Bioresource Technology 116 (2012) 290–294

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Interaction of uranium with a filamentous, heterocystous, nitrogen-fixing cyanobacterium, *Anabaena torulosa*

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ARTICLE INFO

Article history:
Received 14 November 2011
Received in revised form 21 March 2012
Accepted 22 March 2012
Available online 29 March 2012

Keywords:
Cyanobacterium
Anabaena torulosa
Uranium binding
Acid soluble polyphosphates

ABSTRACT

The filamentous, heterocystous, diazotrophic cyanobacterium, *Anabaena torulosa* was found to bind uranium from aqueous solutions containing 100 μM uranyl carbonate at pH 7.8. The uranyl sequestration kinetics exhibited (a) an initial rapid phase, binding 48% uranium within 30 min resulting in a loading of 56 mg U g^{-1} of dry wt, followed by (b) a slower phase, binding 65% uranium with resultant loading of 77.35 mg U g^{-1} in 24 h. Energy Dispersive X-ray fluorescence spectroscopy of uranium loaded biomass revealed all components of UL X-rays (UL_l, UL_α, $UL_{\beta 1}$ and $UL_{\beta 2}$). Heat killed cells or extracellular polysaccharides derived from live cells exhibited limited uranyl binding (~26%) highlighting the importance of cell viability for optimum uranyl binding. The present study revealed the involvement of acid soluble polyphosphates in uranium accumulation by this brackish water cyanobacterium.

1. Introduction

Uranium, known for its chemical toxicity rather than its radiotoxicity, has no known biological function. The bioavailability and toxicity of uranium is dependent on its chemical speciation and oxidation state in the solution. Due to various activities associated with nuclear industry such as uranium ore mining, extraction and processing, uranium is transported to aqueous systems in the environment i.e. to groundwater, ponds and oceans. U (VI) dominates in oxidizing conditions as highly soluble and stable uranyl ion (UO_2^{2+}) in low pH (3–5) environments. At circumneutral pH (i.e. 5.5–7.5), neutral and negatively charged uranyl carbonates dominate the aqueous uranium speciation. Above circumneutral pH, in waters of sea and ponds (pH 7–10), the soluble carbonate species of UO_2^{2+} i.e. $[UO_2(CO_3)_2]^{2-}$ or $[UO_2(CO_3)_3]^{4-}$ are the predominant anionic species which result in a high degree of uranium mobility (Lieser et al., 1992; Gorman Lewis et al., 2005).

Microbial processes of adsorption, precipitation, intracellular accumulation, reduction and complexation play a crucial role in determining the fate and distribution of uranium in the environment (Merroun and Selenska-Pobell, 2008). Majority of the uranyl adsorption studies have focused on low pH environments and relate to adsorption of positively charged UO_2^{2+} onto negatively charged microbial surfaces (Bayramoglu et al., 2006; Khani et al., 2008; Akhtar et al., 2007; Merroun et al., 2005). However, sequestration of anionic uranium species onto the microbial surfaces at alkaline pH (>7.0) has received scant attention. The non specific adsorption of anionic uranyl carbonate species onto the negatively charged surface of *Bacillus subtilis* in the pH range of 7–9 was shown through thermodynamic modeling (Gorman Lewis et al., 2005). A similar phenomenon was revealed recently for uranium sequestration by a marine unicellular cyanobacterium *Synechococcus elongatus* BDU/75042 from aqueous solutions at pH 7.8 (Acharya et al., 2009).

Cyanobacteria are known to inhabit a broad spectrum of environments and are effective biosorbents representing an important sink for trace metals in aquatic environments (Baptista and Vasconcelos, 2006). The capability of these organisms to tolerate, accumulate and detoxify/sequester metal contaminants offers an advantage in the recovery and recycling of desirable metals in heavy metal contaminated sites and qualifies these microbes as suitable bioremediation agents (Baptista and Vasconcelos, 2006). Both live and dead cyanobacterial biomass have been shown to sequester heavy metals such as Cd, Hg, Cr, Al, Zn, Pb (Fiore and Trevors, 1994) and radionuclides like uranium (Sakaguchi et al., 1978; Acharya et al., 2009). While inactive or dead biomass seems to bind metals extracellularly, on the cell wall or extracellular polysaccharides (EPS), live organisms can sequester metals through both intra- and extracellular complexation reactions. Live cyanobacterial cells have been shown to concentrate metal ions like Pb, Sr, Mn and Al in intracellular polyphosphate bodies (PPBs) (Swift and Forciniti, 1997; Baxter and Jensen, 1980; Pettersson et al., 1988). However, interactions of uranium with cyanobacterial cells have been rarely investigated (Acharya et al., 2009).

A fundamental understanding of the mechanism of uranium association with naturally occurring microorganisms above circumneutral pH (>7.5) is crucial for successful implementation of

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0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.03.068