Using Biopolymers to Preferentially Remove Phosphate in Wastewater Streams from Confined Animal Feed Operations

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Background/Objectives. The movement of agricultural processes for the production of animal products from individual farms to large concentrated operations has led to unique challenges associated with wastewater disposal. USEPA lists the main byproducts of animal production as manure (feces and urine), animal parts, dead animals, feed lot runoff, excess feed, and others. As confined animal feed operations (CAFOs) became larger, the volume of wastewater generated was concentrated into smaller areas thereby requiring a different approach to more conventional treatment and disposal systems. In 2003, the USEA reported that poor management of CAFO waste had "caused serious acute and chronic water quality problems". Two of the most common constituents of concern found in CAFO wastewater discharge are nitrates and phosphates, both of which also have value as fertilizers. This has led to an attempt to optimize wastewater treatment and reduce the environmental footprint of CAFOs by applying a portion of the wastewater on agricultural fields. Because the ratio of nitrogen to phosphorous in CAFO wastewater is not optimal for field applications, the amount of wastewater applied over a given time period is limited by the amount of phosphate contained in solution. If the ratio of phosphate to nitrate could be economically manipulated, a much larger percentage of the total discharge could be used for field application. Since phosphate tends to bind with soil particles it is theorized that one method of preferentially reducing the amount of phosphate in water without removing nitrates is through flocculation of the phosphate along with the soil particles. Chitosan, a derivative of chitin, is a natural biopolymer used to treat storm and industrial water, including construction site runoff through flocculation. When used alone or as part of a two-part biopolymer system, the process is extremely effective in flocculating solids. In addition, chitosan is used in the animal feed industry and is completely biodegradable. This presentation reviews laboratory work conducted to prove whether phosphate could be preferentially removed from CAFO wastewater by reducing the total suspended solids (TSS).

Approach/Activities. Two wastewater samples from a cattle feed lot in western Kansas were collected for the study. The samples were analyzed for TSS and then treated with one and two-part biopolymer systems (LBP-2102™ and Liquifloc™ manufactured by HaloSourc of Bothell, WA) at application rates equal to 1 part per million polymer to water. The samples were then analyzed for TSS, total nitrates, and total phosphorous. Additional samples were treated at rates equal to 3 parts per million and sampled for TSS, total nitrates, and total phosphorous. A final sample was treated with a single chitosan polymer at an application rate of 1 part per million for comparison purposes.

Results/Lessons Learned. Results of the study will be discussed as part of this presentation. The results will include a comparison of the concentrations of TSS, total nitrate, and total phosphorous for all three study conditions; single biopolymer application, low concentration dual biopolymer application, and high concentration dual biopolymer application. An evaluation of the economic impact of treating CAFO wastewater as a best management practice for source water protection to improve and restore watersheds will be discussed.

Blending Substrates to Enhance Reductive Dechlorination

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Background/Objectives. The optimization of remedial processes using enhanced halorespiration has been demonstrated through the application various substrates from complex materials like molasses and vegetable oil, to simple substrates such as sodium, potassium, or ethyl lactate, to engineered compounds comprised of a single volatile fatty acid. To varying degrees, most of these substances have been shown to sufficiently enhance reductive dechlorination by promoting and maintaining anaerobic conditions supportive of robust halorespiration. As the science progresses, the entire process seems to have been driven by the goal of finding cheaper substrates rather than optimizing substrate performance to improve the metabolic efficiency and kinetics of site-specific microbial communities. A review of the geochemical, contaminant, volatile fatty acid, and microbial community profiles on many well-documented enhanced reductive dechlorination laboratory, pilot, or full-scale projects generally suggests that as a substrate is metabolized and the volatile fatty acid profile changes, the microbial community profile also changes. Many projects also show changes in the contaminant profile over time that can't be explained by contaminant daughter product degradation rates alone. This suggests that there may be a link between microbial communities and the volatile fatty acids present at any given time. This concept is easy to understand when looking at changes in microbial communities as an environment changes from aerobic conditions to anaerobic conditions but is not easily apparent under anaerobic conditions alone. The question becomes whether can you optimize microbial metabolism, and therefore dechlorination kinetics, by adding a substrate that has a variety of volatile fatty acids.

