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EFFICIENT REMOVAL OF AMOXICILLIN AND LEVOFLOXACIN FROM AQUEOUS SOLUTIONS USING CHITOSAN BEADS

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Abstract

This study investigated the adsorption of Amoxicillin and Levofloxacin using chitosan beads. Both antibiotics are widely prescribed and frequently found in wastewater due to their partially unchanged excretion. Amoxicillin, belonging to the penicillin class, is excreted 60-80% unchanged, while Levofloxacin, a fluoroquinolone, is excreted 80-85% unchanged. The research focused on obtaining adsorption isotherms at room temperature. The experiment was conducted at pH 5, using 25 mL of solution at 25°C, with 50 mg of dry adsorbent. Chitosan, a biopolymer derived from chitin, was chosen for its unique properties, including biocompatibility, biodegradability, and functional groups that facilitate adsorption. Its ability to form beads increases its practical applicability. Results showed an adsorbed amount of 142 mg g^{-1} for Amoxicillin and 209 mg g^{-1} for Levofloxacin, indicating the effectiveness of chitosan beads in removing these antibiotics from aqueous solutions. This method offers a sustainable and efficient solution for mitigating antibiotic contamination in aquatic systems, aligning with principles of green chemistry and sustainable environmental management.

Keywords: Chitosan beads; Antibiotic adsorption; Amoxicillin; Levofloxacin; Sustainable wastewater treatment

1. Introduction

Amoxicillin and Levofloxacin are antibiotics capable of eliminating or inhibiting the multiplication of bacteria (Donnelly et al. 2024). Amoxicillin belongs to the penicillin class and is one of the most prescribed medications in the United States, with over 25 million prescriptions in 2022 alone (Cohen et al. 2023). Amoxicillin continues to see an exponential increase in prescriptions worldwide (Georgin et al. 2020). Common dosing of amoxicillin for adults includes 500 mg every 8 hours or 875 mg every 12 hours (Huttner et al., 2020). However, amoxicillin is largely excreted in the urine within the first few hours without structural alteration. The estimated percentage of the administered amoxicillin dose excreted in the urine without undergoing structural alterations ranges between 60% to 80% (Ding et al. 2023). Consequently, amoxicillin is one of the most commonly found antibiotics in wastewater (Al-Saidi et al. 2023).

Levofloxacin is a broad-spectrum antibiotic medication used to treat various bacterial infections. It belongs to the fluoroquinolone class of antibiotics. It works by inhibiting bacterial DNA replication, thus stopping the growth and spread of bacteria. Levofloxacin is effective against both gram-positive and gram-negative bacteria, making it useful for a wide range of infections. Approximately 85-95% of orally administered Levofloxacin is absorbed by the gastrointestinal tract, with about 80-85% of the administered dose eliminated in urine as unchanged drug within 24 hours, while less than 5% is metabolized and excreted as metabolites, and less than 5% is eliminated in feces.

Conventional water treatment methods, such as chlorination, ozonation, and advanced oxidation processes, often fall short in effectively removing pharmaceutical contaminants like amoxicillin

(Michael-Kordatou et al. 2015; Rivera-Utrilla et al. 2013).

Adsorption stands out as a promising alternative due to its high efficiency, selectivity, and versatility. This technique can effectively capture contaminants from liquids and gases, making it applicable across various industries, including water treatment, pharmaceuticals, and environmental remediation. The use of biocompatible materials like chitosan beads enhances the appeal of adsorption, offering a sustainable and efficient solution for mitigating antibiotic contamination in water systems (Crini and Badot, 2008). Chitosan's unique properties, such as its high adsorption capacity, biodegradability, and non-toxicity, make it particularly suitable for removing pharmaceutical compounds from aqueous solutions. Its ability to form beads further increases its practical applications, allowing for easy handling and recovery in treatment processes. This approach not only addresses the pressing issue of antibiotic pollution but also aligns with the principles of green chemistry and sustainable environmental management.

Adsorption, involving the transfer of a substance from a fluid phase (adsorbate) to a solid phase (adsorbent), proves to be a promising technique. The advantages of adsorption include its relatively low cost, high efficiency, operational ease, possible regeneration of the adsorbent, and versatility in eliminating various pharmaceuticals, regardless of their specific chemical properties (Moro et al. 2017).

Adsorption can be adjusted to various operational conditions, including pH, temperature, and drug concentration. The pH of the medium significantly influences the charge of both the adsorbent and adsorbate, providing a straightforward method to control adsorptive properties. Consequently, adsorption and desorption processes can be managed through variations in pH or ionic strength (Pinheiro et al., 2021). This adaptability allows for fine-tuning of the adsorption process to optimize efficiency for specific applications.

