NEW AND EMERGING GROUNDWATER REMEDIATION TECHNOLOGIES

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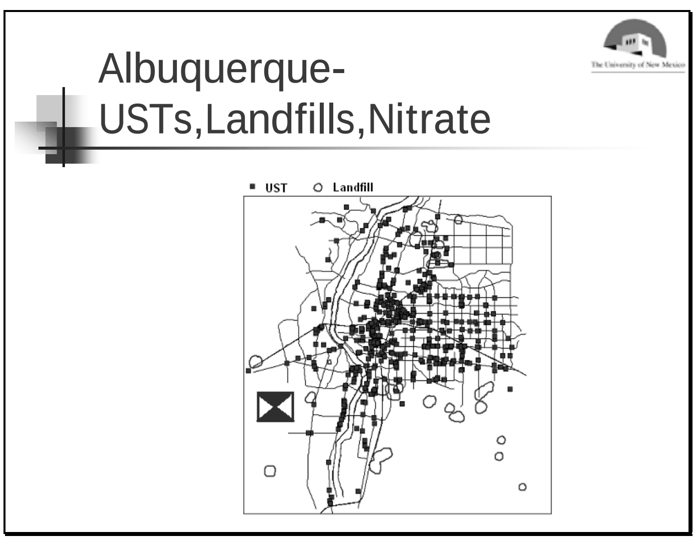
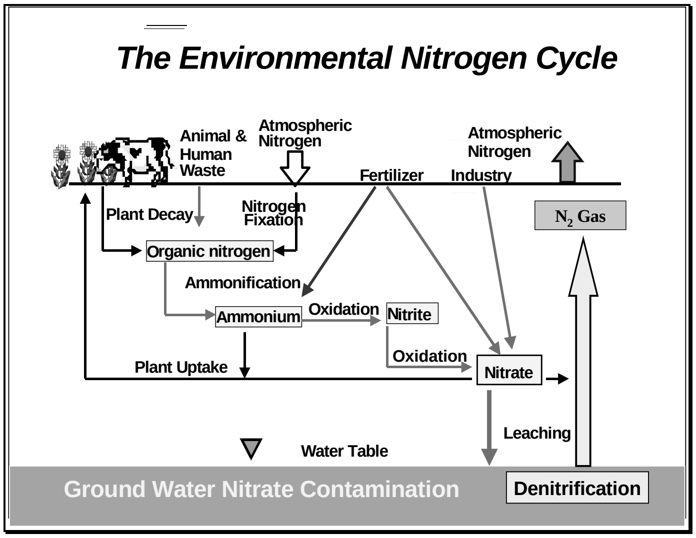
An innovative in-situ biofilm barrier technology was introduced as an emerging technology for groundwater remediation. A pilot scale test was conducted at an alluvium/clay aquifer located in the South Valley of Albuquerque, NM, where this technology was applied to the treatment of nitrate-contaminated groundwater. The biofilm barrier was developed in-situ, using injection well construction, and by stimulating the indigenous bacteria using molasses as the carbon substrate, and yeast extract and trimetaphosphate as nutrients. This amendment results in bacterial growth in the aquifer, covering the sand grains and creating a reactive semi-permeable biofilm. The biofilm barrier reduced the migration of contaminants and provided an active zone for remediation. The circular biocurtain was constructed using 8 wells on the perimeter forming a 60-foot diameter reactive biodenitrification region. Another well at the center was installed to extract the treated water continuously. The intent was to produce a continuous source of nitrate-free water. The system was operated for one year, and during this period the biocurtain was revived multiple times by reinjecting molasses in the 8 perimeter wells.