Approach/Activities. To help understand the changes in the degradation kinetics of a blended substrate, a microcosm study was conducted comparing a substrate made up of a blend of volatile fatty acids and nutrients to systems fed with sodium lactate and nutrients, and sodium lactate alone. The samples were analyzed for chlorinated organics, methane, ethene and volatile fatty acids. Chlorinated organics were analyzed at 25 and 66 days and volatile fatty acids were analyzed at 15 days.

Results/Lessons Learned. The chlorinated organics and methane, and ethene results indicate that the lactate microcosm showed classical degradation profiles at both the 25 day and the 66 day sampling events with over 85% of the PCE degraded past TCE after 25 days. The lactate plus nutrient microcosm showed a similar pattern but with better kinetics. The blended substrate showed complete degradation to ethene at 25 days with an estimated 80% of the hydrogen released being utilized for dechlorination and about 20% being utilized for methanogenesis. At 66 days the lactate and lactate plus nutrient microcosms continued to show classical degradation patterns and the blended substrate showed a decrease in ethene and an increase in methane suggesting that the ethene was being further degraded under highly anaerobic conditions. The original concept of the study was to prove that a blended substrate had similar kinetics to lactate but the results suggest much greater kinetics. Additional testing will be required to evaluate the changes in microbial populations and better define the kinetics of the blended substrate system.

Performance of a Microemulsion as a Carrier for In-Situ Chemical Reductive Minerals

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Background/Objectives. Recent research into the anaerobic degradation pathways of chlorinated ethenes, ethanes, and other anaerobically degradable contaminants has begun to evaluate the biotic and abiotic contributions to overall contaminant degradation. The idea of combined mechanisms has historically not been investigated as the in-situ remediation industry grew from two major approaches, a biological approach and a chemical oxidation approach. Biological processes mainly revolved around the application of a carbon substrate to enhance reductive dechlorination. One evolution of this approach was the use of emulsified vegetable oil as a slow release substrate. Chemical processes evolved to include the use of minerals, predominantly zero valent iron (ZVI), as in-situ chemical reductants (ISCR). The main challenge with the introduction of an ISCR is a general inability to transport the material away from the injection points to ensure adequate coverage. As the biological mechanisms of anaerobic metabolism became better understood, it became apparent that many degradation pathways could not be easily attributable to strictly biological processes but fit easily into chemical reductive processes. Data from some sites where there is evidence of both processes suggest that there may even be a synergistic effect from biotic and abiotic processes.

The current paradigm considers combining the benefits of chemical reduction using ISCRs with reductive dechlorination through the addition of a carbon substrate. The problem for practitioners is how to mix an insoluble ISCR with a soluble organic substrate to form a stable injectate. The use of microemulsion technology to biologically enhance reductive dechlorination is a relatively new technology to the remediation industry. Microemulsions combine two immiscible materials with surfactants to form sub-micron-sized particles that are thermodynamically stable. Since microemulsions are stable systems with sub-micron particles, they exhibit superior subsurface transport. A significant advantage would be achieved if ISCRs could be incorporated into a carbon substrate microemulsion thereby combining both biological and abiotic mechanisms into one easily managed material that incorporates both biotic and abiotic remedial properties with the distribution characteristics of a liquid that transports in ground water like a miscible fluid.

Approach/Activities. In order to investigate whether ISCRs could be incorporated into a microemulsion, a series of laboratory tests were performed. Several different ISCRs were successfully dispersed into a microemulsion carbon substrate forming a low viscosity, single phase liquid that retains the physical properties of a microemulsion. This combined system will be compared in a microcosm study with various ISCRs alone and abiotic ”sterile” systems to demonstrate biotic, abiotic, and possible synergistic effects.

Results/Lessons Learned. The data for this series of tests will be presented. The data collected will include a comparison of the degradation rates, kinetics, and efficiencies based upon the degradation of perchloroethene and its daughter products over time.