Simultaneous oxidation of As(III) and reduction of Cr(VI) by *Alcaligenes* sp.

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ABSTRACT: Arsenic (III) and chromium (VI) are most common environmental contaminants due to its tremendous applications in dye, tannery and pulp industries. They are non-biodegradable as they are heavy metals, and therefore, of major concern. *Alcaligenes* sp. had the ability to efficiently oxidize As(III) to As(V) and reduce Cr(VI) to Cr(III) separately. It could also simultaneously oxidize As(III) in presence of Cr(VI) under shaking conditions. Simultaneous reduction of 5 mg L⁻¹ Cr(VI) and oxidation of 5 mM As(III) was carried out where Cr(VI) was reduced up to 90% and oxidized 36% arsenic in 24 h. With respect to As(III) oxidation, there was no significant decrease in the rate of oxidation of As(III) due to presence of Cr(VI). Whereas, in case of only Cr(VI) exposure, only 40% of Cr(VI) reduction was observed in 24 h. In presence of arsenic the isolate did not show any effect on growth rate, while rate of chromium reduction was enhanced in arsenic presence. So, further scale up experiments can lead to potential use of *Alcaligenes* sp. to simultaneously biotransform toxic forms of both arsenic and chromium to less toxic forms.

1 INTRODUCTION

Chromium (VI) and arsenic (III) are non-biodegradable heavy metal and metalloids and potential carcinogens, and hence, of major concern. Therefore, it is important that the remediation method should be such that brings chromium and arsenic within the range of the permissible limits before the industrial effluent is discharged. This warrants the need for a potential isolate to biotransform more than one heavy metal (Bachate *et al.*, 2013). Several different strategies are adopted by microorganisms for heavy metals removal, mostly involving biosorption and biotransformation or both. With this background, we studied the effect of simultaneous arsenic and chromium detoxification by *Alcaligenes* sp. which was isolated from tannery industry waste. This bacterial strain showing a simultaneous reduction of Cr(VI) and oxidation of As(III) and is a potential candidate for bioremediation of environments contaminated with both of these toxic metal species.

2 METHODS

2.1 Growth curve

The growth of *Alcaligenes* sp. was studied in order to get sufficient biomass in less time interval with its high tolerance to As(III) and Cr(VI). The optimal media composition was found to contain Tris Minimal Media (Bachate *et al.*, 2013) with yeast extract (0.2%) and Na-acetate at 20 mM concentration. 1% of pre-inoculum was used for further studies.

2.2 As(III) oxidation and Cr(VI) reduction

Arsenite oxidation was checked by molybdenum blue method (Nandre *et al.*, 2017) under aerobic condition 37°C, 150 rpm. Chromium reduction was checked using diphenyl carbazide method (Chaudhari *et al.*, 2013) for 24 h 37°C, static condition.

2.3 Evaluation of siderophore production

Siderophore production was evaluated by chrome azurole sulfonate (CAS) test at 630 nm (Louden *et al.*, 2011).

3 RESULT AND DISCUSSION

3.1 Arsenic oxidation and simultaneous biotransformation of chromium (VI) and arsenic (III) under shaking condition

Arsenic (III) at a concentration of 5 mM was oxidized to arsenic (V) in 24 h (Fig. 1) whereas when *Alcaligenes* sp. exposed to arsenic and chromium both there was simultaneous biotransformation. The rate of arsenic oxidation did not increase or decreased in presence of chromium. Arsenic and chromium are often abundant constituents of acid mine drainage and also of tannery industry. Hexavalent chromium Cr(VI) and arsenite As(III) are the most toxic forms of chromium and arsenic respectively, and reduction of Cr(VI) to Cr(III) and oxidation of As(III) to As(V) has great environmental implications as they affect toxicity and mobility of these toxic species. To simultaneously change their oxidation state from As(III) to As(V),

Figure 1. Percent of As(III) oxidized by *Alcaligenes* sp. i) Abiotic control had 5 mM As(III) ii) Isolate + 5 mM As(III) iii) Isolate + 5 mM As(III) + 5 mg L⁻¹ Cr(VI).

Figure 2. Percent of Cr(VI) reduced by *Alcaligenes* sp. i) Abiotic control having 5 mg L⁻¹ Cr(VI) ii) Isolate + 5 mg L⁻¹ Cr(VI) iii) Isolate + 5 mM As(III) + 5 mg L⁻¹ Cr(VI).

and Cr(VI) to Cr(III), is a potentially effective and attractive strategy for environmental remediation.

3.2 Chromium reduction and simultaneous redox conversion of chromium (VI) and arsenic (III)

Chromium (VI) at a concentration of 5 mg L⁻¹ was reduced to chromium (III) in 24 h whereas when *Alcaligenes* sp. exposed to arsenic and chromium both the rate of chromium reduction was found to increase as compared with chromium alone. 5 mM of As(III) and 5 mg L⁻¹ of Cr(VI) was simultaneously biotransformed (Fig. 2). Also, there is an increase in growth rate when arsenic was present in the minimal media.

3.3 Siderophore production

Siderophore production was screened at 5 mg L⁻¹ of Cr(VI) and 5 mM of As(III) individually and in combination using CAS assay. Maximum siderophore production was observed at 48 h in case of both individual 5 mM of As(III) or 5 mg L⁻¹ of Cr(VI). Whereas, in case of exposure of combination of 5 mM of As(III) and 5 mg L⁻¹ of Cr(VI), maximum siderophore concentration was observed at 20 h. Maximum siderophore concentrations at 20 h indicated their co-involvement in biotransformation of arsenic and chromium.

4 CONCLUSIONS

The *Alcaligenes* sp. could not only individually oxidize As(III) to As(V) but also reduce Cr(VI) to Cr(III) separately. The potency of the organism extended to simultaneous arsenic oxidation and chromium reduction. Simultaneously it reduced 90% Cr(VI) and oxidized 36% arsenic in 24 h. Whereas, in case of only Cr(VI) exposure, only 40% of Cr(VI) reduction was observed in 24 h. With respect to As(III) oxidation, there was no significant increase in the rate of oxidation of As(III) due to presence of Cr(VI). *Alcaligenes* sp. exposed to arsenic and chromium both the rate of chromium reduction was found to increase as compared with chromium alone. The isolate has not shown any effect on growth rate in presence of arsenic. So, further scale up experiments can lead to potential use of *Alcaligenes* sp. to simultaneously biotransform toxic forms of both arsenic and chromium to less toxic forms.

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