

Successful In Situ Reductive Biological Treatment of High Explosives

Sarah Seitz, *Victor Holmes, P.h.D.*, Bruce K. Marvin, P.E., and
Wilson S. Clayton, Ph.D., P.E., P.G., (Aquifer Solutions, Inc., Berkeley,
California, USA)

Tony Biggs (BWXT Pantex, Amarillo, Texas, USA)

Groundwater impacted by high explosives (HE) such as RDX and TNT pose great challenges for environmental remediation. The properties of HE tend to lead to the selection of groundwater extraction and treatment while causing above ground treatment processes to be expensive to operate. An interim corrective measure (ICM) pilot test of in-situ reductive biological treatment is ongoing at the U.S. Department of Energy (DOE) Pantex Plant, located in Amarillo, Texas.

A carbon source consisting of soybean oil and lactic acid was injected into a perched aquifer to adjust the geochemical conditions and stimulate the resident bacteria to degrade HE. A total volume of 315,800 gallons of carbon source containing 13,100 gallons of Newman Zone® amendment was injected in two events over the past two years.

Post-injection groundwater monitoring has indicated that carbon donor distribution was effective and geochemical conditions became progressively more reducing over time. Total organic carbon concentrations decreased with a half-life of 19 to 48 days while volatile fatty acid concentrations have increased suggesting fermentation. Higher electron acceptors have been consumed and evidence of methanogenesis was observed. Geochemical affects have been observed over 100 feet down gradient of the injection wells.

RDX was reduced by 52% to 89% within 8 months in three of four monitoring wells. A temporary increase in nitroso derivatives (MNX, DNX, or TNX) followed by further degradation of these products was observed. Following the second injection event, groundwater monitoring has indicated RDX concentrations have continued to decline to less than 97% of the baseline concentrations in the treated wells.

Reductive biological treatment of HE likely involves a combination of three pathways. The fermentation of the carbon-donor produces hydrogen which may be coupled to one or two electron transfers, the denitrification and nitroso pathways respectively. In addition, an alkaline hydrolysis pathway with bimolecular elimination of HNO₂ may also be occurring to some degree. RDX or MNX may be cleaved to forming methylene dinitramine (MDNA), which was detected although it did not persist. MDNA is not stable at near neutral pH and other ring cleavage products, such as formaldehyde and 4-nitro-2, 4-diazabutanol, are also expected to be short-lived in the subsurface and difficult to quantify. RDX degradation at least initially appears to be dominated by the nitroso pathway, i.e. conversion to the nitrosamine MNX. Some of the MNX continues on the nitroso pathway producing lesser nitrosamines DNX and TNX and a fraction may be subject to ring cleavage prior to DNX formation. Molar plots of the nitrosamines indicate that mass loss of HE from groundwater is occurring. While the field data suggests that multiple HE degradation pathways may be occurring, it is consistent with the bench test results that showed that up to 70% of ¹⁴C radio-labeled RDX was converted to CO₂.