On military training ranges across the U.S., exercises use live rounds and explosives. Small percentages of the explosives used in training are duds or partially explode, leaving explosive materials in the environment. These explosives can accumulate in the soil and potentially leach into the groundwater. While these military exercises take place away from civilian homes, the risk of contamination is real.

One potential hotspot for contamination is grenade throwing bays, where soldiers practice with live grenades every day. In these areas, the explosives of concern include hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX, or Royal Demolition Explosive) and 2,4,6-trinitrotoluene (TNT).

These explosive compounds are biodegradable. However, there is limited field data on how rapidly these explosives degrade or how soil properties influence degradation. TNT is considered to be the most rapid to decline through natural attenuation, as it is biodegradable under both aerobic and anaerobic conditions. RDX, on the other hand, is reported to resist biodegradation under aerobic conditions.
Robert Borden, Professor Emeritus at North Carolina State University, is working on a treatment process where organic amendments are applied to the soil surface to enhance the attenuation of these explosive compounds.

**Enhanced Attenuation**

Enhanced attenuation is the addition of soluble, organic compounds that increase oxygen consumption in the soil. Borden is a co-author on two papers recently published in the *Journal of Environmental Quality* that trace the fate of these high explosives in soil and the effectiveness of an enhanced attenuation treatment. Specifically, in these studies, the researchers used a combination of lignosulfonate and crude glycerin to speed up degradation. One experiment was conducted in the field at a military grenade range (http://bit.ly/2C2Y8hq), and the other is a laboratory study using soil from the same hand grenade bays (http://bit.ly/2AVKsoU).

The field experiment was conducted at Fort Bragg in North Carolina. Lysimeters placed in grenade throwing bays collected baseline data for 12 weeks. The researchers then applied the attenuation treatment and monitored it for an additional two years. While any field experiment has unexpected variables, collecting data from a grenade range is unique. “Soldiers [were] out at the site every day throwing hand grenades at the instrumentation that we installed,” Borden says. In addition to the potential for equipment damage, detonation craters from grenade blasts alter the surface of the soil constantly, which can have subsequent impacts on water flow.

During the study, more than 5,000 grenades were thrown in the bays. But during this time, there was little accumulation or leaching of TNT. Additionally, the authors report that RDX degraded naturally in one of the throwing bays where anoxic conditions were present. In contrast, degradation of RDX was limited in a throwing bay where soils drained more rapidly. “I was surprised by the large differences observed in fairly similar soils just 50 ft apart,” Borden says. “This indicates that spatial heterogeneity is very important and needs to be carefully evaluated.” In this rapid draining bay, the addition of lignosulfonate and crude glycerin aided in the degradation of RDX.

Borden explains that the lab experiments were designed to replicate the field experiment as closely as possible. With the exception of live grenades being used. The soil was collected from the same bays and packed into columns to mimic the field conditions. Similar to the field experiment, the researchers reported rapid degradation of TNT in both aerobic and anoxic soil columns. The authors also report the attenuation of RDX was variable, due to differences in soil properties among columns, and leaching was limited under enhanced attenuation treatments.

Combined, these studies demonstrate how degradation of high explosives will occur naturally at some sites, requiring no intervention. Where treatment is required, the addition of lignosulfonate and crude glycerin can aid degradation and reduce leaching of RDX.

**Results Applicable to Nitrate Attenuation**

This research also goes beyond informing the management of military sites. “Explosives biodegradation is very similar to biological denitrification in soils,” says Borden, “so much of our results are also applicable to natural and enhanced attenuation of nitrate in soil from fertilizer, waste application, and septic systems.” The enhanced attenuation methods being tested here may be useful in mitigating nitrate leaching under a range of conditions.

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**Dig Deeper**


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