Environmental Toxicology and Risk Assessment

RECENT ACHIEVEMENTS IN ENVIRONMENTAL FATE AND TRANSPORT

NINTH VOLUME

FRED T. PRICE,

KEVIN V. BRIX, AND

NANCY K. LANE, EDITORS

ASTM

STP 1381

STP 1381

Environmental Toxicology and Risk Assessment: Recent Achievements in Environmental Fate and Transport: Ninth Volume

Fred T. Price, Kevin V. Brix, and Nancy K. Lane, editors

ASTM Stock Number: STP1381

ASTM
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ISBN: 0-8031-2861-4
ISBN:1071-720x

Photocopy Rights

Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

To make technical information available as quickly as possible, the peer-reviewed papers in this publication were prepared "camera-ready" as submitted by the authors.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of the peer reviewers. In keeping with long-standing publication practices, ASTM maintains the anonymity of the peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

Printed Chelsea, MI
March 2000

Foreword

This publication, *Environmental Toxicology and Risk Assessment: Recent Achievements in Environmental Fate and Transport: Ninth Volume,* contains papers presented at the symposium of the same name held in Seattle, Washington, on 19–21 April, 1999. The symposium was sponsored by ASTM committee E-47 on Biological Effects and Environmental Fate. The symposium Chairman was Fred T. Price, Booz-Allen & Hamilton, Inc.

Overview

The Ninth Symposium on Environmental Toxicology and Risk Assessment: Recent Achievements in Environmental Fate and Transport was held on 19–21 April 1999 in Seattle, Washington. The symposium was sponsored by the American Society for Testing and Materials (ASTM) Committee E-47 on Biological Effects and Environmental Fate. The symposium was composed of nine sessions:

- Plenary Session
- Environmental Monitoring
- Aquatic Toxicology
- Risk Assessment I
- Measuring Cultural Impacts
- Reception with Posters
- Risk Assessment II
- Natural Resource Damage Assessment Panel
- Sediment Toxicology

While the symposium's theme centered on recent achievements in environmental fate and transport, the plenary session focused on several issues of interest to the northwestern region of the United States. This publication is comprised of eighteen papers based on papers presented at the symposium. The manuscripts were peer reviewed and revised based on reviewers' comments.

The plenary session addressed issues of balancing forest environmental concerns and cultural considerations with logging operations in risk assessment. An example of this discussion and an excellent overview is provided in the paper by Young, entitled "Commentary on Cultural Considerations in Risk Assessment: An Ethical Responsibility". The theme of cultural impact was continued in the session on measuring cultural impact. An example of this session is provided in the paper by Harper, entitled, "Measuring Risks to Tribal Community Health and Culture."

The two sessions on risk assessment are well represented in this volume, as are the sessions on toxicology and environmental monitoring. Part of the theme of this symposium was recent advances, which are reflected in papers such as, "New Approaches for Toxicity Identification Evaluation of Hydrophobic Organic Contaminants in Sediments," by McElroy, and "Computer Tracking Method for Assessing Behavioral Changes in the Nematode Caenorhabditis Elegans," by Williams.

The panel on Natural Resource Damage Assessment and the special poster session on risk-based corrective actions for ecological resources were well attended, resulting in lively and fruitful discussions. Unfortunately, the formats were not conducive to the production of manuscripts for this volume and are, thus, not represented here.

ASTM Committee E-47 is committed to providing timely and useful information on a variety of subjects on Biological Effects and Environmental Fate. The editors hope that the blend of more traditional technical subjects, such as aquatic and sediment toxicology, and the regionally important subjects, like measuring cultural impacts and environmental logging, will prove to be interesting and useful to the reader.

Fred T. Price
Booz-Allen and Hamilton Inc., McLean, Virginia.
Symposium chairman and editor

Nancy Lane
Lane Environmental, Richland, WA.
Symposium co-chairman and editor

Kevin V. Brix
Parametrix, Inc., Kirkland, WA.
Symposium co-chairman and editor

Contents

Overview vii

ENVIRONMENTAL MONITORING

Advancements in Pipe Monolith Lysimeter Designs—LUCAS G. HEIM, MICHAEL J. TANNER, ALLEN B. CRANE, IAN J. VAN WESENBEECK, AND RANGA R. VELAGALETI 3

Post-Remediation Monitoring for Soil, Sediment and Water Contamination by Lead from a Controlled Superfund Site in Mississippi—PAUL B. TCHOUNWOU, ALAAEIDIN A. SIDDIG, AND MIHAELA L. MARIAN 16

AQUATIC TOXICOLOGY

Evaluation of the Water Quality Significance of OP Pesticide Toxicity in Tributaries of Upper Newport Bay, Orange Country, CA—G. FRED LEE, ANNE JONES-LEE, AND SCOTT TAYLOR 35

