol because of its high surface area and microporous structure.

Several studies have reported the successful removal of various phenols from wastewater with activated carbon, including phenol, 2-chlorophenol, 2-nitrophenol and 2,4-dinitrophenol. In a study by Ma Y, a removal efficiency of 99% was found for phenol using GAC at a time of contact of 8 hours and an original phenol concentration of 200 mg/l. In another study, the removal of 2-chlorophenol by PAC was found to be 93% at a exposure time of 4 hours and an initial concentration，100 mg/L. [7]

Overall, activated carbon has been considered to be an relatively effective method in the area of the removal of phenol from wastewater and its effectiveness can be optimised by selecting the right type of activated carbon and adjusting factors such as initial concentration and time of contacting.

3. Analysis of the Effect of Operating Conditions on The Performance of Activated Carbon

3.1. Contact time

Contact time is defined as the length of time that the wastewater is in contact with the activated carbon. The longer the contact time, the higher the capacity of the activated carbon to adsorb organic compounds..

Several researches have investigated the influence of time of contacting on the performance of activated carbon. For example, Li et al. (2020),as in Fig1, investigated the adsorption of t-chloroaniline on GAC and found that the removal efficiency increased with increasing contact time. [8]

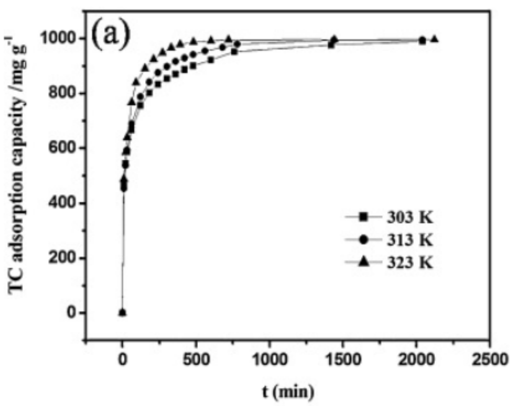

Figure 1. Contact time effect

3.2. pH

The pH value can make effect in the activated carbon there exist surface charge, and the ionisation of pollutants in the wastewater, thus affecting the adsorption capacity of the activated carbon.

There are some studies have investigated something about effects of pH on the performance of activated carbon. For example, as shown in Fig. 2, Gupta et al. (2016) studied the removal rate of the malachite green with activated carbon and reported the effective effect of pH on adsorbing MG on STAC at an starting dye concentration of 100 mg / L, an adsorbent dose of 0.08 g / 100 ml and an equilibrium time of 3 h at 25 ° C. The quantitative result of MG adsorbed on STAC increased from pH 2 to 10, with a significant increase at pH 2-4, while it values above pH 4 remained almost unchanged. The decrease in adsorption below pH 4 is due to the fact that electrostatic can make repulsion between the positively charged cations of the dye and excess H ions competing for adsorbing sites. At a higher pH, the surface of the adsorbent appeared negative charged, which increases the affinity for the positive charged dye molecules. Malachite green becomes more deprotonated with pH increasing, and the zwitterionic form of malachite green in aqueous solution can lead to aggregation of malachite green into larger molecular forms that cannot penetrate the porous structure of the adsorbent.[9]

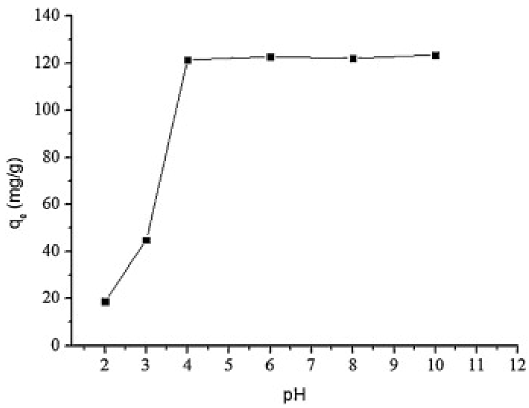

Figure 2. pH effect on sorption of MG onto STAC.

3.3. Temperature

Temperature affects the contaminant and the activated carbon's kinetic energy, thus affecting the capacity to absorb the activated carbon.