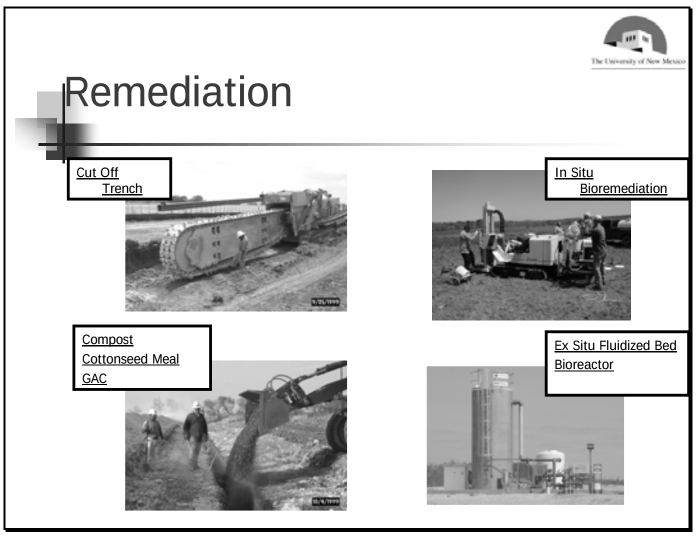
Groundwater and produced water samples are periodically collected and analyzed for nitrate. During the initial 9 months of operation the nitrate concentration of treated water decreased from 275 mg/L (as nitrogen) to well below the EPA drinking water standard of 10 mg/L, reaching to 3.6 mg/L, thus demonstrating the technology as a promising approach for the treatment of contaminated groundwater. The ability to direct groundwater flow using a biofilm barrier could be used to channel contaminated groundwater to an active treatment zone while also contributing to bioremediation of the water. In situations where groundwater flow is minimal, pumping strategies to draw the contaminated groundwater into an active treatment zone could be enhanced with biofilm barrier technology. This technology has commercial value for assisting agricultural businesses, such as feedlots, hog farms, and fertilizer suppliers, in reducing their environmental impact and ensuring the availability of safe drinking water.



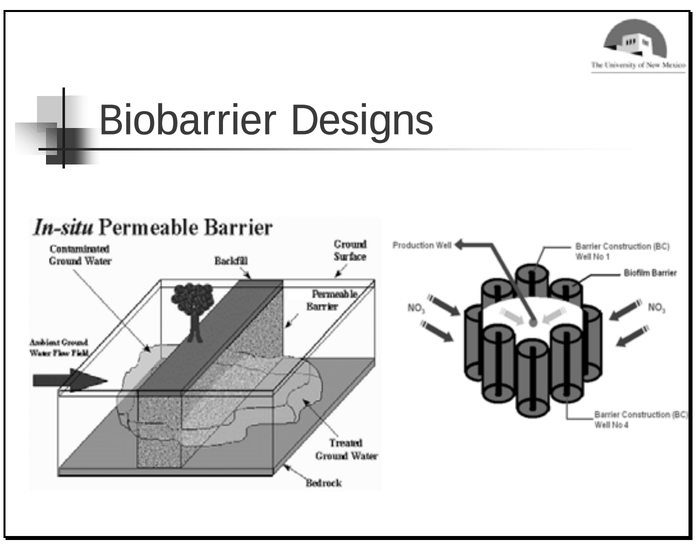
The pressure on Albuquerque's groundwater from Underground Storage Tanks (UST) and Landfills. The blue region in the southwest shows a nitrate contaminated groundwater plume, which was a former vegetable farm where contamination was caused during the 1950s from over fertilization. A blue baby incident was reported in this area in 1980s where an infant was hospitalized after consuming nitrate contaminated water originated from this plume.



Nitrate is a worldwide problem as a groundwater contaminant. Biological denitrification of groundwater is under development as a technology to address this problem. Maximum Contaminant Level (MCL) is 10 mg/L nitrate-N and US EPA estimates MCL is exceeded in 2.4% of domestic wells in US. Two major sources of nitrate in groundwater are over-fertilization and human and animal waste.



Ex-situ remediation uses pump and treat while in-situ treats the plume at the source underground.

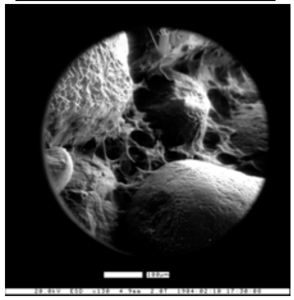


The biobarrier provides an active treatment zone for contamination. As the contaminated water passes through the barrier it contains and remediates it underground.