Cadmium and Aluminum in Yellow Perch, *Perca flavescens* (Mitchell) from Presque Isle Bay, Lake Erie, Pennsylvania—PATRICK R. PONTZER AND CRAIG W. STEELE 52

RISK ASSESSMENT

Design of a Relative Risk Model Regional-Scale Risk Assessment with Confirmational Sampling for the Willamette and McKenzie Rivers, Oregon—W. G. LANDIS, M. LUXON, AND L. R. BODENSTEINER 67

Evaluation of a Terrestrial Foodweb Model to Set Soil Cleanup Levels—PAMELA G. DOCTOR, KENNETH A. GANO, AND NANCY K. LANE 89

Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site, Southeast Washington—CHARLES T. KINCAID, MARCEL P. BERGERON, CHARLES R. COLE, MARK D. FRESHLEY, VERN G. JOHNSON, DANIEL I. KAPLAN, R. JEFFEREY SERNE, GARY P. STREILE, DENNIS L. STRENGE, PAUL D. THORNE, LANCE W. VAIL, GREGORY A. WHYATT, AND SIGNE K. WURSTNER 104

Consideration of Risk in Liquid Effluent Management—MARCEL Y. BALLINGER, KEITH D. SHIELDS, JOHN W. BUCK, AND GARIANN M. GELSTON 118

Using Ecological Site Scoping to Evaluate Contaminant Transport Pathways—RANDALL T. RYTI AND ELIZABETH KELLY 133

Use of PCB Congener and Homologue Analysis in Ecological Risk Assessment— LAURA VALOPPI, MYRTO PETREAS, REGINA M. DONOHOE, LAURIE SULLIVAN, AND CLARENCE A. CALLAHAN 147

General Assessment Endpoints for Ecological Risk Assessment at Los Alamos National Laboratory—DOUGLAS P. REAGAN, ELIZABETH J. KELLY, MARK M. HOOTEN, AND DANIEL I. MICHAEL 162

Development of a Web-Based Risk Assessment Modeling System— PATRICK N. DELIMAN, CARLOS E. RUIZ, AND JEFFREY A. GERALD 178

MEASURING CULTURAL IMPACTS

Measuring Risks to Tribal Community Health and Culture—BARBARA L. HARPER AND STUART G. HARRIS 195

Risk Assessments and Hazardous Waste Cleanup in Indian Country: The Role of the Federal Indian Trust Relationship—MERVYN L. TANO 212

Commentary on Cultural Considerations in Risk Assessment: An Ethical Responsibility—ALVIN L. YOUNG, ELIZABETH K. HOCKING, AND C. WILSON MCGINN 219

SEDEMENT TOXICOLOGY

Computer Tracking Method for Assessing Behavioral Changes in the Nematode *Caenorhabditis elegans*—WINDY A. BOYD, GARY L. ANDERSON, DAVID B. DUSENBERY, AND PHILLIP L. WILLIAMS 225

New Approaches for Toxicity Identification Evaluation of Hydrophobic Organic Contaminants in Sediments—ANNE E. MCELROY, ADRIA A. ELSKUS, AND AMANDA A. FAY 239

Comparison of the Toxicological Effects of Nitrate Versus Chloride Metallic Salts on *Caenorhabditis elegans* in Soils—CHRISTOPHER L. PEREDNEY AND PHILLIP L. WILLIAMS 256

Index 269

Environmental Monitoring

Lucas G. Heim,[1] Michael J. Tanner,[2] Allen B. Crane,[2] Ian J. van Wesenbeeck,[1] and Ranga R. Velagaleti[2]

Advancements in Pipe Monolith Lysimeter Designs

Reference: Heim, L. G., Tanner, M. J., Crane, A. B., van Wesenbeeck, I. J., and Velagaleti, R. R., **"Advancements in Pipe Monolith Lysimeter Designs,"** *Environmental Toxicology and Risk Assessment: Recent Achievements in Environmental Fate and Transport: Ninth Volume, ASTM SPT 1381,* F. T. Price, K. V. Brix, and N. K. Lane, Eds., American Society for Testing and Materials, West Conshohocken, PA, 2000.

Abstract: The self-contained field lysimeter, patented by ABC Laboratories, Inc. (U.S. Patent # 5,594,185) has been used to test the mobility and dissipation of various agrochemicals in a variety of field sites and soil types. In this paper we present data to support the functionality of the pipe lysimeter design and describe some recent design modifications that have been made to improve its performance. The previous design, presented at the ASTM Eighth Symposium on Environmental Toxicology and Risk Assessment, Atlanta, Georgia, April 1998, used a steel soil core casing, which for some test substances could result in unwanted wall sorption or catalyzed degradation. The use of a stainless steel core casing, while generally considered to be inert for most test substances, can become very expensive, increasing the overall cost of the field project. For these reasons, the modular lysimeter design was modified to allow the use of PVC and other non-metallic soil core casing materials.

