Column Study of Bioelectric Remediation of Nitrate in Groundwater Systems

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Introduction

Nitrate is increasingly becoming an environmental and serious health hazard; it often contaminates groundwater through fertilizer runoff, leaking septic tanks, and sewage discharge. The current Maximum Contaminant Level (MCL) for nitrate, as set by the EPA, is 10 mg/L. This research involved developing a new way of enhancing bio-denitrification of nitrate through the use of electrical proton reduction to increase dissolved hydrogen levels in a simulated aquifer.

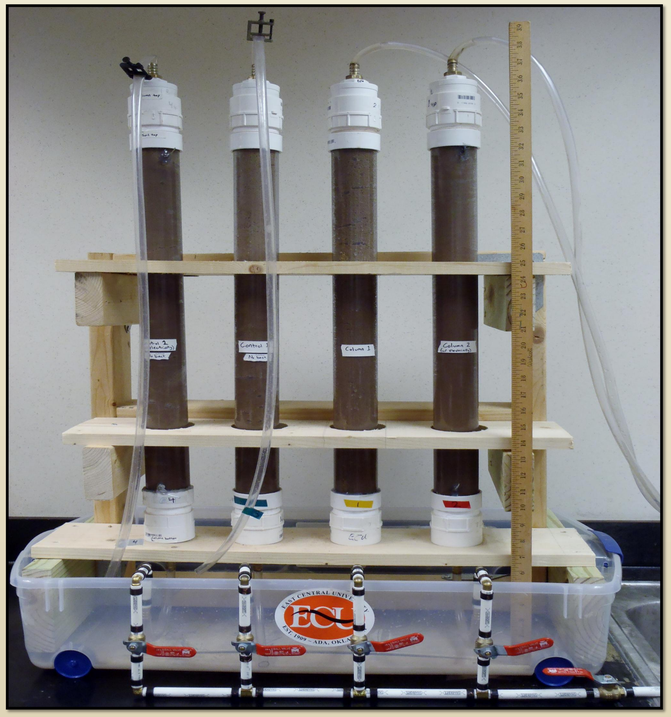


Photo 1. Columns filled with sand to simulate an unconsolidated aquifer.

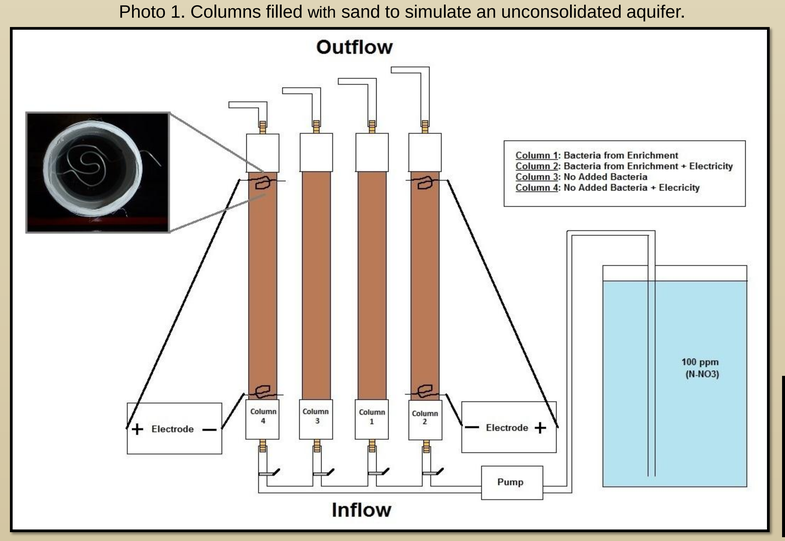
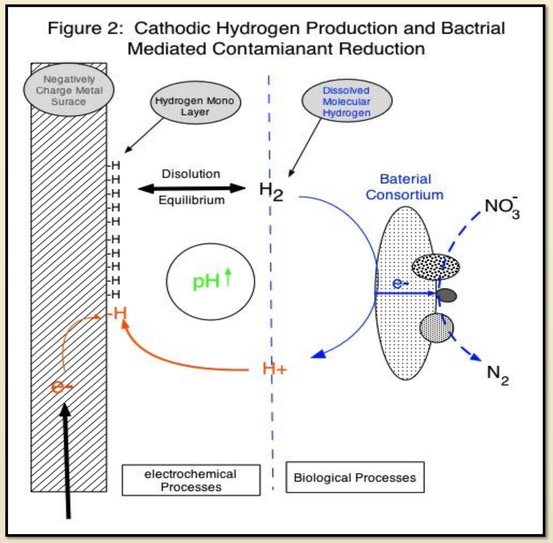


Figure 1. Diagram illustrating column design, including inflow, outflow, and the attached electrical sources. Insert features cross-section of wires that will supply a negative potential to the column.



