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Reduction Remediation of Hexavalent Chromium by Indigenous Bacteria

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ABSTRACT

Chromium (VI) contaminated water has been considered a major environmental concern. In this study, indigenous bacteria were investigated for their effects on the reduction of hexavalent chromium in water. From this sediment, Cr (VI) reduction rates were dependent on temperature. Cr (VI) reduction rates mounted up by reducing primary Cr (VI) concentration. The results showed that pH considerably influenced the rate of Cr (VI) reduction, with faster decrease taking place at pH 7.0. Higher concentrations of CH3COONa decreased the Cr (VI) reduction. These strategies can be considered as efficient for Cr (VI) removal from water because of their very low cost.

Keywords: *Chromium (VI), Reduction, Bacteria.*

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1. INTRODUCTION

Modern industries, like stainless steel manufactures, leather tanning and textile manufactures, electroplating and alloy preparations, discharge Chromium, as a toxic waste into waste water, which may inevitably be entered into the environment (Pattanapipitpaisal *et al*., 2001). Chromium has been identified as one of the most serious pollutants among heavy metals in environment, therefore, removal of chromium pollution should be seriously taken into consideration (Xu *et al*., 2005). As it is known, there are two main stable oxidation states of Chromium namely, Cr (VI) and Cr (III), which have extensively contrasting toxicity and transport parameters (Xu *et al*., 2005). Generally, Cr (III) at very high concentrations is only toxic to plants, and is less toxic or nontoxic to animals (Anderson, 1997). Small amounts of Cr (III) are necessary for metabolism of carbohydrates in humans. Since Cr(VI) has been recognized as a common teratogenic, mutagenic, and carcinogenic chemical, effective means in terms of cost and maintenance to clean up chromium contaminated groundwater are needed (Olazabal *et al*., 1997).

Various methods have been applied for the recovery of hexavalent chromium from wastewaters. Reducing microbes from toxic hexavalent chromium is practically important, because biological strategies provide green technology which is economical (Ganguli and Tripathi, 2002). Various studies have examined the reduction of toxic Cr (VI) to non toxic Cr (III) by several kinds of bacteria under both aerobic and anaerobic conditions (Shen and Wang, 1994; Schmieman *et al*., 1998; Muhammad and Shahida, 2000; Guha *et al*., 2001; Tyrone *et al*., 2001; Camargo *et al*., 2003; Vainshtein *et al*., 2003; Leea *et al*., 2005).

This report has demonstrated that the reduction of Cr (VI) can occur with indigenous bacteria.

2. MATERIALS AND METHODS

The microorganisms used in this study were derived from activated sludge from a local sewage treatment plant (Hangzhou Sibao wastewater treatment plant). To prepare the consortium as an inoculum for the experiments, in 5000 ml serum bottles, 100 ml sediment slurry was mixed with 500 ml of basal medium. The basal medium for the pre-culturing had the following composition: $Na_2HPO_4.12H_2O$ 3000g; KH_2PO_4 1900g; $NaNO_3$ 2000g; Na_2SO_3 0.140g; $MgSO_4$ 0.200g; $C_{10}H_{14}N_2O_8Na_2.2H_2O$ 0.006g; and 20 ml of trace element solution per 2 L of distilled deionized water. Trace element solution was composed of $CaCl_2$ 0.2g; $MnSO_4$ 0.05g; $NaMoO_4$ 0.01g; $CuSO_4.5H_2O$ 0.01g; per 1L. Cr (VI) stock solutions were prepared by dissolving a potassium dichromate $K_2Cr_2O_7$ in distilled deionized water.

After 3 weeks' incubation, the inoculums were used in the experiments to investigate microbial reduction of Cr (VI) with time and temperature.

