Derivation of Site-Specific Soil Clean-up Values Protective of Soil Ecological Receptors, for Energetic Soil Contaminants

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Background

- Assessment and protection of the terrestrial environment at DoD ranges has been advanced by development of ecological soil screening levels (Eco-SSLs) for energetic materials (EM) in soil that present an acceptable ecological risk for ecologically relevant receptors in soil
- These benchmarks are intended for use in early screening level stages of Ecological Risk Assessment and are presumed to be protective of plants and soil invertebrates at EM-contaminated sites
- Until recently, there was no uniform guidance for developing soil clean-up values (SCVs)
- Toxicity benchmarks, as well as draft Eco-SSLs for EMs that were derived from those benchmarks, have been misapplied for soil remediation at EM-contaminated sites
- We propose a new approach for developing site-specific SCVs for EMs that are protective of plants, soil invertebrates, and critical soil processes (when such data are available)

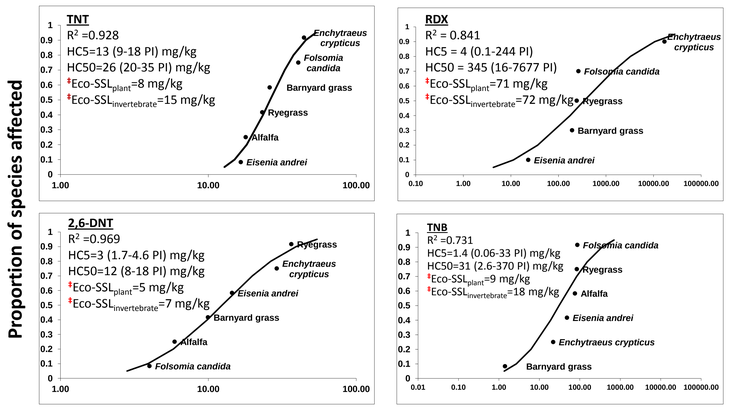
Material and Methods

- **Energetic Materials (EMs):** 2,4,6-trinitrotoluene (TNT), 1,3,5-trinitrobenzene (TNB), 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and nitroglycerin (NG)
- **Test Soils:**
  - All EMs: Sassafras sandy loam (SSL) (1.2 – 2.3% OM; 4.9 - 5.2 pH; 55 - 70% sand; 13 – 28% silt; 17% clay; 5.5 – 9.3 cmol/kg CEC; 18% Water Holding Capacity (WHC))
  - RDX, TNT, and 2,4-DNT: Teller sandy loam (TSL) (1.4% OM; 4.4 pH; 65% sand; 22% silt; 13% clay; 4.3 cmol/kg CEC; 13% WHC
- **Weathering-and-aging EM in soil:** Amended soils used in plant and invertebrate assays were subjected to alternating hydrating and air-drying cycles for one to three months, depending on the degradation rate of individual EM
- **Toxicity Tests**
  - Plant species (USEPA, ASTM): Barnyard grass (*Echinochloa crusgalli*, L. Beauv.); Alfalfa (*Medicago sativa* L.); Perennial ryegrass (*Lolium perenne* L.)
  - Soil invertebrate species (ISO): Earthworm *Eisenia andrei*, Potworm *Enchytraeus crypticus*, Collembola *Folsomia candida*
  - Toxicity data established for plant growth (shoot mass) or soil invertebrate reproduction endpoints (juvenile production-all tests; cocoon production in the earthworm tests)
  - Critical soil processes evaluated using microbial activity assays (OECD): Litter decomposition (*Dactylis glomerata*); Basal Respiration (BR); Substrate-Induced Respiration (S-I Respiration), with microbial biomass determined after 3 h from glucose addition on day 1 (2500 mg glucose/kg dry soil)

Species Sensitivity Distributions (SSD)