Biofilms in Barrier

- Biofilm barrier:
  - Engineered accumulation of microbial cells and extracellular polymeric substances (EPS)
  - Arranged in a porous matrix
  - Reduces subsurface hydraulic conductivity
  - Biochemically treats contaminants

ESEM of sand coated with Biofilm



It has been established that majority of microorganisms exist in the form of a microbial colony attached to a surface rather then as free floating organisms. These micro colonies also termed, as biofilms are formed when millions of microorganisms (bacteria, fungi, protozoa, algae and virus) attach to the surfaces in aqueous environments and start living as a community. Biofilm barriers are produced by growing the biofilms in an engineered manner thus exploiting their potential. In an aquifer, biofilms can be used as semi permeable membranes which can treat contaminated water as it passes through them.

Project objectives

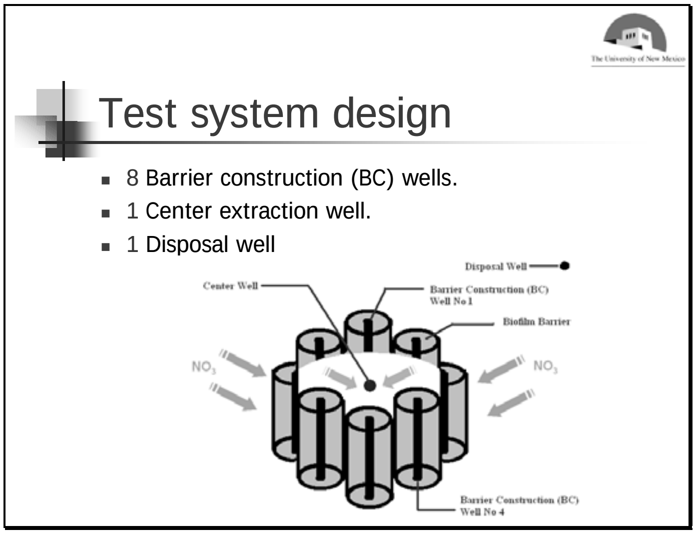
- Develop a biofilm barrier at the site.
- Evaluate the ability to reduce subsurface hydraulic conductivity.
- Determine the possibility to develop an effective barrier without augmentation of bacteria.
- Determine the effectiveness of the biofilm barrier in denitrification of groundwater.

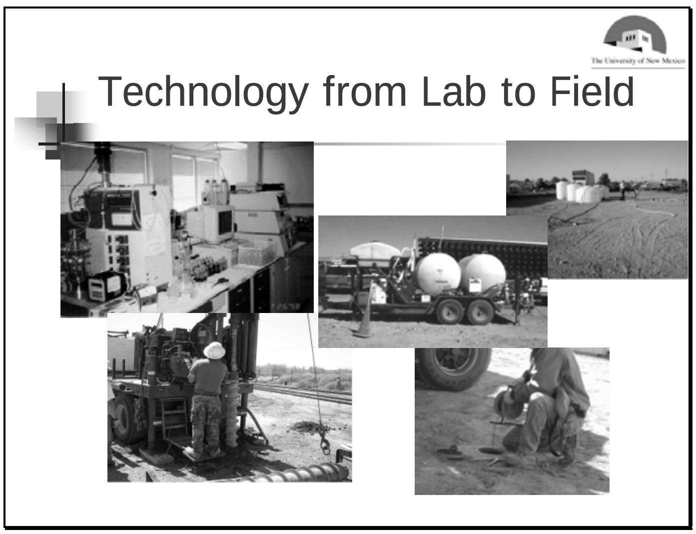
The objective of this study is to develop a successful biofilm barrier at the field site with minimal surface disturbance by simply using a set of injection wells and determine its effectiveness in containment and remediation of nitrate in groundwater. The ability to develop an effective biocurtain by stimulating the indigenous species was another important consideration that would help determine the commercial applicability of the technology.

