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Extraction and recycling utilization of metal ions (Cu^{2+}, Co^{2+} and Ni^{2+}) with magnetic polymer beads

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HIGHLIGHTS

- ▶ Some metal ions were fully recycled during the purification by magnetic sorbent.
- ▶ The concentrations of Ni^{2+}, Co^{2+} and Cu^{2+} reduced down to 1 mg L^{-1} after treatment.
- ▶ The recovery efficiency of captured metal ions is more than 99% in acidic conditions.
- ▶ The excellent regeneration and reuse of magnetic beads makes this technology more efficient.

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ABSTRACT

An effective method was developed to isolate heavy metal ions (Cu^{2+}, Ni^{2+} and Co^{2+}) from the aqueous solution by the magnetic polymer beads. Meanwhile, the bound metal ions could be completely recovered to actualize their recyclable utilization. The magnetic sorbent was prepared with micro-suspension polymerization and its surface was modified with amino groups. After the adsorption by these magnetic beads, the residual concentrations of these metal ions (Cu^{2+}, Ni^{2+} and Co^{2+}) could be reduced to 0.537, 1.0 and 0.01 mg L^{-1}, respectively. The corresponding recovery efficiency of the bound metal ions exceeded 98%, which meant the almost all metal ions could be fully recycled without change their valence state and chemical properties. The adsorption equilibrium and kinetics were also studied. It found that the only a monolayer of metal ions was absorbed on the surface of these magnetic beads. The saturated amount of Co^{2+}, Ni^{2+} and Cu^{2+} reached to 50.3, 49.6 and 51.7 mg g^{-1}, respectively and each amino group on the magnetic beads could capture a metal ion. The adsorption kinetics became more suitable to be described by pseudo-second-order equation. These magnetic beads displayed higher adsorption capacity towards the metal ions in the pH range of 3–5. In addition, temperature had little effect on the adsorption capacity. The regeneration efficiency of this magnetic sorbent in NaOH solution exceeded 98% and the repeated use of these magnetic beads was much excellent.

1. Introduction

Contamination of heavy metals in the surroundings has done great harm to human and other organism due to their high toxicity and carcinogenicity [1–3]. Nickel, cobalt and copper are such metals, which are frequently present in polluted water from various industrial processes, such as catalysts, mineral processing, electrical apparatus, painting and coating and agricultural materials [4–6]. On the other hand, these metals are becoming scarce with their wide applications in many industrial fields resulting in the continuous increase in their price. Therefore, it is urgent to develop some new technologies to recycle these metals in the process of the wastewater treatment due to their great economic value [7].

Although the biological treatment of wastewater is one of the most promising technologies in water purification due to its low cost, large capacity, high efficiency and environment-friendly green composites, it is still difficult to recover the heavy metal ions without changing these chemical properties and avoid the responding biological pollution [8]. Other main technologies have been developed to remove Ni(II), Cu(II) and Co(II) from industrial wastewater, such as adsorption on activated carbon and clay [9], chemical precipitation [10], electrochemical deposition [11], and ions exchange [12]. Adsorption of heavy metal ions on the clay and activated carbon has been widely employed due to the extensive resource of these sorbents [13]. But, the high operational cost of the recovery of bound heavy metals and the regeneration of this sorbent has limited their application in recycling utilization of these heavy metals [14]. Chemical precipitation is much popular in current industry process owing to its simple operation and swift

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