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Competitive Adsorption Studies of Cd(II) and As(III) by Poly (Butylene Succinate) Microplastics: Based on Experimental and Theoretical Calculation

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Introduction

The increasing presence of microplastics in the environment has raised significant concerns about their impact on both ecosystems and human health. Among the various types of microplastics, Poly(Butylene Succinate) (PBS) has emerged as a promising biodegradable plastic that is often used in packaging, agricultural applications, and other industries. However, due to its widespread use, PBS microplastics are increasingly being detected in environmental media such as water, soil, and sediments. Microplastics, including PBS, can act as vectors for the adsorption of heavy metals and other pollutants, which are then transported through various ecosystems. Cadmium (Cd(II)) and Arsenic (As(III)) are two toxic heavy metals commonly found in polluted environments, and their presence poses serious risks to both human and ecological health. Studies have shown that microplastics can adsorb metal ions from contaminated environments, potentially influencing the bioavailability, mobility, and toxicity of these pollutants.

The adsorption of heavy metals by microplastics is a complex process that involves various mechanisms such as electrostatic interactions, van der Waals forces, and chemical bonding. Understanding the competitive adsorption of Cd(II) and As(III) on PBS microplastics is vital for evaluating their potential applications in environmental remediation, particularly in areas where both metals coexist in contaminated environments. This research aims to explore the adsorption behavior of these heavy metals, identify the key factors influencing their uptake, and provide a theoretical model to predict the adsorption capacity and efficiency of PBS microplastics in real-world applications [1].

Description

The competitive adsorption of Cd(II) and As(III) by PBS microplastics was investigated under various experimental conditions, including different pH levels, initial metal concentrations, and contact times. The results indicated that the adsorption capacity of PBS microplastics was significantly influenced by pH, with optimal adsorption occurring at slightly acidic to neutral conditions. At low pH, the surface of the microplastics becomes protonated, which enhances the interaction between metal ions and the microplastic surface. This is particularly important for Cd(II) adsorption, as the positive charge of Cd(II) is more likely to be attracted to the negatively charged sites on the microplastic surface. On the other hand, As(III) tends to be more stable under neutral to slightly acidic conditions, making it more easily adsorbed by PBS microplastics under these pH conditions. The competition between Cd(II) and As(III) for adsorption sites on the microplastic surface was also examined, with results suggesting that Cd(II) exhibited a higher affinity for PBS microplastics compared to As(III). This can be attributed to the smaller ionic radius and higher charge density of Cd(II), which allows for stronger interactions with the functional groups on the microplastic surface.

To further investigate the competitive adsorption process, theoretical calculations based on adsorption isotherms and thermodynamic models were used. The Langmuir and Freundlich isotherm models were applied to describe the adsorption equilibrium between the metal ions and PBS microplastics. The Langmuir model, which assumes monolayer adsorption on a surface with a finite number of adsorption sites, provided a better fit for the experimental data, suggesting that the adsorption of Cd(II) and As(III) on PBS microplastics is primarily governed by surface saturation. The competitive adsorption studies revealed that the presence of one metal ion (e.g., Cd(II)) reduced the adsorption capacity of the microplastics for the other metal (e.g., As(III)), indicating that the metals compete for available adsorption sites. Thermodynamic parameters such as free energy change (ΔG), enthalpy change (ΔH), and entropy change (ΔS) were calculated to assess the feasibility and spontaneity of the adsorption process. The negative values of ΔG indicated that the adsorption of both metals onto PBS microplastics is spontaneous, while the positive values of ΔH suggested that the process is endothermic. This implies that higher temperatures may favor the adsorption of heavy metals onto PBS microplastics, potentially improving the efficiency of the adsorption process in warmer environments.

In addition to the experimental and theoretical approaches, the impact of metal ion concentration and contact time on the adsorption efficiency was examined. The adsorption capacity increased with the concentration of Cd(II) and As(III) up to a certain point, after which the adsorption sites on the PBS microplastics became saturated. The kinetics of the adsorption process were best described by the pseudo-second-order model, which suggests that the rate-limiting step is the chemical adsorption of metal ions onto the surface of the microplastics. The adsorption equilibrium was reached within a relatively short time, indicating that PBS microplastics can be used as efficient adsorbents for the removal of Cd(II) and As(III) from contaminated water. Furthermore, the regeneration and reusability of PBS microplastics were assessed, with results showing that the microplastics could be effectively regenerated using an acidic solution and reused for multiple adsorption cycles. This characteristic makes PBS microplastics a cost-effective and sustainable solution for environmental remediation, particularly in areas affected by heavy metal contamination [2].

Conclusion

In conclusion, PBS microplastics exhibit a significant potential for the competitive adsorption of Cd(II) and As(III) from contaminated environments. The experimental and theoretical studies show that the adsorption of these heavy metals is influenced by factors such as pH, metal concentration, and contact time, with Cd(II) demonstrating a higher affinity for PBS microplastics than As(III). The results also indicate that the adsorption process follows a monolayer adsorption model, with the presence of one metal ion reducing the adsorption capacity for the other due to competition for surface sites. The thermodynamic analysis suggests that the adsorption of both metals is

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spontaneous and endothermic, making PBS microplastics a viable material for heavy metal removal in warmer conditions. Furthermore, the reusability of PBS microplastics, along with their ability to adsorb multiple metal ions, makes them an attractive and sustainable option for environmental remediation applications.

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