The application of bioremediation: reduction of metal concentrations in river water and COD in distillery effluent

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Abstract The major aim of this study was to evaluate and develop artificial bioremediation systems to reduce or remove metal pollutants from contaminated river water and to decrease the chemical oxygen demand (COD) in distillery effluent. Metals were extracted using the nitric acid digestion method, and the concentrations determined using inductively coupled plasma-atomic emission spectrometry. A decrease in metal concentrations was observed for most of the metals analysed in the river water after being pumped through the bioreactor system for approximately two weeks, e.g. Al concentration decreased from 0.75 mg.l^{-1} to 0.18 mg.l^{-1} and for Ni, from 0.19 mg.l^{-1} to 0 mg.l^{-1}. In addition, the COD counts decreased from 2255 mg.l^{-1} to a final value of $<$ 150 mg.l^{-1} in the distillery effluent. It could thus be concluded that the bioreactor system decreased the COD and metal concentrations in the distillery effluent as well as the river water, respectively. A bioreactor is being evaluated on-site at a wine cellar to reduce COD and will be constructed at a site along the Plankenbrug River.

Keywords Bioremediation; distillery effluent; inductively coupled plasma atomic emission spectrometry; metals; pollution; rivers

Introduction

Bioremediation is defined as a treatment technology that uses living organisms (plants, microbes etc.) to reduce the concentration or toxicity of contaminants in soil, water and wastewater (Evangelho *et al.*, 2001). Numerous applications of biofilms in bioremediation exist as these microbial communities are inexpensive labourers capable of cleaning up pollutants such as, metal contaminants, chlorinated solvents, crude oil, sewage water etc. (Langwaldt and Puhakka, 2000), with the ideal bioremediation system being time-efficient, as well as cost-effective (Liu *et al.*, 2001).

The trickling filter, which is one of the most commonly used fixed-film bioreactors, consists of a solid substratum to which microorganisms (biofilm) attach. The ideal substratum material should be highly durable, have a low cost, should not clog easily and should have a high surface area for maximum microbial adsorption (Metcalf and Eddy, 1991; Evangelho *et al.*, 2001).

The current research project focuses on the development and the application of a bioremediation system to reduce or remove metal pollutants from contaminated river water and to decrease the chemical oxygen demand (COD) in distillery effluent.

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Methods

Sampling

Distillery effluent from a settling pond, and river water from a site located near the informal settlement of Khayamandi (Stellenbosch), was evaluated in two bioreactor systems. A volume of 200 L of distillery effluent and river water respectively, was fed through the bioreactors using an Ecopool 6 pump for a period of approximately two weeks. Initial samples were collected and subsequent effluent samples collected every day from the outlet system.

Development of trickling filter bioreactor

The distillery effluent was pumped through a continuous reactor system with the dimensions 30 cm × 30 cm × 100 cm at a flow rate of 1000 L/h at room temperature with a retention time of 2 min. Polyvinylchloride (PVC) sheeting was used as the attachment surface within the reactor. Based on these results, a bioreactor system (Figure 1), with the dimensions of 35 cm × 30 cm × 100 cm, a flow rate of 1000 L/h and a retention time of 3 min, was constructed for the removal of metals from river water. Different materials, such as, Bioballs™ and Alphagrog™, were used to create an increased surface area for maximum metal removal efficiency.

Metal concentration and chemical oxygen demand (COD) determination

The nitric acid digestion method was used to analyse for aluminium (Al), copper (Cu), nickel (Ni) manganese (Mn) and iron (Fe) in the effluent samples of the reactor with the concentrations measured using inductively coupled plasma-atomic emission spectrometry (Saleh *et al.*, 2000). For comparison, a blank (control) of 10 ml 55% nitric acid was analysed along with the collected samples. COD measurements on the distillery effluent samples (vertical reactor) were performed using the COD cell test kit, method photometric (15000 mg/L).

Results and discussion

Mean metal concentration in river water

The metal concentrations at four sampling sites along the Plankenbrug River, Stellenbosch were analysed for a period of one year. Based on these results, river water was collected from the site with the highest metal concentrations.

Metal concentrations recorded from the bioreactor

The recorded concentrations in the effluent samples after being fed through the bioreactor system for a period of two weeks were lower than in the initial samples (Figure 2).

