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Disinfection of Water by Adsorption with Electrochemical Regeneration

S. N. Hussain, H.M.A. Asghar, E. P. L. Roberts, and N. W. Brown

***Abstract*—**Arvia®, a spin-out company of University of Manchester, UK is commercialising a water treatment technology for the removal of low concentrations of organics from water. This technology is based on the adsorption of organics onto graphite based adsorbents coupled with their electrochemical regeneration in a simple electrochemical cell. In this paper, the potential of the process to adsorb microorganisms and electrochemically disinfect them present in water has been demonstrated. Bench scale experiments have indicated that the process of adsorption using graphite adsorbents with electrochemical regeneration can be used for water disinfection effectively. The most likely mechanisms of disinfection of water through this process include direct electrochemical oxidation and electrochemical chlorination.

***Keywords*—**Arvia®; Adsorption; Electrochemical Regeneration; Nyex®.

I. Introduction

INDUSTRIAL growth and increased population is seriously damaging the characteristics of environment due to the discharge of toxic organics into water. Water pollution due to the release of refractory organic contaminants from the industrial and municipal sources has become a severe concern of the world. In addition to the organic constituents, a large number of microorganisms are present in wastewater including bacteria, viruses and fungi. These pathogenic micro-species cause many diseases for example, typhoid, cholera and diarrhea etc [1]. Nearly half of the population of under-developed countries suffers from health related issues due to the microbiological contamination of water [2]. Thus, microbiological contamination is the most important type of pollution to be addressed regarding the health of humans. Arvia® is a spin out company of the University of Manchester and is commercializing a technology for the removal of organics from wastewater [3]. This technology employs graphite based adsorbents for the removal of organics and thereby the adsorbent is electrochemically regenerated for re-use.

This paper presents the results of bench scale experiments using the process of adsorption with graphitic adsorbent coupled with electrochemical regeneration to achieve bacterial disinfection.

S. N. Hussain and H.M.A. Asghar Present Address: Institute of Chemical Engineering and Technology, University of the Punjab, Lahore, Pakistan (phone: +92-3004239260; fax:+92-42-99231261; e-mail:hussain_nadir@hotmail.com).

S. N. Hussain, H.M.A. Asghar, E. P. L. Roberts are with School of Chemical Engineering and Analytical Science, The University of Manchester, UK.

N. W. Brown is with Arvia Technology Ltd, UK.

II. Materials, Equipments and Methods

A. Materials

Nyex 100 The graphitic adsorbent, Nyex®1000 was supplied by Arvia Technology Ltd in the form of flakes with a mean particle diameter of 484 μm. This material is non-porous and therefore possesses a low BET surface area of around 1.0 m2 g^{-1}. Analytical grades of all chemicals were supplied by Sigma Aldrich, UK.

A model microorganism, E. coli MS101 was chosen for the study of adsorption onto Nyex®1000 and its subsequent electrochemical regeneration.

B. Mini-Sequential Batch Reactor (mini-SBR)

The mini-sequential batch reactor is a Y-shaped electrochemical cell in which both adsorption and electrochemical regeneration are carried out in the same unit. The details of the equipment are given in Fig. 1.

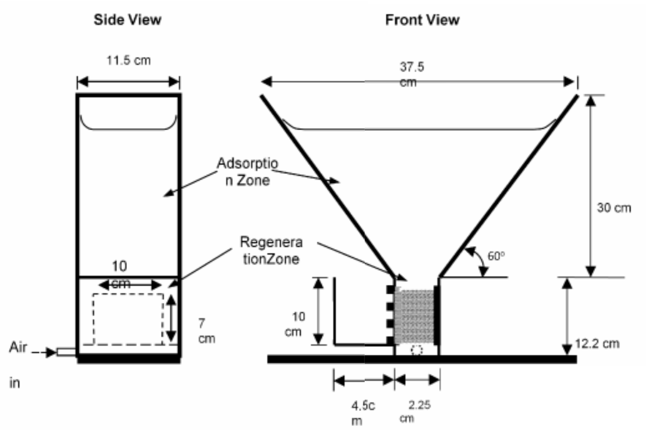

Fig. 1 Schematic diagram of the min-sequential batch reactor (SBR) used for adsorption studies (Hussain, 2012)

C. Methods

The A specified volume of a known concentration of E. coli suspension prepared in normal saline were mixed with a fixed quantity of Nyex®1000 in the min-sequential batch reactor (Fig. 1) for 30 min. After the completion of adsorption, the air supply was turned off and Nyex®1000 particles were allowed to settle into the anodic compartment to form a uniform bed of particles. The adsorbent bed was in contact with the graphite anode and was separated from the steel cathode by the polyethylene membrane. Afterwards, a sample of supernatant above the settled Nyex®1000 was taken from the cell. Electrochemical regeneration of the settled Nyex®1000 was performed at 0.5 A for 20 min (10 mA cm^{-2}). The catholyte used was 0.3% NaCl aqueous solution acidified with 5M HCl (pH<1.5). The water was drained from the cell after the regeneration was completed. E. coli suspension of the same concentration and same volume was added into the cell for re-adsorption followed by regeneration. In this way, five adsorptions and five regenerations were carried out. The results were compared to a control where no current was passed during regeneration.