Li et al. (2010) researched the adsorption of tetracycline on ACF and found that the efficiency of removal increased with decreasing temperature. Fig. 3 shows that temperature's effect on TC adsorption and it's clear that the equilibrium adsorption improved significantly when it is increasing temperature over a range of ACF dosages from 0.01 to 0.5 g. The increase in temperature enhanced TC's diffusion rate into the vicinity of the ACF and into the surface pores due to the reduction in solution viscosity. In addition, the equilibrium adsorption capacity varied with temperature. [10]

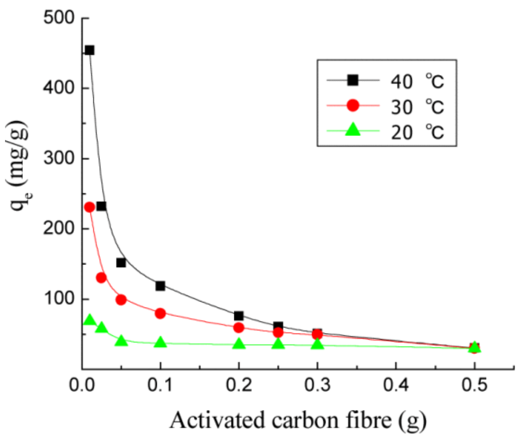

Figure 3. Effect of temperature on the removal of TC. Initial TC concentration 300 mg/L.

3.4. Concentration of pollutants

The concentration of pollutants in wastewater can also affect the absorbency demonstration of activated carbon in wastewater treatment. The adsorption ability of activated carbon decreases with pollutant concentration increased due to saturation of the adsorption point.

Several studies have investigated what was the effect in contaminant concentration on the performance of activated carbon. As shown in Fig. 4 the percentage reduction of atrazine for different doses of PAC as a function of time. Due to the large number of active areas on the PAC surface, the initial rapid decrease of atrazine occurred within the first 30-45 minutes of the experiment. At a total exposure minutes of 60 and carbon doses of 4-20 mg L-1, the reduction of atrazine ranged from 15-83%. After 45 min, the reduction continued to increase, but at a less pronounced slope. However, after contact time up tp 10 hours, the reduction of contaminants increased only slightly, indicating a reduction in the active site of the PAC and thus, inevitably, the drive for adsorption is reduced.[11]

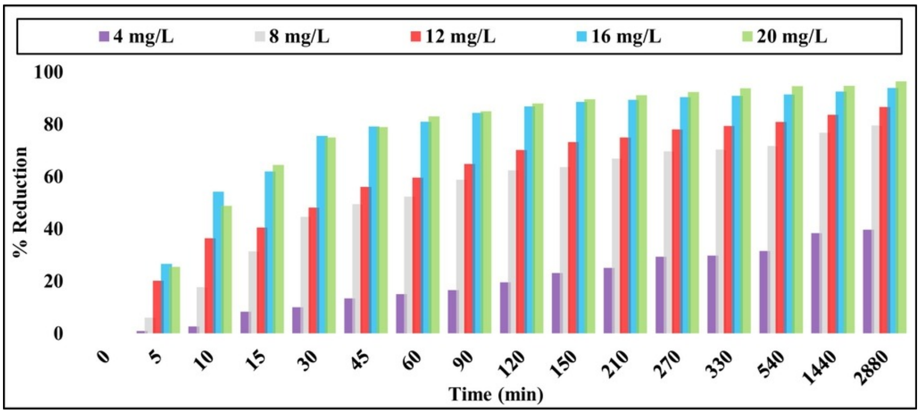

Figure 4. Atrazine reduction evolution over time with different doses of PAC. Experimental conditions: [Atrazine0] = 0.7 mg L−1; [PAC] = 4, 8, 12, 16 and 20 mg L−1.

Overall, the performance of activated carbon in treatment of wastewater can be significantly influenced by various operating conditions such as contact time, pH, temperature and pollutant concentration. It is essential to optimise these operating conditions to achieve optimum performance of activated carbon in wastewater treatment.

4. Data Analytics and Regression Methods

In activated carbon research, regression analysis has been used to study the relationships between the performance of activated carbon in wastewater treatment and various process parameters, for example, contact time, pH and temperature can also do effect on it. The advantages of regression analysis include the ability to identify significant variables, optimise process parameters and develop predictive models. However, researchers must also be aware of the limitations of regression analysis and carefully design their experiments to ensure that the assumptions of the regression model are met.

Linear regression is the simplest and most widely used regression method. As shown in Fig. 5, it is used to establish a linear relationship between a dependent variable and one or more independent variables.

Sometimes we also use multiple linear regression,like Fig. 6. , to categorize the data. It is generally used when there are two or more independent variables and can be used to establish a linear relationship between the dependent variable and two or more independent variables.

