Membrane bioreactors for metal recovery from wastewater: A review

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Abstract

The need to remove or recover metal ions from industrial wastewaters is both financially and environmentally driven, financially in terms of cost savings through metal reuse or sale, and environmentally as heavy metal toxicity can affect organisms throughout the food chain, including humans. Current removal strategies are mainly based on physico-chemical techniques such as filtration, chemical precipitation and solvent extraction. All these "conventional" technologies have raised issues of efficacy when faced with low metal concentrations, high start-up or operating costs and low metal selectivity. Conversely, metal removal using biological and membrane processes is becoming more widely accepted as new evidence is gathered highlighting their lower cost, ease of operation, selectivity and efficacy. Precipitation of metal ions using biogenic hydrogen sulphide, produced by sulphate-reducing bacteria, is not a new technique, and is used by a small number of industrial installations worldwide. While this process has disadvantages such as the hazardous nature of the gas, the advantages inherent in utilising this source of sulphide are greatly enhanced when used in combination with membrane bioreactor technology. Initial studies have shown that the sulphate-reducing bacterial bioreactor coupled with a membrane can remove up to 90% of the metal ions present in an aqueous solution.

Keywords: membrane bioreactor, metal removal, sulphate-reducing bacteria, extractive membrane bioreactor

Introduction

Water is an important resource, vital for both social and economic growth. It is thus imperative that water is managed according to the principles of sustainable development to counteract the combination of increasing economic development and environmental degradation. The constantly increasing degree of industrialisation and urbanisation, rising standards of living, increasing population growth and agricultural activities are strongly impacting on the use of available water sources and on the quality of water that is found therein. This exhaustive use of limited resources and energy by modern society implies a need for changes in present and future urban water and wastewater treatment systems (Holtzhausen, 2002).

A larger problem faces developing countries, like South Africa, that have moderate to high stresses on their freshwater resources, as large inequalities exist in the quality and quantity of water available to rural communities compared to that of the urban areas (Morrison et al., 2001). Thus, appropriate management strategies need to be implemented to optimise the use of these water sources and to ensure the efficient disposal of polluted water (Jooste, 2000).

Water in South Africa

South Africa's average annual rainfall is approximately 480 mm - almost half the world average of 860 mm. The fact that this rainfall is unevenly distributed across the country, much higher in the east than in the west, compounds the problem of water supply (Holtzhausen, 2002). To alleviate this inequality between the eastern and western areas of the country, numerous dams, storage facilities and inter-catchment transfer schemes have been developed. Thus, South Africa is heavily reliant on surface water resources and, with evaporation rates much higher in the west than in the east, the potential water shortage problem is evident (Webster, 2001).

Major industries, mining and power generators account for a large percentage of water usage in South Africa. These are found mainly in Gauteng, Mpumalanga and Limpopo Provinces, which are highly populated, due in part to the labour force required to run such industries and the resulting commercial and residential areas surrounding them. The result is a very high water demand by both industrial and domestic users in an area of generally low rainfall (Fig. 1) (Holtzhausen, 2002).

In combination with the two water-related issues of increasing urbanisation and uneven resource distribution, the need for sufficient water to sustain aquatic ecosystems and the environmental services they provide results in a requirement for a fine balance when it comes to allocating resources to users.

Schutte and Pretorius (1997) state that of the total water resource presently available, 52% is used for agricultural activities, 12.5% by industry, mining and power generation and 12% for domestic and municipal uses. Holtzhausen (2002) echoes these consumption estimates and further states that at least 15% of the water resources remaining are required for nature conservation and ecological purposes such as maintaining estuaries and rivers (Fig. 2.).

This need has been recognised in the national legislation under the National Water Act (1998) that outlines three policy principles for water resource protection strategies. These are:

- Protection of all significant water resources
- Resource sustainability, i.e. use that does not cause long-term deterioration of the overall resource in terms of any measurable

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