

## Cadmium Removal From Aqueous Solution by Capacitive Deionization with Nano-Porous Carbon Electrodes

D.I. Marmanis<sup>1,\*</sup>, K.I. Dermentzis<sup>1</sup>, A.K. Christoforidis<sup>1</sup> and K.G. Ouzounis<sup>2</sup>

<sup>1</sup>Department of Petroleum and Natural Gas Technology, Laboratory of Environment Protection, Kavala Institute of Technology, 65404 Agios Loucas, Kavala, Greece,

<sup>2</sup>Department of Environmental Engineering, Laboratory of Environmental Chemistry, Democritus University of Thrace, 67100 Xanthi, Greece

Received 10 June 2013; Accepted 25 August 2013

### Abstract

The aim of present work is to determine the efficiency of capacitive deionization on removal of cadmium ions from an aqueous solution using nano-porous carbon aerogel electrodes. The electrosorption performance is investigated at various applied voltages and solution pH values. For the optimum conditions of applied voltage 1.2 V and pH 6, the initial cadmium concentration of 200 mg/L decreased to 5 mg/L showing a reduction of 97.5 %.

**Keywords:** Cadmium, Deionization, Removal, Nanoporous

### 1. Introduction

Cadmium is a very toxic heavy metal and one of the major metallic pollutants originating from agricultural, mining and industrial activities. Various treatment processes such as adsorption, biosorption, ion exchange and electrochemical cadmium from aqueous waste streams. Capacitive deionization or otherwise called electrosorption is an electrochemical ion collection/discharge process which relies on the formation of double-layer supercapacitors at the solution /electrode interface [3-6]. When an electric field is applied between two carbon aerogel electrodes, cations and anions are held in the electric double-layers formed at the cathode and anode surface respectively. The high specific area and electrosorption capacity of the carbon aerogel electrodes enables the efficient electrostatic attraction and removal of ions, resulting in the purification of the treated solution.

### 2. Experimental

The experiments were conducted in a 100 ml plexiglass reactor with dimensions 10 cm in length, 10 cm in height and 1 cm in width. Three electrodes of carbon aerogel were used (Marketch Int. USA) with dimensions 8 cm in height and 8 cm in width each one, two anodes and one cathode in the middle. The electrodes were placed vertically in parallel connection to each other at a distance of 0.3 cm between them. The solution volume was 100 ml. The electrodes were

connected to a digital dc power supply (Agilent E3612A, USA) for measuring the electrode potential and current. Conductivity was measured by means of a conductometer (WTW). pH and temperature were determined using a pH-meter (Hanna). The concentration of cadmium ions was determined by atomic absorption spectroscopy (Perkin Elmer 5100 Atomic Absorption Apparatus PC). All experiments were conducted at room temperature.

### 3. Results and Discussion

#### Effect of operating parameters

**Effect of pH:** The value of pH is one of the most important parameters controlling both, the physical and electrochemical uptake of cadmium from aqueous solutions. The effect of pH on removal of cadmium at 1.2 V bias potential and 40 min residence time, was studied at different solution pH values adjusted to 2, 4 and 6 and fixed cadmium concentration of 200 mg/L. Experimental results depicted in Fig.1, reveal that the removal of cadmium increases with increasing pH. At more acidic solutions the competition between  $H^+$  and  $Cd^{2+}$  ions for adsorption on the ion-exchangeable sites of the carbon aerogel surface leads to a lower removal of cadmium. The initial cadmium concentration of 200 decreases to 58, 37 and 5 mg/L at the corresponding solution pH values of 2, 4 and 6, showing a removal percentage of 71, 81.5 and 97.5 % respectively.

**Effect of applied voltage:** In order to study the effect of applied voltage on cadmium, removal experiments were carried out under varying voltages of 0.4, 0.8 and 1.2 Volt at fixed cadmium concentration of 200 mg/L and optimum pH = 6. The results are shown in Fig.2. Higher removal

\* E-mail address: imarm@teikav.edu.gr

efficiency for cadmium was achieved at higher voltages, as increased voltage increases the flow velocity of electrons and the electrostatic attraction of ions by the opposite charged electrodes.

