

# Bioaccumulation of metals by *Scenedesmus*, *Selenastrum* and *Chlorella* algae

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## Abstract

Three species of algae were investigated for their ability to accumulate metal ions. *Scenedesmus*, *Selenastrum* and *Chlorella* species were found to be capable of accumulating metals such as  $\text{Cu}^{2+}$ ,  $\text{Pb}^{2+}$ , and  $\text{Cr}^{3+}$  with 67 to 98% efficiency. Although *Chlorella* was less capable of accumulating these cations than the other two organisms, it possessed a greater capacity for the  $\text{Cr}_2\text{O}_7^{2-}$  anion. A suspension of *Selenastrum* was used to accumulate  $\text{Cr}^{3+}$  from a sample of post-anaerobic digester tannery effluent. The algae removed 39% of the chromium from solution. The rate of metal ( $\text{Cu}^{2+}$ ,  $\text{Pb}^{2+}$ ,  $\text{Cr}^{3+}$ ) accumulation by *Scenedesmus* was rapid, occurring in the first 4 min. Of the 4 metals investigated,  $\text{Cu}^{2+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Pb}^{2+}$  and  $\text{CrO}_4^{2-}$  the former 2 were more toxic to the algae than the latter two.

## Introduction

Bioaccumulation of metals by algae may present a feasible method for remediating waste waters contaminated with metals (Darnall et al, 1986; Jackson, 1978; Nakajima et al., 1981). One of the other advantages of algae is that they may be grown in ponds with little nutritional input or maintenance. Moreover algae can be considered to be non-pathogenic, which gives these organisms an advantage over many other forms of microbial biomass. Algal ponds are a final stage of sewage treatment in many sewage treatment plants, and the use of algal ponds for the bioremediation of tannery effluents has also been investigated recently (Laubscher et al., 1990).

Field experiments reported by Gale (1986) indicate that live photosynthetic micro-organisms can be effective in metal detoxification of mine waste waters. By using cyanobacteria in a system of artificial pools and meanders, 99% of dissolved and particulate metals could be removed. McHardy and George (1990), like Vymazal (1984), studied *Cladophora glomerata* in artificial freshwater channels and found the alga to be an excellent accumulator of zinc, which was concentrated 2 to 5 thousand times.

There have also been reports of accumulation of  $\text{Cu}^{2+}$ ,  $\text{Pb}^{2+}$  and  $\text{Cr}^{3+}$  as well as  $\text{Ni}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Fe}^{2+}$  and  $\text{Mn}^{2+}$  by algae (Sicko-Goad and Stoermer, 1979; Vyzamal, 1984). Algae in experimental rice paddies were found to accumulate and concentrate  $\text{Cd}^{2+}$  by a factor of about 10 000 times when compared to the ambient water (Reiniger, 1977). Reports of algal species present in algal ponds are inevitably mixed and may include both algae (eukaryotes) and blue-green algae (prokaryotes) and data from such experiments should be interpreted with this in mind.

The mechanism of metal accumulation by algae is primarily via binding of metals to the cell wall surface, although intracellular uptake also contributes to the total accumulation (Vyzamal, 1984). The binding of metal to algae could be either ionic or by complex formation with ligands on the cell wall. The polymers which constitute the cell wall are rich in phosphoryl, carboxyl, aromatic and hydroxyl groups (Ehrlich, 1986) which bind cationic metals

(Crist et al., 1981). Investigations of zinc accumulation by algal cultures under various lighting conditions proved that light was not necessary for the common freshwater alga *C. glomerata* to accumulate zinc, as accumulation levels were independent of the photosynthetic period. This in turn implied that energy-dependent mechanisms were not necessary for metal accumulation (Vymazal, 1987) and it was concluded that the dominant Zn cation accumulation process was therefore an adsorptive mechanism. It has been found that pH, outside the 5 to 7 unit range, decreases bioaccumulation of metals by algae (Schenck et al., 1988).

In this study, the accumulation of  $\text{Cu}^{2+}$ ,  $\text{Pb}^{2+}$  and  $\text{Cr}^{3+}$  from solution by 3 freshwater algal species, namely *Scenedesmus* sp., *Selenastrum* sp. and *Chlorella* sp. (which will henceforth be referred to by genus), was studied. The objective was to use these algae for accumulation of metals from solutions, including a preliminary study of  $\text{Cr}^{3+}$  accumulation from tannery effluent.

## Methods

### Culture maintenance

The starting cultures were obtained from the Department of Zoology and Entomology at Rhodes University. Isolates of the 3 species were obtained by the spray plate method in which filtered air was forced into a vessel containing an algal culture, which consequently propelled the medium out of a fine outlet (in this case a Pasteur pipette). The resultant aerosol was directed onto BG 11-agar plates. The plates were incubated at 22°C on a light table of 165.4  $\mu\text{E}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$  light intensity. Working cultures of each species were grown from a single colony. The cultures were maintained on 2% agar plates (prepared by adding 2 g of normal nutrient agar to 100 ml of BG 11 medium, autoclaving for 15 min, and then pouring 15 ml into sterile disposable petri dishes).

All cultures were grown in BG 11 medium, pH 7.4, prepared according to Allen (1968) with ultra-pure water (Milli-Q). The medium had low turbidity, allowing for penetration of light required by the photosynthetic algae. The medium was sterilised by autoclaving at 121°C for 15 min. The medium was stored at 4°C until inoculated. The 3 species (one from each of the genus of *Scenedesmus*, *Selenastrum* and *Chlorella*) were harvested in the log phase.

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