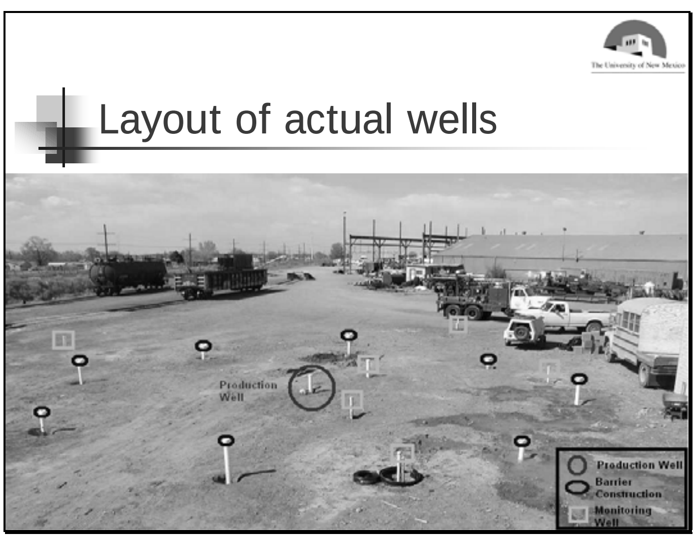
Site overview

- 50 year old vegetable farm contaminated by over fertilization with nitrate.
- Nitrate plume spread over 550 acres with a volume of 1.7 billion gallons
- Average plume concentration: **100 mg/L** (over 10 times MCL)
- NO_3- N : 290 mg/L → *** EPA MCL : 10 mg/L**
- Depth to water table : **47 feet**

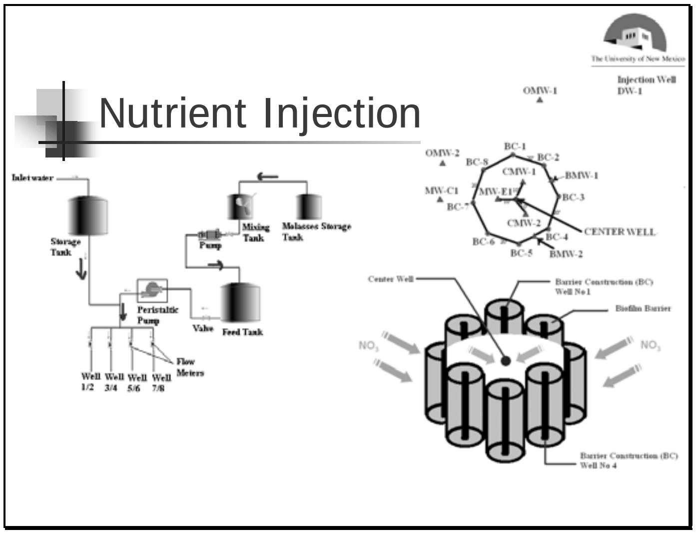
The test site chosen was the Mountainview Subdivision located in the South Valley of Albuquerque, NM. The contamination of groundwater with nitrate at this site was caused by over fertilization of a vegetable farm in the 1950s. The nitrate plume covers an area of about 550 acres and has a volume of approximately 6.4 billion liters. The nitrate concentrations at the site were measured to be of the order of 300 mg/l, which is 30 times more than the primary drinking water MCL of 10 mg/L set by the US EPA. A methemoglobinemia (blue baby syndrome) incident was reported at this site in 1980's where an infant was hospitalized in the mountainview community due to consuming water from a private well that contained high concentrations of nitrate.



