## Executive Summary

Industrial effluents are a major cause of heavy metal contamination, thus the removal and recovery of heavy metals from effluent streams are essential to the protection of the environment. Conventional technologies are either not able to remove and recover heavy metals to a satisfactory level, or they are too costly to implement. The ability of biomaterials to bind and concentrate heavy metals from dilute aqueous solutions has been well-documented, and offers a potentially cost-effective approach to the removal of heavy metal pollutants from industrial waste waters. However, little has been done with regard to the commercialization of technology based on the use of biosorbents and the objective of this project was therefore to investigate the feasibility of using biomaterials for the removal of heavy metals from aqueous effluents.

The study consisted of several successive steps, first of which was the identification of a suitable biosorbent, followed by characterization of the sorbent and biosorption mechanisms and finally doing some experimental work with packed columns to evaluate the use of adsorbent on an industrial scale.

The metals used in this investigation were mainly zinc, nickel, lead and copper, while the biomaterials were tobacco dust, saw dust, peat moss and seaweed. Limited experiments with other metals, such as cadmium and chromium were also conducted. The biomaterials that were considered are readily available and easy to prepare. An attempt was made to describe the biosorption capacity of the materials in terms of lignin and organic content, but this was not particularly successful.

*Screening of biomaterials*

Biomaterial screening experiments (including kinetics and adsorption capacity, as well as the regeneration of the sorbents) were conducted in batch adsorption tests with single species solutions. Limited work with multiple species solutions has indicated that interaction between metal species can play

a role in the performance of the biosorbents and that this would have to be taken into account in detailed industrial-scale equipment design.

*Characteristics of selected biosorbent*

On the whole, the seaweed appeared to be the most effective adsorbent. With the seaweed (marine alga), the adsorption equilibria of Cu, Pb and Cd could be represented by Langmuir isotherms and the capacity of fresh alga for Cu, Pb and Cd was approximately 85-94 mg/g, 227-243 mg/g and 83.5 mg/g respectively. By way of comparison with conventional ion exchange technologies, the performance of the seaweed was slightly better than that of a chelating C467 resin (approximately 80 mg Cu/g) and worse than that of a strong acid IR120 resin (about 101 mg Cu/g) for copper.

The rate of adsorption onto the marine alga was high and appeared to be controlled by both reaction and film diffusion, owing to the non-homogeneity of the algal surface, which contained a variety of functional groups. The alga particle size played an important role in the adsorption behaviour. Coarse alga particles (0.8-1.2 mm) had a higher adsorption capacity and slower adsorption kinetics, and could be regenerated without significant loss of capacity. In contrast, the fine alga particles (0.075 mm) had a lower adsorption capacity and faster adsorption kinetics, and could not be regenerated without significant loss of capacity.

*Assessment of packed columns as a potential configuration for industrial implementation*

Granulated seaweed was used in a packed column in order to evaluate the design of equipment. A synthetic heavy metal solution comprised of Pb, Ni, Cr, Cu and Zn with a total concentration of 100 mg/L was passed through the column at a flow rate of approximately 15 BV (bed volume).

For all practical purposes, 100% of the Pb and Cr were removed with approximately 95% of the Cu and 75% of Zn and Ni. Sorption equilibrium was reached within 10 minutes for all heavy metals. The Pb and Cr removal remained constant at sclose to 100%, whereas the other heavy metals peaked close to 90% and then decreased steadily afterwards. The decrease in Ni and Zn concentrations could be attributed to the displacement of these heavy metals with Pb and Cr. This shows that the seaweed is very selective for Pb and Cr and to a lesser extent for Cu.

By using a 2M HCl solution, 95% of the Cr and Pb could be removed within 120 minutes. Initial heavy metal removal was fast, with more than 70% being removed within the first 20 minutes of operation. In summary, although further work still needs to be done to assess the reuse of the seaweed after biosorption and regeneration. the technology appears sufficiently promising to continue with steps towards industrialization.