ANALYSIS OF TNT AND 2,4-DNT PERSISTENCE AND DEGRADATION IN SOILS: INSIGHTS FROM GAS CHROMATOGRAPHIC QUANTIFICATION

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Military conflicts and explosive ordnance disposal often result in the accumulation of 2,4,6-trinitrotoluene (TNT) and 2,4-dinitrotoluene (DNT) in soils, posing significant environmental and health risks. These nitroaromatic compounds, widely used in munitions, can leach into groundwater, disrupt microbial communities, and persist for extended periods, leading to soil infertility and ecosystem imbalance. For humans, exposure through contaminated water or food chains may cause methemoglobinemia, liver damage, and carcinogenic effects, underscoring the urgent need for monitoring and remediation strategies in post-conflict zones.

In this study, we developed a robust gas chromatographic (GC) method for the quantitative analysis of TNT and DNT using Shimadzu GCMS QP-2010 instrument, optimized for sensitivity and precision in complex soil matrices. The methodology involved soil spiking with three distinct concentrations of each analyte: 0.5 mg/kg, 8 mg/kg, and 128 mg/kg to simulate varying levels of contamination. Samples were analyzed monthly over a four-month period, with each concentration tested in five independent replicates across different soil zones to account for spatial heterogeneity and ensure statistical reliability.

Our findings revealed a marked temporal degradation of both compounds. After four months, residual TNT concentrations declined to 0.017 mg/kg, 0.072 mg/kg, and 22.5 mg/kg from the initial low, medium, and high spikes, respectively. Similarly, DNT levels reduced to 0.5 mg/kg (*the same amount*), 2.02 mg/kg, and 40.14 mg/kg, indicating faster breakdown at lower concentrations but persistent residues at higher ones. These data clearly demonstrate time-dependent attenuation, likely driven by microbial metabolism and abiotic processes in the soil environment.

Further GC analysis identified key degradation products, confirming biotic transformation pathways: azobenzene, 2-ANT (2-amino-4-nitrotoluene), 2,4-DAT (2,4-diaminotoluene), 4-ADNT (4-amino-2,6-dinitrotoluene), 2,6-DANT (2,6-diamino-4-nitrotoluene), 2-ADNT (2-amino-4,6-dinitrotoluene), and 2,4-DANT (2,4-diamino-6-nitrotoluene). The presence of these metabolites, including partially reduced nitro groups and diamines, highlights sequential reduction steps and potential for further mineralization.

This research not only advances analytical techniques for explosive residues but also informs bioremediation efforts, emphasizing the role of natural attenuation in mitigating long-term soil pollution. Future work could explore microbial consortia to accelerate degradation, enhancing environmental recovery in affected areas.

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