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Sorption Characteristics and Removal Efficiency of Pharmaceutical Pollutant "Tylosin" in Wastewater using Activated Carbon

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ABSTRACT

Tylosin, a commonly used antibiotic, is widely detected in the aquatic environment. Its presence in water has a potentially negative impact on aquatic ecosystems and human health. This study focused on the removal of tylosin from water by adsorption on activated carbon. Batch experiments were carried out to study adsorption kinetics, equilibrium isotherms and the influence of operating parameters such as adsorbent mass, temperature, pH and solution ionic strength on the adsorption capacity. The kinetics were best described by a pseudo second-order model and the adsorption isotherm followed the sips model. Temperature and adsorbent mass, together with solution chemistry such as pH show a clear effect on the sorption of tylosin onto activated carbon.

Keywords: Adsorption, Tylosin, Activated carbon, Water treatment

1 Introduction

Tylosin, one of the most commonly used veterinary antibiotic, has been shown to promote animal growth and is widely used as a therapeutic substance in the treatment of mycoplasmosis in poultry and livestock. Unfortunately, 50% to 80% of tylosin is excreted [1] and frequently detected in aquatic environments around the world. Tylosin has been detected in raw wastewater, treated wastewater, surface water and even in drinking water at concentrations ranging from undetected to 3400 ng.L^{-1} [2,3,4,5]. Accumulated tylosin could induce genetic exchange, increase the resistance of bacteria to drugs and have a potentially negative impact on aquatic ecosystems and human health. Therefore, the efficient removal of low concentrations of tylosin from water is of great concerns for water condition and ecological environment protection. Adsorption technology is an important method in advanced water treatment due to its versatility, easy operation and high efficiency. Comparing to biodegradation, oxidation and photocatalyticdegradation, adsorption is a preferred strategy for dealing with wastewater containing hard-degradable pollutants such as pharmaceutical antibiotics [6]. Porous carbons are the most frequently used adsorbents in contaminant removal and exhibit excellent adsorption performance towards various chemicals ranging from hydrophobic organic contaminants to heavy metals [6]. In this study, a commercial activated carbon of a high specific surface area (720m^2.g^{-1}) was used to investigate the predominant factors that control the tylosin removal by adsorption onto activated carbon.

2 Experimental

The adsorption experiments were carried out in static mode, which consisted of bringing a volume (50mL) of a tylosin solution of known concentration (from 5 to 100 ppm) into contact with a mass of carbon (5mg) previously dried at 105°C. The adsorbate-adsorbent systems were stirred continuously for a specified time. After adsorption, the samples were taken, centrifuged, filtered using a syringe filter (0.45µm) and then analysed by UV-visible spectrophotometry at a wavelength of 290 nm. By comparing the residual tylosin concentration of the supernatant with that of the initial solution, the sorption capacity of the adsorbent was determined. These experiments highlighted the influence of several operating parameters (contact time, initial tylosin concentration, carbon mass, pH, temperature and ionic strength) on the adsorption capacity of the activated carbon.

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3 Results and Discussion

These experiments showed that for fine particles of activated carbon (dp ≤150 µm), the removal efficiencies reach a value of 74% for an antibiotic initial concentration of 10 ppm. This efficiency increases with the mass of carbon and is much higher in basic media (pH>6,60). Apart from pH**,** ionic strength may be another important factor that influences the adsorption process. The results of this study showed that, despite a significant increase in the electrolyte concentration (from 0.5 to 4 M), ionic strength an insignificant effect on the adsorption capacity of activated carbon compared to pH, which may be due to electrostatic screening of the concentrated ions of NaCl.

The adsorption kinetics of tylosin onto the activated carbon exhibits three-stage intra-particle diffusion mode: initially, the kinetics of adsorption is rapid reflecting a good affinity of tylosin with the free active sites present on the surface of the carbon, then slows down to tend towards a plateau due to the saturation of the surface of the adsorbent. These adsorption kinetics data are well described by the pseudo-second-order model [7]. This indicates that the adsorption behaviour of tylosin is obvious and that the rate during the adsorption is controlled by a chemical process.

The adsorption capacity of the activated carbon increases with the antibiotic initial concentration (from 5 to 100 ppm) and the relative experimental adsorption isotherm (type L) is well represented by the Sips model [8]. This model is based on the heterogeneity of the adsorption sites with adsorbate-adsorbent interactions that become more important with increasing temperature which results in an endothermic adsorption mechanism. The adsorption tests carried out under different temperatures (from 5 to 35°C) show that the adsorption efficiency increases with the increase in the adsorption temperature. This thermodynamic study reveals that the phenomenon of adsorption of tylosin on activated carbon is spontaneous, endothermic and chemical in nature.

4 Conclusions

Adsorption on activated carbon appears to be a promising technique for decontaminating water polluted by a pharmaceutical pollutant such as tylosine widely used in the veterinary medicine throughout the world.

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