The utilization of non-metallic soil core casing materials requires the use of a custom manufactured cutting tip and pressing ring for generation of the soil core. Other significant modifications include enhanced methods for the leachate and over-flow module attachment to the soil column, and the instrumentation used for the leachate collection void at the base of the soil column.

Development of the monolith lysimeter design to include non-metallic soil core casings provides a comprehensive method for use of all potential core casing materials in the generation of intact, undisturbed soil columns. Benefits of the PVC lysimeter modification include minimal compaction during soil-core generation, chemically inert casing materials for some test substances, and reduced materials costs. In addition, the instrumentation scheme used for the PVC lysimeter allows for more pre-fabrication prior

---

[1]Senior Chemist and Senior Research Chemist, respectively, Global Environmental Chemistry Laboratory, Dow AgroSciences, LLC, 9330 Zionsville Road, Indianapolis, IN 46268.

[2]Scientist, Manager, and Vice President of Corporate Programs, respectively, ABC Laboratories, Inc., 7200 E. ABC Lane, Columbia, MO 65202.

to field deployment, and minimal labor requirements in the field for instrumentation and installation, significantly reducing the overall cost of field lysimeter projects.

Keywords: lysimetry, field dissipation, environmental fate, mobility, degradation, groundwater, and run-off

Introduction and Historical Perspective of Lysimeter Design and Use

The lysimeter concept has been used since the 19th century. In the early days, lysimeters were used to study the fluxes of soil and water and dissolved substances, and to provide a balance of the nutrient budget. Soils were placed in the lysimeter in layers; undisturbed soil cores were not obtained. In 1927, a large scale experiment was set up at the BASF Agricultural Experiment Station in Limburgerhof, Germany where water balance and nutrient utilization were studied on 232 plots. A survey and discussion of lysimeters and a bibliography on their construction and performance was published by the USDA as early as 1940 (Kohnke et al. 1940). In 1984, a bibliography on lysimeter experiments was compiled by BASF (Doerry 1984).

An ecosystem approach to study the fate of pesticides using lysimeters was developed by the Institute for Radioagronomy of the Nuclear Research Center, Jülich, Germany and the Bayer AG, Leverkusen, Germany starting in 1972 (Führ et al. 1998). Initially 1-m^2 lysimeters packed with 0.45-m plow layers were used to study the fate of pesticides. Beginning in 1974, soil monoliths with an undisturbed profile and depths of up to 80 cm and cultivated surface areas of 0.25 to 0.5 m^2 were used in various studies. Since 1983, the lysimeter program at the institute has been further expanded by installing 50 lysimeters (20 of 0.5 m^2 and 30 of 1.0 m^2 cultivated area) with a profile depth of 1.10 m (Steffens et al. 1992). The precipitation at the site as well as relative humidity and soil moisture at various soil depths are recorded continuously by time domain reflectrometry (TDR) (Führ et al. 1998).

Arthur (Arthur et al. 1998) described a field box lysimeter design to study the fate of pesticides under field conditions, while maintaining a somewhat contained system. According to the author, the box lysimeters are advantageous for conducting rain simulations over the lysimeters, using various cropping systems, monitoring pesticide movement to tile drains and determining soil water concentrations by including suction lysimeters in the design. The major disadvantages of the system are the excavation of soil structure, time for reestablishment of soil structure, and the large size of the box lysimeters to be removed and analyzed for pesticide residues.

Jones (Jones et al. 6) described salient features of the Rhone-Poulenc lysimeter facility in Manningtree, Essex, U.K. The lysimeter facility is similar to that described by Führ (Führ et al. 1998) but has special features such as glass reinforced plastic shells of 0.5-m^2 and 1-1.2 m in depth for collecting intact soil cores and a leachate collection system. Winton and Weber (Winton et al. 1996) described a system where the stainless steel casings are pressed into the soil, and trenches are dug next to the soil cores in casings to collect the leachate from the bottom of the soil cores. Van Wesenbeeck (van Wesenbeeck et al. 1998) described a modular lysimeter design where the intact soil core is instrumented with overflow and leachate collection components. This lysimeter is the subject of this paper.