The regeneration efficiency (RE) of the adsorption cycles was evaluated using:

$$RE = \frac{\text{Adsorption capacity of regenerated adsorbent}}{\text{Adsorption capacity of fresh adsorbent}} \times 100$$

D. Analysis

The plate counting technique was used in order to determine the number of viable (living) cells in water.

III. Results and Discussions

The effect of electrochemical regeneration was investigated using 400 ml of E. coli suspension (6 × 107 CFU ml^{-1}) in a saline solution (0.9% NaCl solution in deionised water) over a number of adsorption/regeneration cycles. This was the first attempt to investigate whether the adsorbed E. coli cells were destroyed during the electrochemical regeneration of Nyex®1000 under the above mentioned conditions. In order to further validate the destruction of E. coli a blank run was conducted in such a way that all the above experimental steps were exactly the same except that no current was passed during the regeneration cycles.

The results revealed that 100% regeneration efficiency of Nyex®1000 loaded with E. coli was obtained as shown in Fig. 2 because not even a single CFU per mL was found after any adsorption. In contrast, the number of CFU per mL increased after each adsorption for a blank run where no current was supplied during the respective regeneration cycles (Fig. 3). Subsequently, the percent regeneration efficiency decreased from the first to fourth regeneration cycle as shown in Fig. 2. These results undoubtedly indicated the continuing exhaustions of the adsorption capacity of Nyex®1000 during the course when no current was passed during the electrochemical regeneration cycles. It recommends that electrochemical regeneration has a considerable effect in deactivating the E. coli cells adsorbed onto the surface of Nyex®1000 at a low current density of 10mA cm^{-2}. Brown and Roberts has already suggested that organic species adsorbed onto the surface of graphite based adsorbents are completely oxidised leaving no objectionable material [4]. However, the mechanism of disinfection during electrochemical regeneration could include direct electrochemical disinfection and electrochlorination [5]. In the direct electrochemical disinfection, the microorganisms are supposed to be deactivated due to the passage of electrons through the microbes. In electrochlorination, chloride in the solution is oxidised to chlorine at the anode. The Arvia process uses aqueous sodium chloride solution in the cathode compartment and therefore the generation of high concentrations chlorine at the surface of adsorbent could be a significant cause of disinfecting microorganism present in water. However, this needs further investigation.

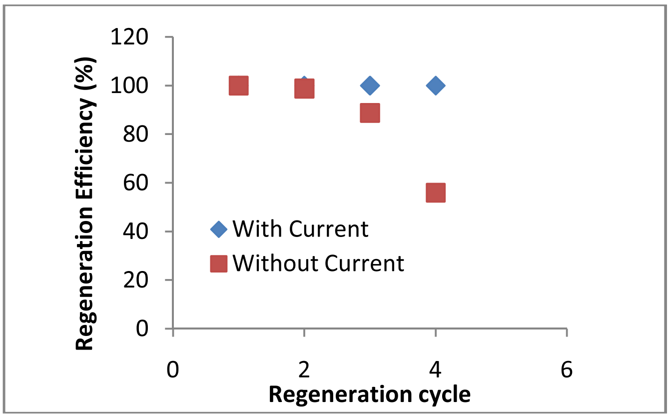

Fig. 2 Comparison of regeneration efficiency for the adsorption of E. coli onto Nyex®1000 with and without current, 0.5 A for 20 min at 10 mA cm^{-2}, charge passed: 6 C g^{-1}

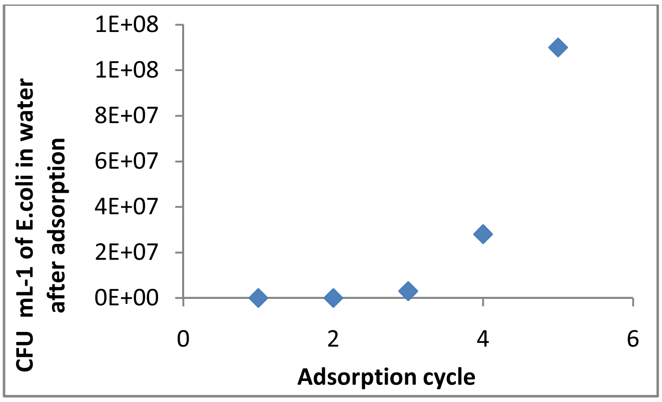

Fig. 3 Multiple adsorption cycles during blank run with an initial concentration of 2.5 × 108 CFU mL^{-1} when no current was supplied during respective regenerations

IV. Conclusion

This study has confirmed that the Arvia® Process could be used for the disinfection of water using a process of adsorption and electrochemical regeneration. It has also been concluded that the adsorption of microorganism onto graphitic adsorbents is rapid and comparable to the adsorption of organics. The process was found to be effective with the attainment of complete disinfection after electrochemical regeneration of Nyex®1000. It has also been suggested that the mechanism of inactivation of E. coli could be due to direct electrochemical disinfection and electro-chlorination.

Acknowledgment

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