Materials/Methods:

- 4 columns with a volume of ~168 in^3, filled with sand
- Sediment and water collected from Wintersmith Lake, Ada, OK
  - DI water added to make a 20:1 enrichment solution
- Solutions of 100 ppm N-NO_3
- MasterFlex Easy-Load Pump set at flow rate of ~0.36 L/hour
- GW Instek DC-Power Supply set at 3 volts (0.001 amps)

A bacterial enrichment was fed various solutions of potassium nitrate, ethanol, and yeast extract to promote bacterial nitrate reduction (Photo 1, Graph 1). Other parameters such as ammonia production, pH, and conductivity were determined to monitor the conditions in the enrichment (Table 2).

The enrichment solution was pumped through two columns filled with sand to simulate an unconsolidated aquifer (Photo 1, Figure 1). The ingoing and outgoing solutions of these columns were monitored for nitrate levels while the bacteria colonized the columns.

Once stabilized, a negative potential charge was applied to an electrode within one column. This negatively charged electrode provided a dissolved hydrogen source, via proton reduction, and thus also a bio-oxidizable energy source which could enhance denitrification. Samples for ammonia were taken to support the conclusion that nitrogen gas was the major end-product (Figure 2).

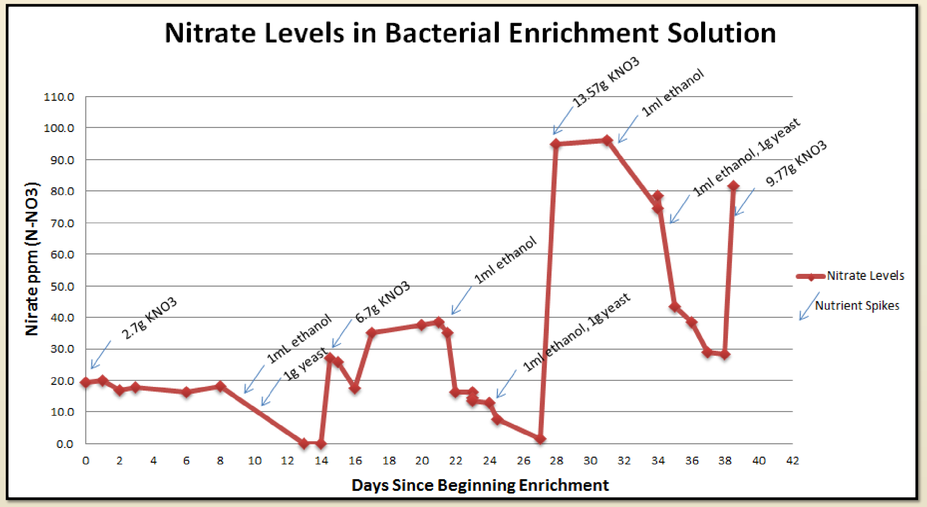
	Empty Column Weight (kg)	Soil Weight (kg)	Column w/ Soil Volume (cubic in)	Estimated Water Porosity	Estimated Detention Time (hrs)
Column 2	1.1	2.4	167.7	22%	2
Column 1	1.1	2.7	167.7	21%	2
Column 3	1.1	2.3	168.5	24%	2
Column 4	1.1	2.1	168.1	25%	2

Table 1. Column capacities and characteristics.

References:

- "Basic Information about Nitrate in Drinking Water." U.S. Environmental Protection Agency. 21 May 2012. Web.

Results:



Graph 1. Nitrate levels in the bacterial enrichment solution over time.

Photo 2. Enrichment solution obtained from sediment and water in lake.

Day	Date	pH	NH3 (ppm)	Conductivity (uS)
16	8/8/13	8.30	3.0	1070
17	8/9/13	7.70	3.0	734
20	8/12/13	8.00	3.0	721
21	8/13/13	7.57	3.0	753
Added 1ml ethanol				
21.5	8/13/13	7.58	3.0	758
22	8/14/13	7.75	3.0	705
23	8/15/13	8.14	3.0	688
24	8/16/13	7.88	3.0	669
Added 1g yeast extract, 1ml ethanol				
24.5	8/16/13	7.67	3.0	683
27	8/19/13	7.51	4.0	693
Added 13.57g KNO3				
28	8/20/13	8.01	5.0	1624
31	8/23/13	8.02	4.0	1572
Added 1ml ethanol				
34	8/26/01	8.16	4.0	1523
Added 1g yeast extract, 1ml ethanol				
35	8/27/13	8.20	3.5	1528
36	8/28/13	8.23	3.5	1507
37	8/29/13	7.90	5.0	1579
38	8/30/13	7.85	5.0	1582

Table 2. Parameters used to monitor enrichment's stability.

Discussion/Next Steps:

The enrichment data shows evidence to support that the solution contains sufficient bacteria to yield the desired level of nitrate reduction.
Our next step includes continuing data collection as the negatively charged electrode provides an electron source to the column to potentially enhance bacterial denitrification. Additional column controls will be utilized. From this data, a nitrate concentration curve will be created to show the relationship between nitrate levels and the addition of hydrogen through proton reduction.

Acknowledgements:
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