



Groundwater Ammonia and Nitrate Bioremediation

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Summary

Based on our work, microbial driven bioremediation of ammonia and nitrate contaminated groundwater is now feasible and reasonable. Science's understanding of the nitrogen cycle has changed dramatically in the past few years. Previously, fragile nitrifying and denitrifying bacteria were the focus. Recent studies show the majority of ammonia oxidation is driven by robust Crenarchaea and related Archaeal organisms, even at low oxygen levels. And evidence is accumulating that Archaea are also responsible for denitrification, even under aerobic conditions.

Our Arkea™ cocktails successfully reduce ammonia and nitrate in a variety of wastewater environments. Combining new peer-reviewed literature findings with our wastewater knowledge and know-how; we undertook preliminary laboratory and full-scale field-tests to evaluate Arkea™ driven ammonia and nitrate removal from groundwater.

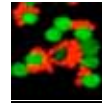
The result ... Success ... Field testing of Arkea™ bioremediation of both ammonia and nitrate contaminated groundwater was operationally and economically successful ... at contamination levels from 150 mg/L to greater than 2,500 mg/L

Introduction

The role of bacteria in ammonia breakdown and the nitrogen cycle was originally discovered 117 years ago, and little changed in science's knowledge base for 100+ years. But in recent years, science's view of ammonia metabolism and the nitrogen cycle has tipped over ... twice. First was the discovery of anaerobic ammonia oxidation (Anammox Reaction) and second the dominant role Archaea organisms play in ammonia oxidation and the nitrogen cycle, even in very low dissolved oxygen conditions.

Early laboratory work here led to treating ammonia and nitrate contaminated WWTF's, ranging from ponds to activated sludge plants. All lacked the variety of environments thought necessary for ammonia and nitrate elimination. In addition, they often lacked adequate carbon to fuel the required biochemical reaction stoichiometry. Even so, Arkea™ cocktails were developed that consistently and economically resolved excess nitrogen problems.

These WWTF successes led to working with groundwater contaminated with ammonia and nitrate. Why? The low oxygen and carbon concentrations in groundwater mimicked



the above ground WWTF work we had completed with specific Arkea™ cocktails. With these insights and data, field tests were initiated.

Field Test Arkea™ in Groundwater

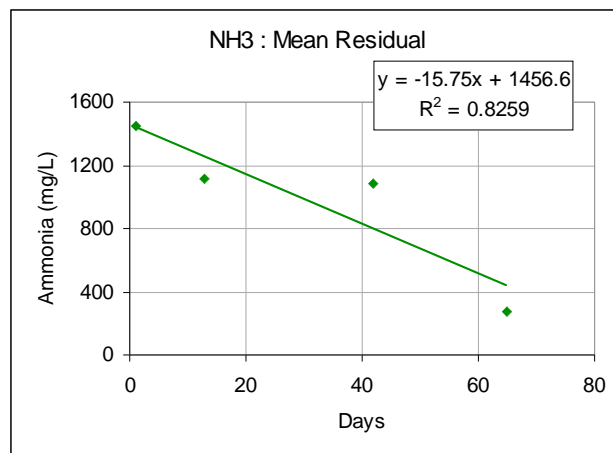
NOTE: There is a Confidential Disclosure Agreement between ArchaeaSolutions, Inc. and the third-party providing the testing site. Fortunately, they have allowed us to publish non-attributed “arithmetic means” data.

Method.

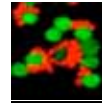
Three sites were selected by the third party. The sites were all anaerobic, with a pH +/- 4.0, and a COD < 5.0. Two inch diameter dosing wells were drilled, extending into the groundwater zone. Ten monitoring wells were drilled in concentric circles around the dosing well. The monitoring wells’ distribution radius was greater than 20 feet. The volume of groundwater in the space outlined by the monitoring wells was calculated. Gravity dosing of an Arkea™ suspension at 1% of this (vol/vol) followed (actually either gravity dosing or injection can be used). Time zero samples were taken for ammonia and nitrate measurement. Subsequent dosing occurred on days 13 and 42 and sampling on days 13, 42, and 65 after Time 0.

Results: Ammonia

The chart below presents mean ammonia levels as a function of days of treatment. Each data point represents the mean of 30 monitoring wells’ data.



Sampling continued for 65 days after treatment began. For planning purposes, a linear equation was generated. An r-square of 0.8259 was calculated for a $y = mx + b$ equation



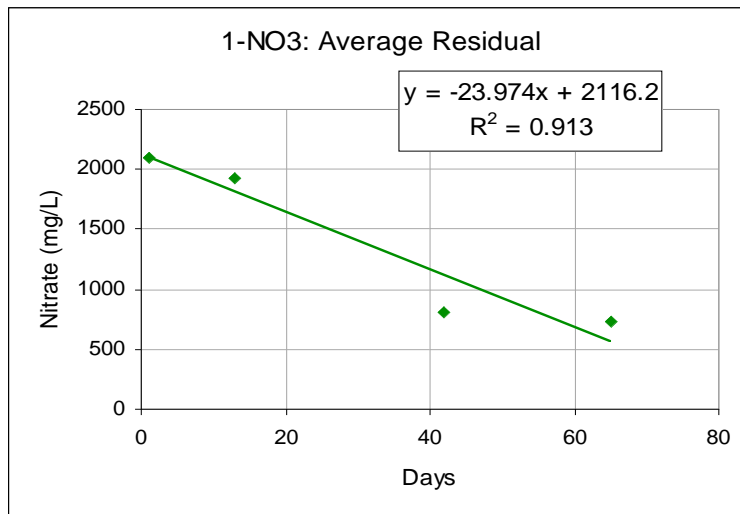
where x is days of treatment and y is remaining ammonia (mg/L). The calculated equation was:

$$y = -15.75x - 1456.6$$

Using this equation, 90-days treatment should provide residual ammonia levels less than 10 mg/L. Scheduling 120 to 150 days for this project should trigger positive schedule and budget variances.

Results: Nitrate

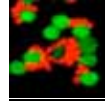
The chart below presents mean nitrate levels as a function of days of treatment. Each data point represents the mean of 30 monitoring wells' data.



Sampling continued for 65 days after treatment began. A linear equation ($y = mx + b$ equation where x is days of treatment and y is remaining ammonia (mg/L)) was generated with an r-square of 0.9130. The calculated equation is:

$$y = -23.97x + 2116.2$$

Using this equation, 90-days treatment should provide residual nitrate levels less than 10 mg/L. As with ammonia, scheduling 120 to 150 days for this project should mean positive time and budget variances.



Approach

The results of groundwater work paralleled results of WWTF work. Based on the combined body of data and experiences, the following generalized approach to managing ammonia and/or nitrate in groundwater is suggested:

1. Select one or more pilot testing sites as a function of presence or absence of geological variation.
2. Complete a 60 to 75 day pilot test with dosing and sampling parameters similar to this work.
3. Analyze results to generate schedule and budget.
4. Proceed to full-scale remediation of site or slowly expand treatment area if preferred.

We typically work with an engineering firm on these projects and our contribution is providing product and counsel.

Next Steps

Would enjoy reviewing these data in more depth and assessing any specific project you might have in mind.