The samples of 1g of the initial culture were transferred to flasks containing 100 ml of a basal medium to invest microbial reduction of Cr (VI). The influences of pH, culture composition, and initial Cr (VI) concentrations on chromate reduction were researched. For the effect of pH, culture medium was adjusted to pH 4.0, 5.0, 6.0, 7.0 and 8.0, and pH adjustment was made by adding aliquots of either HCl or KOH. The effect of initial Cr (VI) concentration on chromate reduction was examined with four different initial Cr (VI) concentrations of 5, 10, 15, and 20 mg/L. The effect of culture composition was examined with three different CH_3COONa concentrations 0.2, 1.0, and 2.0 mg/L. All experiments were incubated at temperature of (30^0C). Oxygen was removed from the solutions by sparging with nitrogen. All samples were filtered with 0, 45 µm syringe filter.

Analytic methods

Aqueous concentrations of Cr (VI) were determined by a diphenylcarbazide procedure at 540 nm using UV-VIS spectrophotometer (TU-1800PC, Beijing, China).

3. RESULTS AND DISCUSSION

An elevated Cr (VI) concentration was maintained by respiking the culture with $K_2Cr_2O_7$ after 75, 172, 267, 360, 459, 556, 645, 722, 815 and 888 hr (Fig 1).

Microbial reduction of Cr (VI) was dependent on temperature. The highest Cr (VI) reduction was observed in the culture (II). Fig. 1. indicates that temperature was an important selection factor for bacterial growth and would affect enzymatic reactions necessary for Cr (VI) reduction.

In the first hexavalent chromium concentration of 0.58mg/l in the culture (II) and 0.68mg/l in the culture (I), after 69 hr, 56.89% and 55.88% reductions were observed in the culture (II) and culture (I) under anaerobic condition, respectively. To this point, there was a considerable drop in reduction rates, as observed in initial experiments, which leads to a long time needed for total reduction. Thus, in order to accelerate the startup, and keep a high reduction rate, the system was reloaded at this point. Nutrients and hexavalent chromium were added again to a concentration of 22.25mg/l in the culture (II) and 21.76 mg/l in the culture (I). A new series of operating cycles was performed, as shown in Fig 1, until a minimum period of 90 hr which was needed for 69.07% reduction hexavalent chromium in the culture (II) and 37.72% in the culture (I). The hexavalent chromium reduction rates were observed the highest after about three weeks, and 42.71 hr was needed for complete reduction (100% removal) of 19.95 mg/l hexavalent chromium in the culture (II), and 96.91% reduction of 20.75 mg/l hexavalent chromium which were observed in the culture (I), and at this point, the startup period was considered complete, and the culture was ready for full operation.

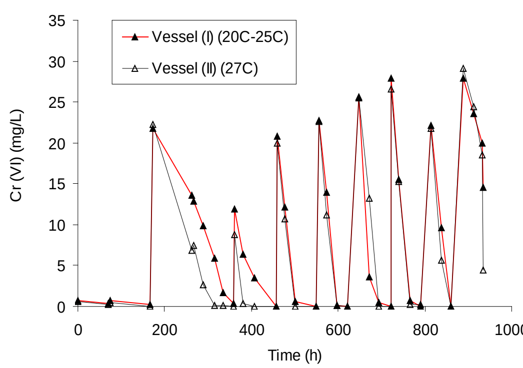

Figure 1. Operating cycles of the Cr (VI) reduction in enrichment culture under anaerobic condition with various temperatures

Effect of initial Cr (VI) concentration

The effect of initial Cr (VI) concentration on the chromate reduction is shown in Fig. 2. When Cr (VI) concentrations were less than 5 mg/l, all Cr (VI) were removed within 13 hr. However, when the initial concentrations of Cr (VI) increased up to 20mg/L, the time required for the complete removal of Cr (VI) substantially increased. And, when the initial concentration of Cr (VI) was increased, the reduction rates were decreased. That may occur due to the toxicity of Cr (VI) to the cells (Xu *et al.*, 2005).

The total amount of dissolved Cr simultaneously reduced when Cr (VI) was decreased, this was happened may be because of precipitation of Cr $(OH)_3$ after microbial reduction of Cr (VI) to Cr (III).

