



# Adsorption and desorption of thallium(I) on multiwalled carbon nanotubes

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## HIGHLIGHTS

- Cation exchange and outer-sphere complexes predominated the adsorption processes.
- Adsorption of Tl(I) on MWCNTs were spontaneous chemisorption.
- CNTs with more negative surface charges had the greatest Tl(I) adsorption ability.
- Tl<sup>+</sup> was harder to replace K<sup>+</sup> than to Na<sup>+</sup> in adsorption on MWCNTs.
- Lower pH did benefit the desorption of Tl(I) from MWCNTs.

## ARTICLE INFO

### Article history:

Received 10 October 2012

Received in revised form 5 January 2013

Accepted 7 January 2013

Available online 16 January 2013

### Keywords:

Thallium

Carbon nanotubes

Adsorption

Desorption

Environmental implication

## ABSTRACT

Increasing applications of multiwalled carbon nanotubes (MWCNTs) and thallium (Tl) would raise their exposure risks to aquatic environment. MWCNTs might affect the environmental behavior of Tl(I) by adsorption, and it is critical to understand the interactions between them. The adsorption kinetics, isotherms, thermodynamics, and desorption of Tl(I) by three MWCNTs were studied. In addition, the influences of solution pH, ionic strength on adsorption were also evaluated. The adsorption of Tl(I) on MWCNTs started at very low pH values and increased abruptly, then maintained high level with increasing pH values at pH > 6.5. MWCNTs with more hydrophilic groups and negative surface charges had the greatest Tl(I) absorption capacity. The existence of K<sup>+</sup> significantly inhibited Tl(I) adsorption on purified-MWCNTs. Tl(I) adsorption on MWCNTs was spontaneous occurred by ion exchange with H<sup>+</sup>/Na<sup>+</sup>/K<sup>+</sup> at the exchange sites and forming outer-sphere surface complex. Moreover, Tl(I) could be easily desorbed from MWCNTs and the lower pH benefited the desorption.

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## 1. Introduction

Thallium (Tl) was accidentally discovered by William Crookes in 1861 by burning the dust from a sulfuric acid industrial plant [1]. Tl occurs primarily in association with base metal and precious metal bearing sulfides [2]. In the 20th-century, Tl was widely used as rodenticide and a medical agent. Tl can also be used in alloys, gamma radiation detection equipments, high-temperature superconductors (HTSs), low temperature thermometers [3]. These specialized uses increase the demand for Tl because Tl materials are superior and cost-saving. Although absolute amounts of Tl used in high technology industries are relatively low, Tl will inevitably

leak into the environment from a variety of sources such as metal-based mining, ore processing and smelting [4]. In fact, water pollution by Tl is insidious and really happening [5–8]. Acute toxicity values of thallium sulfate or thallium nitrate indicate that Tl(I) is more toxic than Hg(II), Cu(II), Zn(II), Pb(II), and Cd(II) in fish or mammals [9–11]. Though Tl(III) was much more toxic than Tl(I) [12], inorganic Tl(I) form is more stable than Tl(III) compounds in aqueous solution at neutral pH [13]. Moreover, Tl is a mobile element in the environment and difficult to be removed [4], which will lead to its unavoidable dispersal and increased mobilization in the environment. However, scanty attention has been given to Tl compared with other toxic elements.

Carbon nanotubes (CNTs), one (single-walled, SWCNT) or more (multiwalled, MWCNT) graphene sheets roll into a hollow cylindrical shape with outer diameters in the nanometer range (1–100 nm) and length up to several micrometers, have been extensively studied since their discovery [14,15]. CNTs have been widely used in

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