Practical Considerations towards Implementing a Capacitive Deionization Device for Water Treatment

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Capacitive deionization (CDI) has recently emerged as an alternative method for chemical-free water treatment, with particular emphasis in desalination and water softening. This technology is based on the electro-sorption of ions upon the application of an electric potential (or current) to a pair of porous electrodes. Ion desorption, achieved by reversing the applied potential, allows regenerating the electrodes, whereas the desorbed ions are discharged into brine. This mechanism is attractive as the output water does not have added sodium, unlike in salt-based water softening, and the process is potentially more energy efficient than reverse osmosis. However, there are several remaining challenges associated to its practical implementation.

In this work, we discuss the performance, in terms of ion removal, energy requirements, and continuous use, of a single pass CDI device able to handle between 45 and 110 ml/min of water. The unit was fed with calcium and sodium coupled with sulfate and chloride anions. Sodium carbonate removal was also analyzed with the purpose of assessing pH-buffering effects. Ion concentrations were measured by inductively coupled plasma (ICP) and correlated with in-line conductivity and pH readings. During ion adsorption, the unit was powered with electric cell potentials between 0.8 and 2.4 volts. After the ion removal period (15 minutes), the unit subject to a potential ranging between -1 to 0 volts for at least 12 minutes, with the purpose of desorbing the ions into a brine. Current was measured with an independent ammeter.

The results suggested that the unit was able to work as a CDI system in sequential adsorption/desorption cycles without major loss in removal performance. Specific calcium adsorption was also detected. In treating unbuffered solutions with voltages up to 1.2 volts, pH oscillated within a decade from circumneutral levels, suggesting that the rates of adsorption for counter ions are asymmetrical. At higher potentials, acidification of the treated water was observed up to pH 3, leading to a mismatch between conductivity and ion concentrations as measured by ICP. No evidence of chloride oxidation was found at potentials of 1.2 volts or below.

From an energy point of view, the electric charge invested in ion adsorption was correlated with the equivalent charge of the adsorbed ions, suggesting that, after a short period of energy loss due to electrode polarization, sorption of ions can achieve efficiencies over 60%, sufficient to be competitive with methods such as reverse osmosis for deionizing brackish waters. Taken together, these results show the promise of CDI to become an efficient alternative for water treatment, in terms of continuous use, clean water output and energy use.