Interest in the recovery of metals from dilute aqueous solutions is steadily increasing because of environmental concerns and potential economic rewards. Since conventional electrowinning cell systems with parallel plate electrodes are unsuitable for an efficient and economic treatment of effluents, many novel electrolytic methods with two-, semithree- and three-dimensional electrodes have been developed and few cell designs are already successfully applied on an industrial scale. The most important characteristic of these cell systems to ensure high current efficiencies and high production rates is improved mass transfer by use of extended cathode surfaces and vigorous agitation of the electrolyte. In competition with other effluent treatment methods such as adsorption, evaporation, precipitation, cementation, ion exchange, liquid-liquid extraction and reverse osmosis, the electrolytic processes offer the possibility of recovering the metal values from dilute solutions as a marketable metal product in a one step process. This review is focused on industrial applied cell designs and their special field of application. Their economics and cost savings in comparison with conventional treatment techniques are outlined and discussed.

INTRODUCTION

To meet the challenges of increasingly stringent environmental directives for emission of metal concentrations in industrial discharges, effluents, or waste waters, improved technologies for metal recovery have to be developed and introduced in a short period of time.
Fig. 1. Electrolytic treatment of dilute solutions.

The main sources of metal containing dilute solutions include: mine waters or leach liquors from natural ore leaching; solutions from primary ore as well as mine dump or heap leaching procedures; spent electrolytes from hydrometallurgical operations; echants and pickling solutions from metal working processes; and rinse waters, spills and effluents from metal finishing and electroplating industries. In most cases, these solutions contain less than a few grams of metal per liter.

As shown in Fig. 1, these low metal contents have to be reduced either to predetermined values after which the solution can be recycled into the process or to residual values of few ppm or less before draining into a sewer to meet effluent guidelines or other environmental regulations. In Table 1 are summarized some of the residual concentrations of waste water to be discharged as proposed by the US Environmental Protection Agency for 1982.\(^1\)

For the recovery of the metal values from these dilute solutions many physical, chemical, and electrolytic methods have been developed which involve various separation and concentration procedures as well as the production of marketable compounds or metals.\(^2,3,4,5\) In Table 2 is a comparison of the advantages and disadvantages of some of the most frequently applied methods for effluent treatment in industry.\(^6\) The obvious attractions for considering electrolytic metal extraction method for the treatment of dilute solutions are that it is a one step process, it does not create further waste, and it recovers metal directly as a marketable product.