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Fast and selective removal of trace concentrations of bismuth (III) from water onto procaine hydrochloride loaded polyurethane foams sorbent: Kinetics and thermodynamics of bismuth (III) study

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ABSTRACT

Bismuth (III) species are included in the list of potential toxins for motor neurons. Thus, fast and selective method for removal of bismuth (III) species has been developed. The method was based upon the formation of tetraiodobismuthate $[BiI_4]^-_{aq}$ in the test aqueous solution in the presence of KI-H_2SO_4 followed by subsequent extraction of $[BiI_4]^-_{aq}$ by procaine hydrochloride ($PQ^+{\cdot}Cl^-$) immobilized polyurethane foams (PUFs). The rate of removal of bismuth (III) ions from aqueous solution by procaine hydrochloride ($PQ^+{\cdot}Cl^-$) immobilized polyurethane foams (PUFs) were studied in batch conditions employing Weber–Morris, Lagergren, Bhattacharya and Venkobachar, and Bt models. The rate of sorption of bismuth (III) was rapid initially within 5–15 min and reached a maximum in 30 min compared to other solid sorbent. Initially, the uptake of $[BiI_4]^-_{aq}$ onto $PQ^+{\cdot}Cl^-$ loaded PUFs was fast followed by kinetically first–order sorption with an overall rate constant, $k = 0.132 \pm 0.033\ min^{-1}$. Thus, film and intraparticle transport are the two steps that might be influence bismuth (III) sorption. The negative values of ΔG of the retention step of bismuth (III) dictate that the uptake of the analyte onto the used sorbent is spontaneous phenomena. Exothermic nature of bismuth (III) sorption is governed by the negative value of ΔH. The positive value of ΔS reflects the organized uptake of bismuth (III) on the used sorbent in a more random fashion. The PUFs offers unique advantages of $[BiI_4]^-_{aq}$ retention over conventional solid sorbents in rapid and effective separation of trace concentration of bismuth (III) from aqueous media. Thus, the developed $PQ^+{\cdot}Cl^-$ treated PUFs sorbent could be packed in column for removal of bismuth (III) species from industrial wastewater.

1. Introduction

Bismuth is found in nature in trivalent state as bismuthinite, Bi_2S_3, bismite, Bi_2O_3 and bismuth sulfide-telluric, Bi_2Te_2S. It is also found as a secondary component in some lead, copper and tin minerals [1]. Bismuth (V) compounds do not exist in solution and are important in the view of pharmaceutical analytical chemistry [1]. In the Earth's crust, bismuth presents at trace concentration ($8\ \mu g\ kg^{-1}$) while, bismuth minerals rarely occur alone and are almost associated with other ores [2]. Bismuth appears to be environmentally significant because its physical and chemical properties have led it to be used in different areas of life. Pamphlett et al. [3] have reported that, bismuth compounds after oral intake enter the nervous system of mice, in particular, in motor neurons [3]. Hence, bismuth species are included in the list of potential toxins [3].

The development of selective, separation, pre-concentration, purification and determination methods for bismuth at sub-micro levels is a challenging problem because of the extremely low concentrations of bismuth present in natural samples and of its strong interferences from the sample matrices. Several methods, e.g. hydride generation atomic absorption spectrometry [4], electro thermal atomic absorption spectrometry [5], atomic fluorescence spectrometry [6], hydride generation atomic absorption spectrometry [7], and cathodic and anodic adsorptive stripping voltammetry [8–10] have been reported for the determination bismuth (III). Most of these methods have required, preconcentration of bismuth for precise determination because most analytical techniques do not possess adequate sensitivity for direct determination.

Solvent extraction in the presence of co-extractant ligands, e.g. bis (2,4,4-trimethyl pentyl) monothiophosphinic acid [11], pyrolidine dithocarbamate [12], etc. has received considerable attention. However, these methods are too expensive, suffered

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