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Evaluation of electrodialysis for the treatment of an industrial solid waste leachate

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Abstract

A hazardous leachate from an industrial landfill site is stored in lined dams. The TDS (approximately 100 g/l) and the organic concentration (approximately 70 g/l COD) of the leachate are high. The high TDS concentration of the leachate would make treatment with reverse osmosis (RO) very difficult. The leachate also contains high concentrations of iron, manganese, barium, strontium and phenolics. This leachate has the potential to pollute the water environment, if the dams overflow. Therefore, electrodialysis (ED) was evaluated as an alternative technology to desalinate/concentrate the leachate for effluent volume reduction and pollution control. Physical/chemical pre-treatment of the leachate with fly ash and chemicals have shown that the fouling potential of the leachate for membrane systems could be significantly reduced. The AFN anionic membrane from Tokuyama Soda was found to be the most resistant anionic membrane towards membrane fouling during tests in a membrane fouling test cell. This membrane was then used in a laboratory-scale ED stack to evaluate the process for treatment of the leachate. It was found that the leachate could be effectively desalinated/concentrated with ED. The desalinated effluent was significantly less toxic and more biodegradable than the ED feed or brine which comprised approximately 38% of the treated leachate. It also appears that it should be possible to control membrane fouling with regular membrane cleanings. Electrodialysis pilot tests were finally conducted in the batch and feed-and-bleed modes to develop process design criteria for a full-scale application. It was found that an excellent quality water could be produced with batch ED treatment followed by RO desalination. The treated water is almost of potable quality (645 mg/l TDS) except for high COD (935 mg/l). Feed-and-bleed ED pilot tests have shown that the TDS of the leachate could be reduced from 116,255 mg/l to 2,435 mg/l (5 stage ED). Brine volume comprised approximately 41% of the treated leachate. The capital cost of an 80 kl/d (feed) ED plant is estimated at 2.38 million US$. Operational costs are estimated at 28.96 US$/kl.

Keywords: Electrodialysis; Reverse osmosis; Leachate characterisation; Leachate treatment; Membrane fouling; Membrane characteristics; Volume reduction; Pollution control; Treatment costs

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1. Introduction

The minimum requirements for waste disposal to landfill sites according to the Department of Water Affairs and Forestry (DWAF) in South Africa is that all hazardous waste sites should have a leachate management system. The minimum requirements for the classification, handling and disposal of hazardous wastes according to DWAF states that all leachates are hazardous, and DWAF is beginning to push waste disposal companies to manage leachate treatment effectively. Therefore, suitable technologies will be required for the successful treatment of the hazardous leachates.

Two types of hazardous leachates are produced in landfill sites in South Africa. The one is a high TDS (50–100 g/l), high organic (10–80 g/l COD) concentration leachate containing hazardous chemicals like phenols, sulphides, ammonia-nitrogen, chromium, cadmium, etc. (industrial solid waste leachate, ISWL). This ISWL is unique to South Africa with its relatively low rainfall compared with Europe and past waste disposal practices. The other leachate is a low TDS (2–6 g/l), low organic (2–6 g/l COD) concentration leachate (municipal solid waste leachate, MSWL). The ISWL cannot be discharged into the municipal sewer system because the high salinity levels, as well as the other hazardous chemicals (phenols, chromium, heavy metals) will adversely affect the biological treatment processes. However, the MSWL can, in some cases, be discharged directly into the municipal sewer system without any problems, depending on the dilution water available. Municipal solid waste leachate, however, cannot be discharged into the municipal sewer system where little dilution water is available and where hazardous chemicals are present in the leachate. Therefore, the leachates should be treated prior to disposal, to prevent adverse effects on municipal biological treatment processes, and to prevent pollution of the water environment.

The treatment of MSWL with reverse osmosis (RO) is an established process [1–10]. However, it would be difficult to treat the ISWL with its high TDS (50–100 g/l) effectively with RO. Electrodialysis (ED), however, is an alternative technology which has the potential to desalinate high TDS effluents effectively. However, very little information is available in the literature regarding the desalination of leachates with ED [11,12] in comparison with other technologies [13–15]. Membrane fouling may be a problem. Pretreatment of the ISWL with adsorbents or absorbents (ash) and other physical/chemical (coagulation–flocculation, lime, soda ash, etc.) and membrane methods, is therefore considered to be important for the removal of most of the membrane foulants prior to ED desalination. Electrodialysis membranes are also available, which are claimed to be more fouling-resistant than conventional ED membranes [16].

Preliminary work on the ISWL has shown that approximately 50–60% of the salinity could be easily removed with ED desalination [17]. However, it was not possible to remove the remaining salinity with ED and membrane fouling was also experienced. Reverse osmosis, however, has the potential to desalinate the ED diluate further to very low concentration levels.

The main objective of this investigation was therefore to evaluate ED technology for the treatment of the ISWL [18]. Other objectives include: a) characterisation of the leachate; b) determination of the biodegradability of the leachate; c) evaluation of pretreatment of the leachate for the removal of suspended material, organics and inorganics; d) determination of the fouling potential of the leachate for ED membranes as well as membrane cleaning strategies; e) evaluation of ED and RO performance for the desalination/concentration of the leachate; f) determination of the preliminary economics of the process.

2. Experimental

2.1. Characterisation of the leachate

All chemical and biological analysis on leachate