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Concurrent removal of Cr(III), Cu(II), and Pb(II) ions from water by multifunctional TiO_2/Alg/FeNPs beads

Devagi Kanakaraju [a, *], Nurfatyha Rusydah bt Mohamad Shahdad [a], Ying-Chin Lim [b], Andrea Pace [c]

[a] Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, Malaysia
[b] School of Chemistry and Environment, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[c] Dipartimento di Scienze e Tecnologie Biologiche Chimiche e Farmaceutiche - STEBICEF, Università Degli Studi di Palermo, Viale Delle Scienze, Edificio 17, I-90128, Palermo, Italy

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ABSTRACT

The use of multifunctional materials for water remediation is a modern approach where adsorption phenomena and heterogeneous photocatalysis can be applied for the removal of pollutants. Since the ideal remediation system should be able to remove both organic and inorganic pollutants, a crucial aspect to consider is the knowledge of operational parameters affecting the removal process, especially when heavy metal ions are present in concoction as in real systems. Given the proven efficiency of multifunctional TiO_2/Alg/FeNPs magnetic beads for the removal of model organic pollutants, this study investigated the possibility to exploit such system also for the removal of mixed heavy metals (MHM), specifically Cr(III), Cu(II), and Pb(II) ions, under ultraviolet irradiation at a wavelength of 254 nm. After a preliminary screening on the optimal catalyst loading, operating parameters such as the initial concentration of metal ions, contact and irradiation time, and pH were investigated to optimize the removal of metal ions using response surface methodology (RSM) via Box–Behnken design. Starting from a MHM solution containing 44 ppm of each metal ion, the removal of Pb(II), Cr(III), and Cu(II) ions in the aqueous solution was nearly completed (>98.4%) for all three ions within 72 min of irradiation at almost neutral pH (pH ≈ 6.8). The stability of TiO_2/Alg/FeNPs was confirmed by retrieving and reusing the beads in three consecutive cycles of heavy metals removal without observing significant changes in catalyst efficiency.

1. Introduction

The continuous release of heavy metals from various industrial activities has been recognized as one of the major causes contributing to water pollution. Indeed, heavy metals are non-biodegradable, toxic, and have a tendency to accumulate in living organisms (Pu and Wang, 2011; Benjwal et al., 2015; Joseph et al., 2019). Therefore, the presence of heavy metals in water bodies cannot be ignored and the number of studies investigating removal techniques to contrast their presence and accumulation over the long term has recently increased. Various types of treatments such as chemical precipitation, adsorption, electrochemical, and ion exchange have been used for the removal of heavy metal ions from wastewaters (Barakat, 2011; Lakherwal, 2014; Arbabi et al., 2015; Azimi et al., 2017; Al-Qodah et al., 2017; Zare et al., 2018; Pawar and Bhosale, 2018). Among these methods, adsorption has been widely applied due to its simplicity and relatively low cost (Behnajady et al., 2014; Burakov et al., 2018; Kristić., 2018) also for the removal of both metals and organic pollutants (Han et al., 2019; Varghese et al., 2018). In the context of wastewater treatment, modern technologies have looked at the use of titanium dioxide (TiO_2), an economically accessible photoactive semiconductor that has been extensively studied in photocatalytic applications, especially in advanced oxidation processes for the degradation/mineralization of organic pollutants (Yan et al., 2013; Miklos et al., 2018). Interestingly, due to the photogeneration of a hole (h^+) and electron (e^-), TiO_2 photocatalysis can be exploited in both oxidation and reduction processes. For instance, photogenerated electrons on TiO_2 can be employed for the reduction of metal ions including toxic heavy metals (Chen and Ray, 2001; Kabra et al., 2004; Joshi et al., 2011). In this case, before photocatalytic reduction, adsorption of the metal ion on the TiO_2 surface must occur and can involve either electrostatic interactions or the formation of covalent Ti–O-Metal bonds. As a result, metals will be deposited onto the semiconductor photocatalyst

* Corresponding author.
E-mail address: kdevagi@unimas.my (D. Kanakaraju).

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