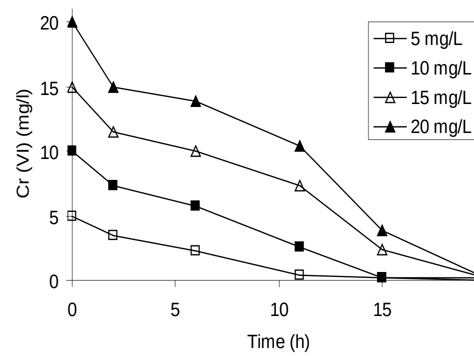

Figure 2. Effect of initial Cr (VI) concentration on anaerobic chromate reduction

Effect of pH

The pH value has been an important index reflecting the microbial activity (Xu *et al.*, 2005). The chromate reduction was found to depend on the pH of solution. Microbial reduction of toxic hexavalent chromium capacity was found to decrease with an increase in the pH (5, 6, 8), and maximum reduction was observed at pH 7 (Fig. 3).

In this examination, the studied factors affecting Cr (VI) reduction have been important environmental factors managing remediation strategies for ecosystems contaminated with natural or anthropogenic Cr (VI) (Camargo *et al.*, 2003).

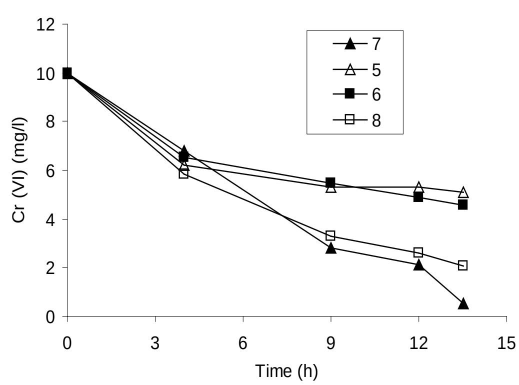

Figure 3. Anaerobic chromate reduction at four different pH.

Effect of culture composition

The effect of culture composition on Cr (VI) reduction was investigated under varying ratios of CH_3COONa (Fig. 4). Cr (VI) reduction was affected by the composition of the an-aerobic consortium. Higher Cr (VI) reduction rates were observed in the presence of 2g/l CH_3COONa. But the microbial reduction of Cr (VI) was much slower in the higher CH_3COONa concentrations (10 g/l, 20 g/l), indicating that smaller concentrations of CH_3COONa would accelerate microbial reduction of Cr (VI), and higher concentration of CH_3COONa might cause low Cr (VI) reduction.

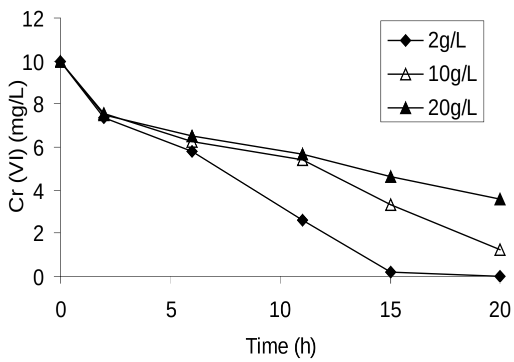

Figure 4. Anaerobic chromate reduction with three Different CH_3COONa concentrations

4. CONCLUSION

Hexavalent Chromium (Chromium VI) has had wide spread, long-term use in industry for its ability to inhibit the formation of rust. Contrarily, Hexavalent chromium has also been a known human carcinogen. The indigenous bacteria have been responsible for the reduction of Cr (VI) in contaminated sediments (Leea *et al.*, 2005). Therefore, the activities of indigenous bacteria probably lead to the natural attenuation of Cr (VI) toxicity, and can be the key players in remediating chromium-contaminated sediments (Leea *et al.*, 2005). Reducing the most toxic Cr (VI) to the less toxic Cr (III) biologically, requires taking such microorganisms as biotechnological tools for remediation of Chromate contaminated wastewaters. The costs and energy could be decreased by biological treatment compared with conventional physico-chemical treatment.

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