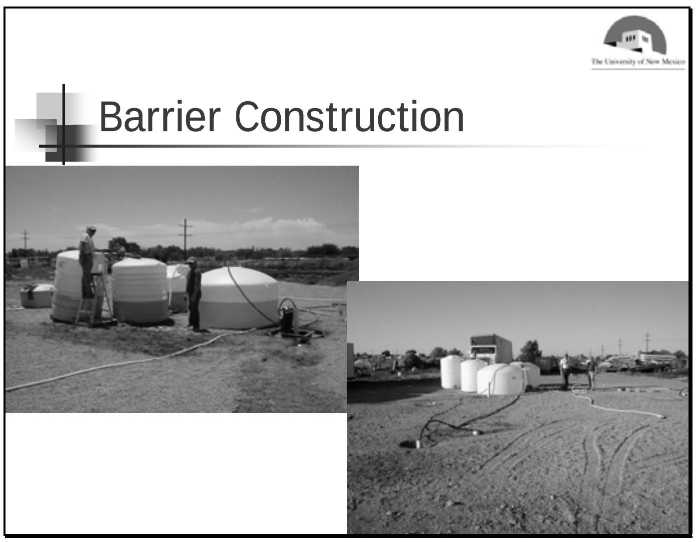


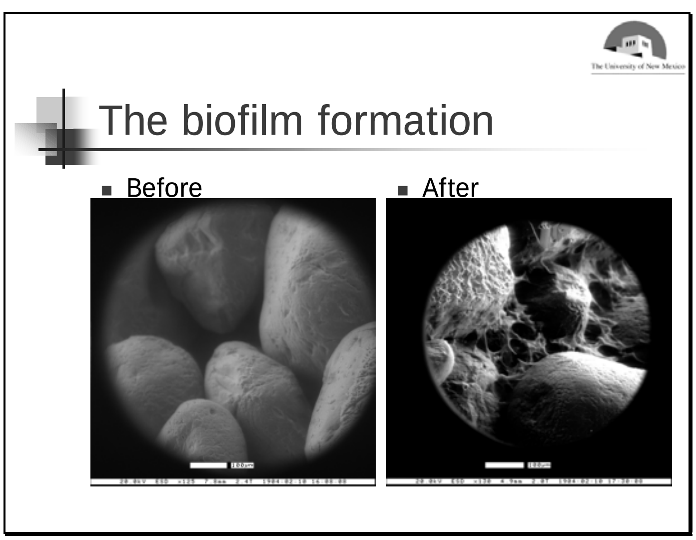


A circular zone of 3000 sq. ft was chosen based on the requirements to use both the containment capability and the reactivity of the biocurtain to produce an efficient remediation of the nitrate contaminated plume. The test pattern uses 8 barrier construction wells [BC (1-8)] installed uniformly on the perimeter of the circular zone, 10 monitoring wells setup inside [CMW-(1-2) and MW-E1], on [BMW-(1-2)] and outside [OMW-(1-2), MW-C1] the circular pattern, and a center well to continuously produce clean water .



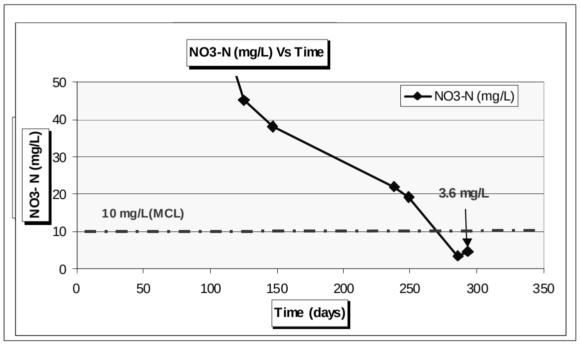
The nutrient mixture comprised of molasses, yeast extract and tri-meta phosphate. The nutrients were diluted and fed initially to barrier construction (BC) wells 2, 4, 6, and 8. After injecting the desired amount of nutrients into the BC wells 2, 4, 6, and 8 the extraction pumps were pulled out and nutrients were then injected into the wells BC 1, 3, 5 and 7. An incubation period of two weeks was allowed after that to allow biofilm to grow in the circular region.





Column experiments simulating the field conditions were conducted in the laboratory to study the process of biofilm formation. The sand used in columns were studied under an Environmental Scanning Electron Microscope (ESEM) before and after plugging. The pressure of the chamber gas in the ESEM was 2.2 Torr, magnification was 130 X, and the accelerating voltage was 20.0 KV. The images were taken at 100 microns resolution. The figure gives a comparison of clean sand to sand after biofouling. During in-situ bioremediation, the formation and bridging of biomass in the pores between the sand particles is responsible for plugging of the packing and zone in the aquifer.

Results: Production Well



The nitrate values in the CENTER WELL dropped from 275.1 mg/L (as nitrogen) at the start of the experiment to a value of 3.6mg/L (MCL= 10mg/L) during 286 days of operation. The initial nitrate reduction was rapid, nitrate-nitrogen values dropped from 275 mg/L to 64mg/L in the first 57 days. The subsequent rise may be due to organic carbon limitation in the biocurtain. Nutrients were re-injected after intervals of 86 and 196 days from the start of the operation.

Summary and conclusions

- Advantages
  - Passive system
  - Applicable at many sites and can treat deep aquifers
  - Barrier created using boreholes
  - Barrier can be rejuvenated as needed
  - Good performance-- reduced nitrate concentration over 100 fold and met drinking water MCL requirements
  - Low cost
- Design Considerations
  - Barrier construction must be designed to match site geology
  - Production well must be pumped at the design rates in order to achieve maximum remediation of the nitrate.
  - Barrier must be designed and engineered to avoid biofouling of the production well.