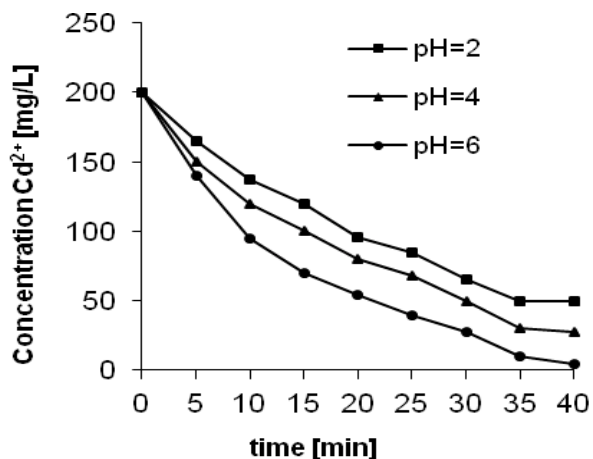


Fig. 1. Concentration variation of cadmium versus time at various solution pH values

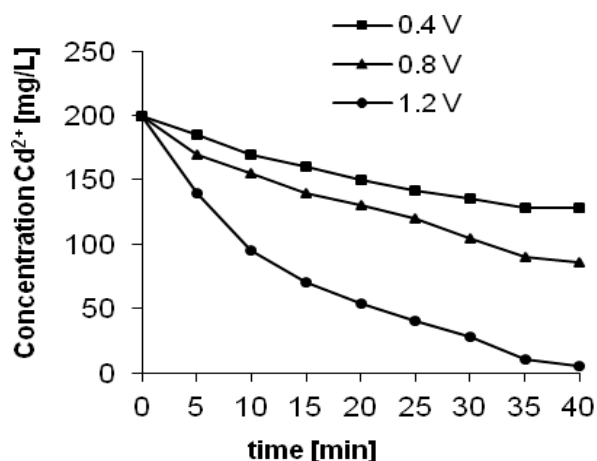


Fig. 2. Concentration variation of cadmium versus time at various applied voltage

The initial concentration of cadmium decreased from 200 to 138, 83 and 5 mg/L at the corresponding applied voltages of 0.4, 0.8 and 1.2 V.

**Electrodesorption:** The electrodesorption process is reversible, as the electrode charge/discharge procedure can be repeated several times without any significant loss of the salt sorption capacity. The electrodesorption step helps to regenerate the electrodes and recover the adsorbed  $\text{CdCl}_2$  from the electrodes. Regeneration of electrodes can be done in two ways, namely discharging the cell at 0.0 V or reversing the cell polarity at an opposite charge.

#### 4. Conclusions

In this paper, the performance of capacitive deionization for removal of cadmium from dilute aqueous  $\text{CdCl}_2$  solutions using carbon aerogel electrodes was investigated. Experimental results showed that the electrodesorption capacity of cadmium effectively increases with increasing pH and increasing applied voltage. Electrodesorption is a very economic and energy efficient method for water deionization and removal of heavy metals, such as cadmium from wastewater. Further research is needed in order to gain more information about this very promising water deionization technique.

#### References

1. K. Dermentzis, A. Christoforidis, D. Papadopoulou, A. Davidis, *Environ. Progr. Sust. Energy*, **30**, 37 (2011).
2. M. Kobya, E. Demirbas, N.U. Parlak, S. Yigit, *Environ. Technol.* **31**, 1471 (2010).
3. I. Cohen, E. Avraham, M. Noked, A. Soffer, D. Aurbach, *J. Phys. Chem.*, **C 115**, 19856 (2011).
4. M.A. Anderson, A.L. Cudero, J. Palma, *Electrochim. Acta*, **55**, 3845 (2010).
5. R.L. Clifton, C.A. Rios Perez, R. Naylor, C. Hidrovo, *Conf. proc. ASME 2012*, 8-12 July 2012, Rio Grande, Puerto Rico.
6. A. Subramani, M. Badruzzaman, J. Oppenheimer, J.G. Jacangelo, *Water Res.* **45**, 1907 (2011).