Improving Science-Based Methods for Assessing Risks Attributable to Petroleum Residues in Soil Transferred to Vegetation

FEW EE-1760

Program

This project was funded through DOE's Natural Gas and Oil Technology Partnership Program. The program establishes alliances that combine the resources and experience of the nation's petroleum industry with the capabilities of the national laboratories to expedite research, development, and demonstration of advanced technologies for improved natural gas and oil recovery.

Project Goal

The overarching goal of this study was to improve risk-based decision making at petroleum-contaminated sites. The specific goal was to directly measure soil-to-vegetation bioconcentration factors for a series of polycyclic aromatic hydrocarbons (PAHs) and high molecular weight n alkanes. These compounds are relevant to phytoremediation sites and appropriate for establishing risk-based screening levels (RBSLs) at hydrocarbon-impacted exploration and production sites. The ultimate objective was to generate high-quality data to support the development and/or experimental evaluation of models describing the potential accumulation of soil-borne hydrocarbon residues in vegetation.

Performer

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Petroleum Environmental Research Forum (PERF 99-13)
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Project Results

Over the course of this project, researchers constructed a highly controlled chamber system for measuring the transfer of soil-borne contaminants into vegetation over environmentally relevant time scales and plant-growth conditions. The system was initially tested using wheat grass grown in agricultural soils spiked with a range of PAHs and high molecular weight n-alkanes.

Benefits

Because empirical data on the transfer of soil-borne organic contaminants to vegetation are sparse and models for estimating this transfer are highly uncertain, current methods for establishing risk-based screening levels typically do not consider dietary exposure to food or feed grown on or near a contaminated site. This project contributes relevant data and helps reduce uncertainties that severely limit the reliability of existing plant uptake models. Through this effort, researchers are improving the reliability of risk assessments in which the critical and (often) most uncertain element is the accumulation of chemicals in plants.

Of particular value is the development of an experimental chamber system that provides a unique opportunity to examine the combined role of uptake and loss through multiple pathways over the life cycle of the plant or crop. The experimental system will continue to provide an opportunity to improve regulatory models. The data generated through this research should contribute to improved mechanistic modeling capabilities for evaluating terrestrial food-chain exposure pathways. The main benefits will be increased confidence in models that link soil residues to risk, resulting in the increased use of risk and risk-benefit concepts by industry, government, and public health organizations.

Background

Both ecological and human health risk analyses rely on models that link soil residue concentrations to exposure concentrations in vegetation. These models are limited by a lack of quantitative information about direct (soil-to-plant) and indirect (soil-air-plant) transfers of pollutants into vegetation. This is particularly true for the contaminants and conditions that are relevant to phytoremediation sites and upstream exploration and production sites. Existing models use empirical relationships developed from a relatively small number of plant species and chemicals where the uptake of pollutant into vegetation is often assumed to follow a linear plant-soil partitioning relationship derived from the octanol/water partition coefficient (Kow). Existing models ignore transformation processes, variations among vegetation types, and competing uptake pathways. As a result, linking chemical residues in soil to exposure concentrations for food or feed has a high level of uncertainty. Without an improved mechanistic understanding of plant uptake, the credibility of current risk-based analyses of soil residues will remain limited.

Project Summary
The project researchers:

- Constructed a controlled environmental chamber system for plant uptake measurements.
- Developed laboratory capabilities for analyzing petroleum hydrocarbon mixtures extracted from complex environmental matrices (plants and soil).
- Completed an initial chamber evaluation using wheat grass grown in agricultural soil.
- Completed sample collection efforts for related field study.

As a first step in this project, researchers modified chambers at the Controlled Environment Facility at the University of California-Davis to reduce ambient levels of semi-volatile organic chemicals in the air. This made possible long-term exposure studies. Then they collected soil from an organic farm and spiked the soil with PAHs and n-alkanes at various concentration levels. The spiked soils were allowed to age and then planted with wheat grass in pots and placed in the exposure chamber using a grid layout, where the different concentration levels were distributed uniformly across the growth area. The combination of distributed soils, reduced ambient air concentrations, and the well-mixed air compartment in the chamber made it possible to evaluate soil-to-plant transfer separately from soil-to-air-to-plant pathway.

Preliminary findings for 12 PAHs indicate that:

- The concentration ratio between grass and soil are linear over a large concentration range, demonstrating that uptake processes in the chamber had not reached saturation.
- The concentration ratios for the PAHs were not influenced by elevated levels of n-alkanes in the soil.
- The measured concentration ratios were generally below those predicted by an empirical Kow-based model-particularly for the 2- and 3-ring PAHs-and not linear relative to the chemical's Kow. Measurements of the n-alkanes (C20-C30) revealed no accumulation in the above-ground vegetation over a wide range of contaminant concentrations in the soil. This indicates that this particular class of chemical may not accumulate in vegetation from soil. However, the uptake of n-alkanes has not been measured previously, and the current results have not yet been corroborated, so these results should not be extrapolated to other scenarios.

Current Status (August 2005)
This project was completed in April 2005. The results from the initial study led to two subsequent proposals for work designed to use and improve the study system to further address data limitations and modeling gaps for plant uptake of organic chemicals from contaminated soils. A large set of chamber-generated samples and field samples have been archived for future analysis, funding permitting.

Publications
Bimonthly progress reports submitted to DOE and available online at http://132.175.127.176/ngotp/ngotp.htm.

Maddalena, R.L., McKone, T.E., and Kado, N.Y., Exposure Chamber Measurements of Mass Transfer and Partitioning at the Plant/Air Interface, Environmental Science and Technology 2002, 36, 3577-3585.

