World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:17, No:12, 2023

The Treatment of Nitrate Polluted Groundwater Using Bio-electrochemical Systems Inoculated with Local Groundwater Sediments

Authors : Danish Laidin, Peter Gostomski, Aaron Marshall, Carlo Carere

Abstract : Groundwater contamination of nitrate (NO3-) is becoming more prevalent in regions of intensive and extensive agricultural activities. Household nitrate removal involves using ion exchange membranes and reverse osmosis (RO) systems, whereas industrial nitrate removal may use organic carbon substrates (e.g. methanol) for heterotrophic microbial denitrification. However, these approaches both require high capital investment and operating costs. In this study, denitrification was demonstrated using bio-electrochemical systems (BESs) inoculated from sediments and microbial enrichment cultures. The BES reactors were operated continuously as microbial electrolytic cells (MECs) with a poised potential of -0.7V and -1.1V vs Ag/AgCl. Three parallel MECs were inoculated using hydrogen-driven denitrifying enrichments, stream sediments, and biofilm harvested from a denitrifying biotrickling filter, respectively. These reactors were continuously operated for over a year as various operating conditions were investigated to determine the optimal conditions for electroactive denitrification. The mass loading rate of nitrate was varied between 10 – 70 mg NO3-/d, and the maximum observed nitrate removal rate was 22 mg NO3- /(cm2•d) with a current of 2.1 mA. For volumetric load experiments, the dilution rate of 1 mM NO3- feed was varied between 0.01 – 0.1 hr-1 to achieve a nitrate loading rate similar to the mass loading rate experiments. Under these conditions, the maximum rate of denitrification observed was 15.8 mg NO3- /(cm2•d) with a current of 1.7mA. Hydrogen (H2) was supplied intermittently to investigate the hydrogenotrophic potential of the denitrifying biofilm electrodes. H2 supplementation at 0.1 mL/min resulted in an increase of nitrate removal from 0.3 mg NO3- /(cm2•d) to 3.4 mg NO3- /(cm2•d) in the hydrogenotrophically subcultured reactor but had no impact on the reactors which exhibited direct electron transfer properties. Results from this study depict the denitrification performance of the immobilized biofilm electrodes, either by direct electron transfer or hydrogen-driven denitrification, and the contribution of the planktonic cells present in the growth medium. Other results will include the microbial community analysis via 16s rDNA amplicon sequencing, varying the effect of poising cathodic potential from 0.7V to 1.3V vs Ag/AgCl, investigating the potential of using in-situ electrochemically produced hydrogen for autotrophic denitrification and adjusting the conductivity of the feed solution to mimic groundwater conditions. These findings highlight the overall performance of sediment inoculated MECs in removing nitrate and will be used for the future development of sustainable solutions for the treatment of nitrate polluted groundwater.

Keywords : bio-electrochemical systems, groundwater, electroactive denitrification, microbial electrolytic cell
Conference Title : ICW 2023 : International Conference on Wastewater
Conference Location : Auckland, New Zealand
Conference Dates : December 04-05, 2023