Chitosan is a biopolymer with unique properties that make it attractive for adsorbing pharmaceutical compounds from aqueous solutions (Benettayeb et al., 2023). It is derived from chitin through a deacetylation reaction process in an alkaline medium. This natural polymer offers several advantages, including biocompatibility, biodegradability, and the presence of functional groups that facilitate the adsorption of various molecules, including antibiotics. Its renewable source and eco-friendly nature further enhance its appeal for environmental applications. Chitosan's versatility and effectiveness in adsorption processes make it a valuable material for removing contaminants from water, particularly in the context of pharmaceutical pollutants.

The objective of this study was to investigate the adsorption of Amoxicillin and Levofloxacin using chitosan beads. The research focused on obtaining adsorption isotherms at room temperature for both antibiotics. These isotherms were then fitted to two widely used adsorption models: Langmuir and Freundlich. By conducting these experiments and applying these models, the study aimed to characterize the adsorption behavior of Amoxicillin and Levofloxacin onto chitosan beads, providing insights into the efficiency and mechanisms of this adsorption process. This approach allows for a comprehensive understanding of the adsorption capacities and the nature of the interactions between the antibiotics and the chitosan bead adsorbent under ambient conditions.

2. Material and methods

After establishing standard curves for amoxicillin and levofloxacin using a spectrophotometer at wavelengths of 279 nm and 294 nm, respectively, these curves were used to determine the concentrations of amoxicillin and levofloxacin solutions.

The adsorption of levofloxacin and amoxicillin using chitosan beads was performed under controlled conditions. The experiments were conducted at pH 5, using 25 mL of solution for each test, at a constant temperature of 25 °C. Fifty milligrams of dry chitosan bead adsorbent were used in each trial. The adsorption process was allowed to proceed for 12 hours to ensure equilibrium was reached. The initial concentrations of the antibiotics ranged from 50 mg L^{-1} to 600 mg L^{-1}.

The pH of each solution was adjusted using McIlvaine buffer, a mixture of disodium phosphate and citric acid. The buffer was added at 5% of the total volume of the antibiotic solution. This method was applied to both amoxicillin and levofloxacin solutions to maintain consistent pH conditions throughout the adsorption experiments.

The adsorbed amount was calculated by Equation 1.

$$q_e = \frac{(C_0 - C_e)}{m} V \qquad (1)$$

where q_e is adsorbed amount (mg g^{-1}), C_0 and C_e are the initial and equilibrium antibiotic concentrations in the liquid phase (mg L^{-1}), respectively; m is the adsorbent mass (g) and V is the volume of the solution (L),

3. Results

Table 1 presents the relationship between the initial concentration of Amoxicillin in solution (mg L^{-1}) and the amount of Amoxicillin adsorbed per gram of chitosan beads (mg g^{-1}). There is a clear positive correlation between the initial concentration of Amoxicillin and the adsorption capacity of the chitosan beads. As the initial concentration increases, the amount of Amoxicillin adsorbed also increases.

The relationship is not strictly linear. The rate of increase in adsorption capacity tends to slow down at higher concentrations, suggesting a potential approach to saturation. The adsorption capacity ranges from 0 mg g^{-1} (at 0 mg L^{-1} initial concentration) to 142 mg g^{-1} (at 600 mg L^{-1} initial concentration).

Even at relatively low initial concentrations (50-100 mg L^{-1}), the chitosan beads show significant adsorption capacity (20-38 mg g^{-1}).

Table 1. Amoxicillin amount adsorbed on Chitosan beads

Initial concentration of Amoxicillin (mg L^{-1})	Amoxicilina (mg g^{-1})
0	0
50	20
100	38
150	46
200	66
250	80
300	88
350	108
400	112
450	120
500	134
550	138
600	142

The table 2 presents the results of an experiment investigating the ability of chitosan beads to remove levofloxacin from aqueous solutions. The amount of levofloxacin adsorbed by the chitosan beads increases as the initial concentration of levofloxacin in the solution increases. This indicates that the chitosan beads have a higher adsorption capacity when there is more levofloxacin available to be removed. From a certain initial concentration of levofloxacin, the adsorbed amount seems to stabilize. This suggests that the chitosan beads have reached their maximum adsorption capacity for levofloxacin.

The adsorption of levofloxacin by the chitosan beads likely occurs through intermolecular interactions, such as van der Waals forces, hydrogen bonding, and ionic interactions. The structure of chitin, with its functional groups, favors the adsorption of polar molecules like levofloxacin

Table 2. Levofloxacin amount adsorbed on Chitosan beads

Initial concentration of Levofloxacin (mg L^{-1})	Levofloxacin (mg g^{-1})
0	0
50	32
100	55
150	66
200	80
250	98
300	112
350	132
400	155
450	166
500	192
550	200
600	209

4. Conclusion

The results indicate that chitosan beads could be an effective adsorbent for removing levofloxacin and amoxicillin from wastewater. This has significant implications for the treatment of water contaminated with antibiotics.

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