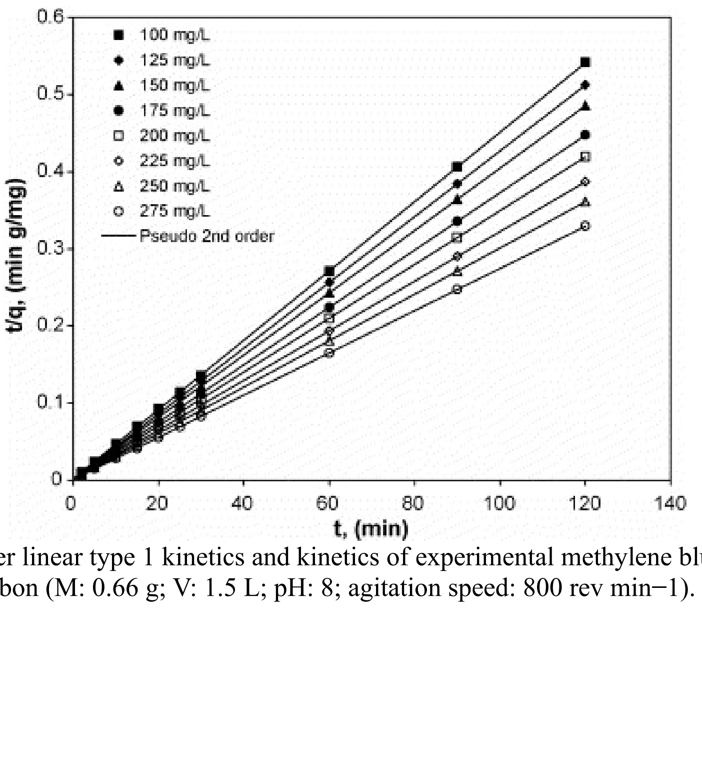

Figure 5. Pseudo-second-order linear type 1 kinetics and kinetics of experimental methylene blue absorption on activated carbon (M: 0.66 g; V: 1.5 L; pH: 8; agitation speed: 800 rev min−1).

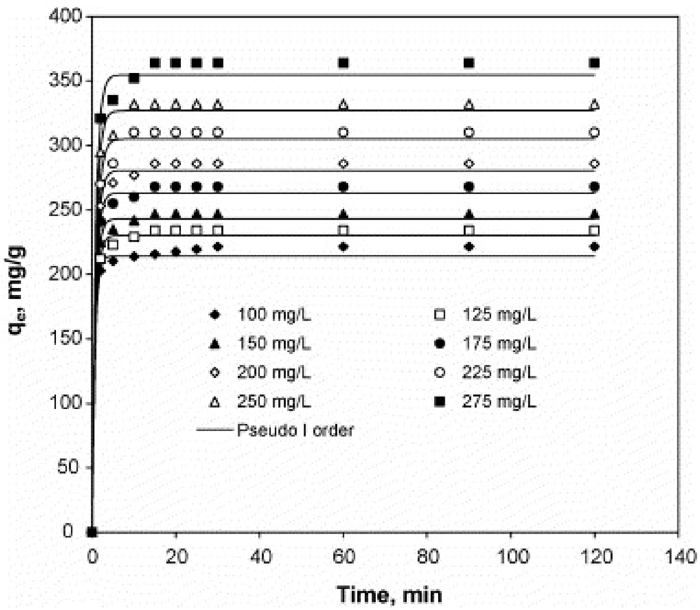

Figure 6. Pseudo first-order Lagerhren kinetics by nonlinear methods and absorption kinetics of methylene blue on experimental activated carbon (M: 0.66 g; V: 1.5 L; pH: 8; agitation speed: 800 rev min−1).

5. Conclusion

Activated carbon is an effective adsorption material for reducing organic compounds from wastewater. The functional efficiency of activated carbon in wastewater treatment depends on several factors, such as the type of activated carbon used, the conditions of use and the type of organic compounds to be treated. The mechanisms by which activated carbon removes organic compounds include physical and chemical adsorption, as well as pore filling and surface complexation. The adsorption capacity and efficiency of activated carbons are influenced by several factors, including pore size distribution, surface functional groups, surface area, and pH. Comparative studies have shown that activated carbon is generally superior to other adsorption materials in the organic compounds removal.

However, further research is necessary to make progress in the effectiveness and activated carbon-based efficiency in wastewater treatment processes. For instance, more study is strongly needed to optimize the use of different types of activated carbon, develop new treatment processes and technologies, and improve the regeneration and reuse of spent activated carbon. In addition, there is a need to investigate the long-term performance and stability of activated carbon in wastewater treatment. The environmental impact of activated carbon production and disposal is another critical issue that needs to be addressed.

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