Original Article

Bioremediation of Hexavalent Chromium Pollution by *Sporosarcina saromensis* M52 Isolated from Offshore Sediments in Xiamen, China[*]

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Abstract

Objective Cr(VI) removal from industrial effluents and sediments has attracted the attention of environmental researchers. In the present study, we aimed to isolate bacteria for Cr(VI) bioremediation from sediment samples and to optimize parameters of biodegradation.

Methods Strains with the ability to tolerate Cr(VI) were obtained by serial dilution and spread plate methods and characterized by morphology, 16S rDNA identification, and phylogenetic analysis. Cr(VI) was determined using the 1,5-diphenylcarbazide method, and the optimum pH and temperature for degradation were studied using a multiple-factor mixed experimental design. Statistical analysis methods were used to analyze the results.

Results Fifty-five strains were obtained, and one strain (*Sporosarcina saromensis* M52; patent application number: 201410819443.3) having the ability to tolerate 500 mg Cr(VI)/L was selected to optimize the degradation conditions. M52 was found be able to efficiently remove 50-200 mg Cr(VI)/L in 24 h, achieving the highest removal efficiency at pH 7.0-8.5 and 35 °C. Moreover, M52 could completely degrade 100 mg Cr(VI)/L at pH 8.0 and 35 °C in 24 h. The mechanism involved in the reduction of Cr(VI) was considered to be bioreduction rather than absorption.

Conclusion The strong degradation ability of *S. saromensis* M52 and its advantageous functional characteristics support the potential use of this organism for bioremediation of heavy metal pollution.

Key words: Hexavalent chromium; Sediment; *Sporosarcina saromensis*; Degradation

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INTRODUCTION

Chromium (Cr) is one of the most toxic heavy metals and is widely used in electroplating, steel production, wood preservation, tanning, and textile dyeing, resulting in the discharge of Cr-containing effluents[1-2]. Release of Cr without treatment causes serious anthropogenic contamination due to its nondegradable and persistent properties[3-5].

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Untreated industrial effluents are also a critical threat to public health because heavy metals have biomagnification properties and accumulate in the food chain, causing toxicity at a cellular level[6].

Cr has two stable forms in the environment: hexavalent chromium [Cr(VI)] and trivalent chromium [Cr(III)], whose toxicity depends on the metal redox state[7]. Cr(VI) has been reported to be 100 times more toxic and 1000 times more mutagenic than Cr(III)[8]. Due to its high solubility, availability, and mobility in soil as well as its ability to penetrate biological membranes, Cr(VI) in industrial effluent does great harm to organisms, including humans, through the food chain[9-10]. Moreover, its strong oxidizing properties give Cr(VI) carcinogenic, clastogenic, and teratogenic potential[11]. Thus, Cr(VI) has been classified as a class A contaminant by the US Environmental Protection Agency (USEPA)[12-13]. As a consequence, some agencies have established maximum allowed levels of Cr(VI) in water. For example, according to the Comprehensive Emissions Standard for Sewage, China (GB 20426-2006), the maximum permissible effluent concentration of Cr(VI) is 0.5 mg/L, and the total maximum allowable Cr is 1.5 mg/L.

Currently, the sheer number and diversity of contaminants in ground and drinking water are serious challenges[14]. Cr(VI) removal from the environment, particularly from industrial effluents and sediments, is an urgent goal for researchers and environmental organizations. Because Cr(III) has long been regarded as an essential human micronutrient[15], transformation of Cr(VI) into Cr(III) may be considered a simple, economical, and practical method to treat industrial effluents. Conventional chemical or physicochemical treatment processes, such as adding lime, ion exchange, membrane separation, and adsorption followed by chemical precipitation and coagulation as $Cr(OH)_3$, have been described in the last few years[16-17]. However, these methods suffer from a number of problems that restrict their application, including complex operational procedures, high cost, and low efficiency[18]. Moreover, some of these methods create secondary pollution that may be even worse for the environment.

The search for new and innovative technology has focused on bioremediation methods for heavy metal detoxification; such methods are thought to be economical and environmentally friendly[4,19]. Many native microorganisms have been identified and reported to have the ability to reduce Cr(VI) to Cr(III) under aerobic or anaerobic conditions[5,20-21]. Microorganisms belonging to polluted sites are usually preferred in the development of an efficient system for Cr(VI) bioremediation because they tolerate Cr(VI) and may evolve to develop some mechanisms to remove the pollutant[22]. Moreover, some native microorganisms may even have the ability to remove several pollutants simultaneously[23-24]. With the increase in offshore pollution, strains with high tolerance and Cr(VI) removal ability have been commonly isolated from offshore and intertidal zones[25-27]. Bioremediation of Cr(VI) involves different approaches, including biosorption, bioreduction, and bioaccumulation[28-29]. The degradation efficiency of Cr(VI) is influenced by many factors, including the presence of sufficient nutrients, the temperature and pH used during the bioremediation process, and the presence of other contaminants in the environment. Therefore, it is very important to identify bacteria with the capacity for efficient degradation, optimize degradation conditions, and clarify degradative mechanisms during the bioremediation process.

In the present study, bacteria used for bioremediation were isolated from sediment samples in intertidal zones and identified using 16S rRNA gene sequencing. A bacterial strain with high tolerance for Cr(VI) was then selected, identified, and characterized. Optimization of several parameters that affect practical treatment of industrial effluents was then performed. In addition, we obtained preliminary results to elucidate the main mechanisms involved in Cr(VI) bioremediation by this microorganism. Our present work will contribute to knowledge related to Cr(VI) bioremediation by a native microorganism and provide a potentially practical application to minimize heavy metal contamination by bioremediation.

MATERIALS AND METHODS

Sample Collection

Seven sediment samples were collected from the intertidal zones at low tide in Xiamen, Fujian Province, China. All sampling sites are shown in Figure 1. The samples were stored at 4 °C until use in microbiological analyses.

Nutrient Medium

All of the nutrient media in the study are