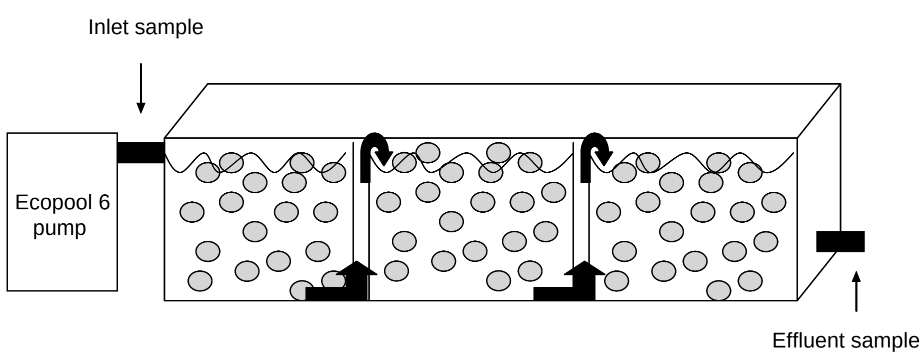

Figure 1 Horizontal trickling filter bioreactor system

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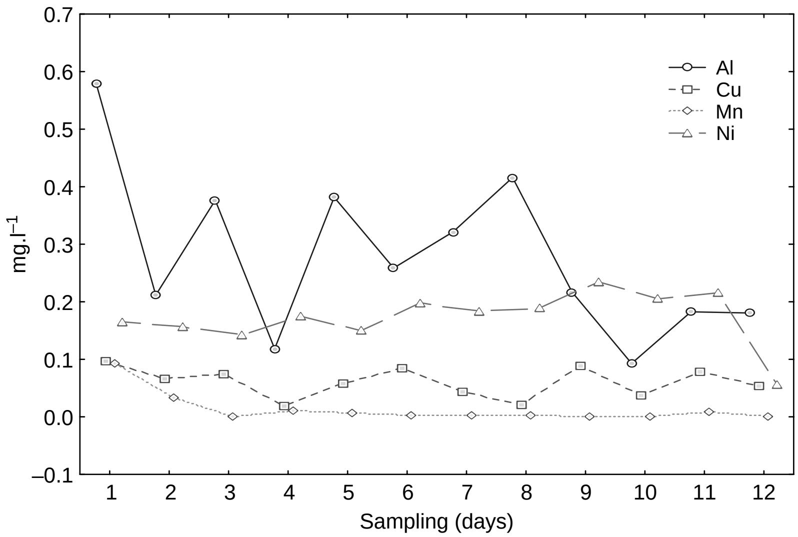

Figure 2 Mean metal concentrations (mg.l^{-1}) in effluent samples over the three sampling times

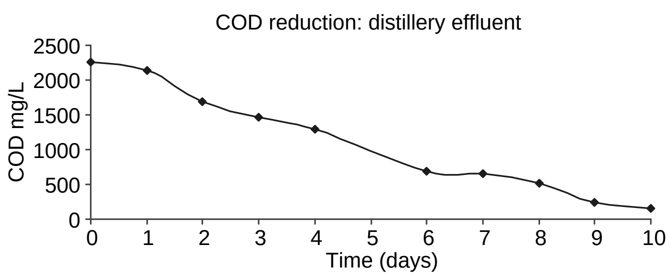

Figure 3 Graphical representation of reduction in COD (mg/l^{-1}) for samples obtained from the 3rd settling dam

The decrease in metal concentrations were as follows: Al, 0.75 mg.l^{-1} to 0.18 mg.l^{-1}, Cu, from 0.10 mg.l^{-1} to 0.06 mg.l^{-1}, Mn, from 0.10 mg.l^{-1} to 0 mg.l^{-1}, Ni, from 0.19 mg.l^{-1} to 0.06 mg.l^{-1}, and Fe from 4.9 mg.l^{-1} to 4.8 mg.l^{-1} (results for Fe not shown). The bioreactor effluent concentrations for Al, Cu and Fe were however still significantly higher than the recommended safe concentrations as stipulated by the South African Department of Water Affairs and Forestry (DWAF) and the Canadian Council of Ministers of the Environment (CCME) in their guidelines published in 1996 and 2001, respectively.

COD results using a trickling filter bioreactor

Results obtained from the COD cell test kit, method photometric (15000 mg/L) for distillery effluent, revealed a significant ($P < 0.05$) decrease in COD concentration. COD concentrations decreased from an initial value of 2255 mg/L to a final value of < 150 mg/L as shown by the graphical representation in Figure 3. A severe limitation of this method is that the COD could only be measured up to a concentration of 15,000 mg/L and the exact initial concentration could thus not be determined.

Conclusions

The bioreactor system used for the remediation of the river water sample, proved to be effective in decreasing the metal concentrations. In addition, results show a significant

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decrease ($P < 0.05$) in the COD concentrations of the distillery effluent pumped through the bioreactor. This system is currently being evaluated on a large-scale for winery effluent and will be constructed on-site at the most contaminated location along the Plankenbrug River.

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