BIOLOGICAL REDUCTION OF HEXAVALENT CHROMIUM: A POTENTIAL STRATEGY FOR THE BIOREMEDIATION OF Cr(VI)-POLLUTED WASTEWATER

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ABSTRACT

The potential for biological treatment of Cr (VI)- polluted wastewaters has attracted increased interest, because this alternative is more efficient and less expensive than conventional physicochemical treatments. In this work, a microbial enrichment capable of tolerating and reducing high Cr(VI) was isolated. The kinetic parameters of the Cr(VI) reduction process indicate that the enrichment culture has a significant potential for bioremediation of Cr(VI)-laden wastewaters.

KEYWORDS

Chromium, hexavalent chromium, trivalent chromium, Cr(VI) reduction.

INTRODUCTION

Hexavalent chromium [Cr(VI)] is the major chromium species used in industrial processes, including chrome plating, petroleum refining, manufacture of pigments, leather tanning, wood processing, and so on (Salunke et al., 1998). Improper handling and storage of chromium-laden effluents or wastes has led to Cr(VI) contamination of surface water, groundwater, soil and sediment (Desjardin et al., 2003), which has posed acute and chronic health risks to animals and humans, since Cr(VI) is acutely toxic, mutagenic, carcinogenic, and teratogenic (Marsh and McInerney, 2001; McLean and Beveridge, 2001). Focusing on its toxicity and exposure potential, the United States Environmental Protection Agency (USEPA) lists hexavalent chromium as a priority pollutant (Smith et al., 2002).

The biological reduction of hexavalent chromium to trivalent chromium [Cr(III)] has attracted increased interest, since this process may not only relieve the toxicity of chromium acting on living organisms [Cr(III) is 100 times less toxic and 1000 times less mutagenic than Cr(VI)], but it

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also aids in the precipitation of chromium at near-neutral pH [mainly as Cr(OH)₃] for further physical removal (Wang, 2000). This promising technique appears to be efficient, environmentally friendly and cheaper than currently used processes (Chardin et al., 2002).

However, the potential of biological treatment of Cr(VI)-contaminated waste is limited because microorganisms lose viability in the presence of high concentrations of Cr(VI). The isolation of microorganisms capable of reducing high Cr(VI) concentrations would be therefore very useful.

The main purposes of this work were to obtain an enrichment consortium capable of tolerating and reducing very high Cr(VI) concentrations and to evaluate its potential for reductive chromate detoxification using glucose as a widely available and economical electron donor.

**MATERIAL AND METHODS**

Wastewater from two mining companies were used as sources of inoculum to obtain microbial consortia capable of reducing Cr(VI) under aerobic conditions. The culture media used for the enrichment process and for the biological Cr(VI) reduction studies contained glucose (10 g/L), essential inorganic nutrients for microbial growth, and different concentrations of K₂CrO₄.

A small volume of the mining effluents was added to Erlenmeyer flasks containing culture medium with a Cr(VI) concentration of 1.0 mM. The flasks were incubated in a shaker at 54 cycles/min, at 30 °C for 72 h. A microbial mixed culture, designated as primary enrichment culture, was obtained by repeated transfers into fresh enrichment medium with an initial Cr(VI) concentration of 1.0 mM, for at least a 3-month period. The microbial culture was further enriched by serial transfers into fresh medium with an initial Cr(VI) concentration of 1.5 mM; a new stable microbial mixed culture was so obtained, which was designated as secondary enrichment culture. A tertiary enrichment culture was established in the same way as the secondary one, but an initial Cr(VI) concentration of 2.5 mM was used.

In order to evaluate the enrichments’ potential for reductive chromate detoxification, a kinetic study of cell growth, glucose consumption and Cr(VI) reduction was performed.

Cell concentration was estimated by dry cell measurements. Glucose concentrations were determined enzymatically using a glucose oxidase–peroxidase assay procedure. The Cr(VI) and total chromium analyses were performed according to the procedures described in the Hach Water Analysis Handbook (Hach, 2002).
RESULTS AND DISCUSSION

From the two mining wastewaters sampled, only one yielded microbial enrichments that stably maintained Cr(VI) reducing phenotype when were repeatedly sub-cultured in culture medium with 1, 1.5 and 2.5 mM Cr(VI). These enrichments were capable of transforming the highly toxic and soluble hexavalent chromium to the much less toxic and less mobile trivalent chromium.

High Cr(VI) reduction efficiencies were attained at the different Cr(VI) concentrations tested (Figure 1). The maximum overall efficiency of Cr(VI) reduction was obtained when an initial Cr(VI) concentration of 1.5 mM was used (~98.6% reduction efficiency). The Cr(VI) efficiency dropped to 89.3% at the highest Cr(VI) concentration tested, which might be due to the toxicity exerted by the heavy metal. The Cr(VI) concentrations that were reduced by the microbial enrichments in our experiments (1–2.5 mM) were much greater than those commonly found with bacteria, which are below 0.6 mM (Cheung and Gu, 2003).

The enrichments consumed completely the glucose present in culture medium at the different Cr(VI) concentrations tested (100% efficiency of monosaccharide utilization) (data not shown).

Figure 1. Cr(VI) reduction efficiency of the microbial enrichments
The specific and volumetric rates of Cr(VI) reduction as well as the Cr(VI) reduction yield increased as the Cr(VI) concentration increased (Figures 2-4). These results suggest that the cell populations were progressively enriched with the microbial species more capable of reducing Cr(VI) as the initial concentration of Cr(VI) was increased.
The fact that higher specific and volumetric Cr(VI) reduction rates and Cr(VI) reduction yield were attained at higher Cr(VI) concentrations indicates that the tertiary enrichment has a remarkable ability to reduce Cr(VI). This finding is potentially useful because this enrichment could be employed in detoxification of wastewaters with high Cr(VI) concentrations.

CONCLUSIONS

It was possible to enrich microorganisms capable of tolerating and reducing very high Cr(VI) concentrations. The kinetic parameters of the reduction process indicate that the tertiary enrichment culture has a significant potential for bioremediation of Cr(VI)-laden wastewaters.
REFERENCES