Maddalena, R.L., and Sohn, M.D., Extending Sensitivity Analysis Methods beyond the Input/Output Relationship, ISEA/ISEE Conference, Vancouver, BC, Canada, 2002.

Kobayashi,R.; Okamoto,R.A., Maddalena, R.L., and Kado, N.Y., Measurement and Mechanism of PAH Uptake in Wheat Grains, poster presentation at Toxic Substances Teaching and Research Program Annual Meeting, Oakland, CA, 2003.

Maddalena, R.L., Kobayashi, R., McKone, T.E., and Kado, N.Y., Controlled Chamber Measurements of the Multipathway Uptake of PAHs from Soil into Wheat, paper presented at the Society of Environmental Toxicology and Chemistry Annual Meeting, Austin, TX, 2003.

McKone, T.E., and Maddalena, R.L., Soil-to-plant bio-concentration factor (BCF) estimates: Experimental variability versus model uncertainty, SETAC North America, November 14-18, 2004, Portland, OR.

Project Start: April 17, 2002
Project End: April 16. 2005

Anticipated DOE Contribution: $660,000
Performer Contribution: $75,000 (in kind support, about 11% of total)

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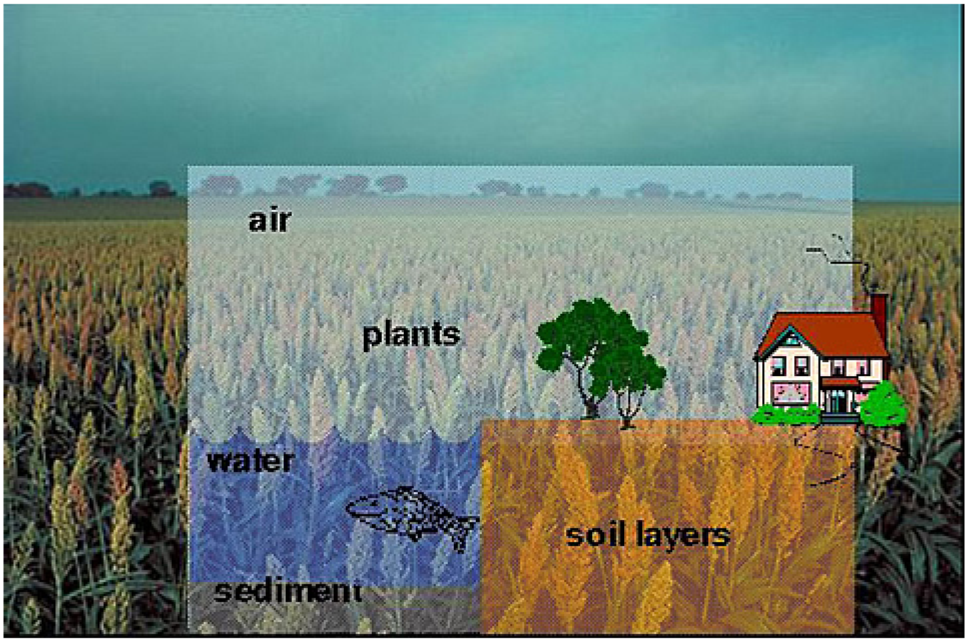
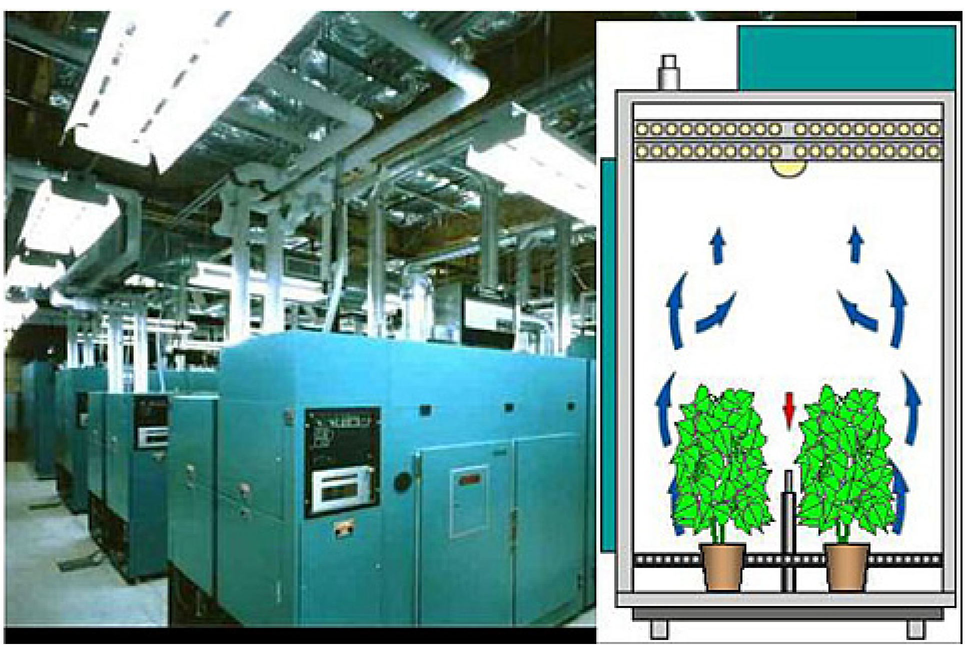


Predicting exposure concentrations in vegetation using a multimedia modeling framework requires bioconcentration ratios that account for the range of uptake and loss pathways.



Controlled Environment Facility at the University of California-Davis, was fitted with an air intake filtration system designed to remove volatile and semi-volatile organic pollutants, providing an opportunity to track the long-term transfer of soil-borne chemicals into vegetation and to monitor specific uptake pathways.