Continuous and sequencing batch operations of a hydrogen based moving bed biofilm reactor to achieve very low effluent perchlorate concentrations with the presence of RDX

Jin Woo Lee 1, Sanghyung Lee 1, Lance Schideman 2, Byung J. Kim 3 and Eberhard Morgenroth 1,4, * 1. Department of Civil and Environmental Engineering, 4. Department of Animal Sciences University of Illinois at Urbana-Champaign Urbana, IL 61801
2. Department of Agricultural and Biological Engineering, University of Illinois at Urbana-Champaign Urbana, IL 61801
3.U.S. Army Engineer Research and Development Center, Champaign, IL 61826
*Corresponding author. E-mail address: emorgen@illinois.edu

Introduction

• Perchlorate (CO-4) and Royal Demolition Explosive (RDX, Hexahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) are major components of wastewaters produced during ammunition and solid rocket fuel production.
• Perchlorate inhibits the thyroid function and may affect fetal cerebral development. Guideline values for perchlorate in drinking water range from 2 µg/L (Massachusetts) to 24 µg/L (US EPA).
• Perchlorate and RDX were added to the US EPA list of priority pollutants. The US EPA has defined a guideline value for drinking water of 2 µg/L.
• Biological treatment can be used to remove perchlorate and RDX before discharging wastewater.
• Treatment processes can be differentiated according to the type of electron donor, the type of reactor configuration, and the flow regime.
• Biological removal of perchlorate and RDX using hydrogen as the electron acceptor.

Background

- Both the plug flow reactor (PFR) and the sequencing batch reactor (SBR) take advantage of higher removal rates due to higher bulk phase concentrations for most of the reactor (in the PFR) or most of the reaction time (in the SBR).
- In a continuous stirred tank reactor (CSTR) reaction rates in the reactor are determined by substrate concentrations in the effluent. For very low effluent concentrations (e.g., in the g/L range as in the current study) this results in very large reactors.
- During the SBR cycle perchlorate is rapidly removed while RDX removal is slower.
- Slightly reduced RDX fluxes were observed when the reactor was operated with both perchlorate and RDX in the influent compared to feeding only RDX.

Materials & Methods

- Reactor: 16 L moving bed biofilm reactor
- Carrier material: Kaldnes K-1 with 50% of Rin ratio (Surface area: 500 m2)
- Electron donor: Hydrogen gas
- Influent perchlorate concentration: 10 – 1,000 mg/L
- Influent RDX concentration: 25 - 50 mg/L
- HRT: 4 – 83 hr
- pH: 4 – 6.5
- ESS: 5% – 100 %
- Cycle times: 2 - 24 hr
- Influent flow: 10 – 400 mL/min
- Influent gas flow: 0 – 10 L/min
- Hydrogen gas recirculation: 190 L/h
- Influent CO2 gas concentration: 5 – 20 vol%
- pH control: 10 mM phosphate buffer in the influent and addition of CO2 gas
- Gas recirculation rate: 10 L/h

Results

- Perchlorate flux for bulk phase concentrations below 6.02 mg/L can be approximated with a first order rate expression (Flux(g/m2-d) = 2.73 C (mg/L)) corresponding, for example, to a flux of 0.557 g/m2-d at bulk phase concentrations of 20 mg/L.
- Complete perchlorate removal was achieved in with SBR operation at loading rates up to 15 g/m2/day while at the same loading rates effluent perchlorate concentrations increased up to 205 mg/L.
- PFR and SBR operation is especially beneficial for treatment systems with large differences between influent and effluent substrate concentrations. In the current study target perchlorate removal efficiencies are on the order of 99.99% (e.g., from 100 mg/L, down to 5 µg/L). For these removal efficiencies SBR (or PFR) type operation results in 10 – 40 times smaller reactors compared to CSTR type operation.

Conclusion

• Sequencing batch operation of the MBBR takes advantage of higher removal rates with increased bulk phase concentrations in smaller reactors and improved reactor performance.
• Reduced rates of perchlorate reduction were observed in the presence of RDX compared to operation with perchlorate alone.
• Perchlorate could potentially have a negative effect on RDX removal.

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References


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