- SSD model the variation in the sensitivity of different species/processes to a chemical exposure
- Created using USEPA SSD Generator (http://www.epa.gov/caddis/da_software_ssdmacro.html)
- Fits the log-probit (i.e., linearized log-normal) distribution to data for concentrations at which different species/processes exhibit a standard response (EC50 level) to an EM exposure
  - *Toxicological data*: nonlinear regression analyses to determine EC50 values (50% decrease from carrier control treatment) for each EM
  - *Analytical Determinations*: USEPA 8330A Method for chemical extraction and analyses
- EC50 values obtained from standardized plant, soil invertebrate, soil respiration assays, and from litter decomposition assay
- Allows calculation of specific hazardous concentration (HCp) values for a specified percent-of-species (e.g., HC5 providing 95% protection level with corresponding Prediction Intervals)
- Can generate clean-up values by choosing the fraction of the species to be protected, then using the corresponding concentration from the SSD

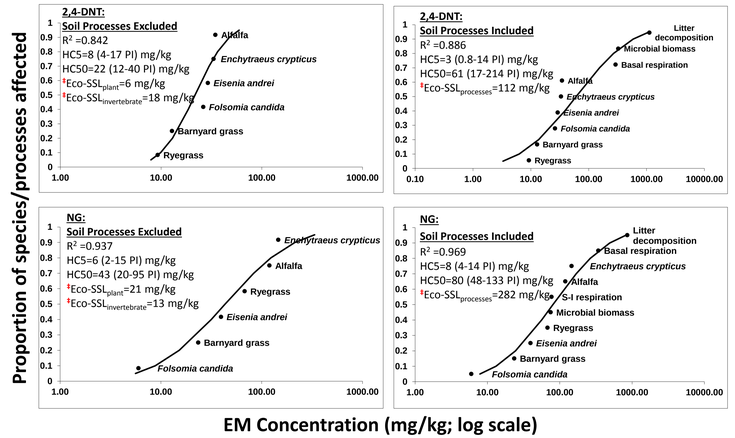
SSDs for TNT, RDX, 2,6-DNT, and TNB



- SSD curves were developed for TNT, RDX, 2,6-DNT, and TNB using EC50 values for plant growth and soil invertebrate reproduction endpoints (traditional ecological receptor groups used for derivation of Eco-SSLs)
- Good fit of SSD model to the toxicity data
- Good data distributions for each EM SSD (no clustering for a specific receptor group)

‡Eco-SSLs are proposed draft concentrations. Eco-SSL values are not official until released by USEPA. Soil processes were excluded from Eco-SSL development by USEPA.

SSDs for 2,4-DNT, and NG



- Separate SSD curves were developed for 2,4-DNT, and NG using respective EC50 values for plant growth and soil invertebrate reproduction endpoints, with and without EC50 values for critical soil process
- Good fit of SSD model to the toxicity data
- Good data distributions for NG SSD; EC50 values for critical soil process clustered at the upper range of the 2,4-DNT SSD (>100 mg/kg)

Discussion and Conclusions

- The EC50 values for the respective plant growth and soil invertebrate reproduction endpoints were used to develop SSDs for TNT, TNB, 2,4-DNT, 2,6-DNT, RDX, and NG, respectively
- EC50 values for critical soil processes were used to develop additional SSDs that included all three ecological groups for 2,4-DNT, and NG, respectively
- The toxicity data were established in definitive studies with individual EMs weathered-and-aged in similar sandy loam soils that provide conditions of relatively high bioavailability for these compounds; thus data required no leaching-aging factor correction, or data normalization to a specified soil
- HC values estimated for plant growth and soil invertebrate reproduction endpoints were comparable with Eco-SSL values for the same EMs
- Incorporating soil processes endpoints into SCV development resulted in more ecologically robust calculated hazardous concentration values (HC5 and HC50), similar (based on the PI ranges) to those without consideration of critical soil processes (i.e., an ecologically less robust current procedure)
- The newly developed approach provides site managers and regulators with a risk assessment tool that allows them to select the specific protection level (HCp) they wish to use to derive robust site-specific SCVs that are protective of plants, soil invertebrates, and critical soil processes for EM-contaminated soils that require remediation