Lysimeters have been used for registration of potentially mobile compounds in Germany for 10 years (BBA 1990). In Europe, lysimeters have become a widely used technique for studying the behavior of crop protection products in the environment. The European Crop Protection Association (ECPA) has also recommended their use for the more recently defined European registration process (Führ et al. 1992 and ECPA 1993). In the United States, lysimeters have been used for studying the fate of crop protection chemicals at the product development stage, although the U.S. Environmental Protection Agency (EPA), has not provided firm registration guidance regarding either study conduct, or use of lysimeter data for regulatory decision-making, as in Europe. There is, however, growing interest to use lysimeters for understanding the degradation, fate, and transport of compounds that are under development.

In recent years, the growing use of lysimeters has been due to their demonstrated advantages in terms of understanding the fate and transport of chemicals in soil. Jones (Jones et al. 1998) has summarized the advantages and disadvantages of lysimeter studies over the laboratory and field studies. The following table adds some additional information that has been gathered based on experiences of conducting seven field experiments using the ABC Lysimeter design during the past five years.

Historical Use and Practical Utility	Lysimeter	Field	Laboratory
Use of ^{14}C-Labeled Test Material	Yes	Yes	Yes
Containment of ^{14}C-Radioactivity	Yes	No	Yes
Radioactive Mass Balance	Yes[1]	No	Yes
Leachate Collection	Yes	No	Yes
Run-off/Overflow Collection	Yes	Yes	No
Simulation of Actual Field Conditions (*In Situ*)	Yes	Yes	No
Maintenance of Soil Profile and Structure	Yes	Yes	No
Partitioning of Degradation Processes • Biodegradation • Hydrolysis • Photodegradation	 No No No	 No No No	 Yes Yes Yes
Mobility Through the Soil Profile	Yes	Yes	No
Decline of Test Substance and Formation of Degradates at Various Depth up to 1.5 m	Yes	Yes	No
Bioavailability and Bound Residues at Various Depths up to 1.5 m	Yes	Yes	No
Study of ^{14}C-Material at Depths Below 1.5 m	No[2]	Yes	No

[1]Collection of ^{14}C-volatiles is necessary through special instrumentation to achieve mass balance.

[2]Possible in ideal sites with uniform soils with sand to sandy loam textures.

The self-contained modular field lysimeter design patented by ABC Laboratories, Inc. (U.S. Patent # 5,594,185) has been used as a research tool to predict the mobility and dissipation of various agrochemicals in a variety of field sites and soil types. The monolith pipe lysimeters provide a cost-effective mechanism to do field research while maintaining laboratory-type controls on the system. Since inputs are controlled and all outputs collected, with the exception of volatiles at this time, the field lysimeter provides valuable information on the mobility and dissipation of a test substance and allows for determination of mass accountability. Since the pipe lysimeters have a smaller surface area and are less expensive than the cube monolith lysimeters, they are more amenable to replication and frequent sampling which provides statistical information on the mobility and dissipation of a test substance. Lysimeters also provide a controlled use of radiolabeled materials since all of the soil column, leachate, and overflow can be collected and used, if necessary. Since all outputs are controlled and collected and the radioactivity is contained, site remediation is minimal. Furthermore, soil columns can be transported from a collection site allowing for multiple tests to be run at one convenient, centralized facility.

Functionality of the ABC Pipe Lysimeter Design

Field data generated using the ABC lysimeter design by Dow AgroSciences has shown 98% bromide mass accountability (80% in the leachate and 18% in the soil column), classical bromide breakthrough curves, and excellent replication. The near ideal bromide mass accountability suggests that the dosing and application techniques used are appropriate and all components of the lysimeter worked as expected, demonstrating its functionality. The classical bromide breakthrough curves (Figure 1) and replication of total bromide mass (Figure 2) show that column casing wall effects are negligible, if present at all, and the movement of bromide through the soil column was as expected.

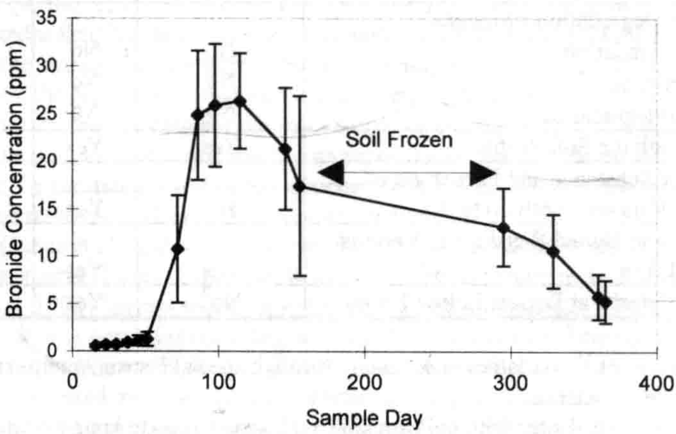

Figure 1 - *Representative Bromide Break-through Curve*

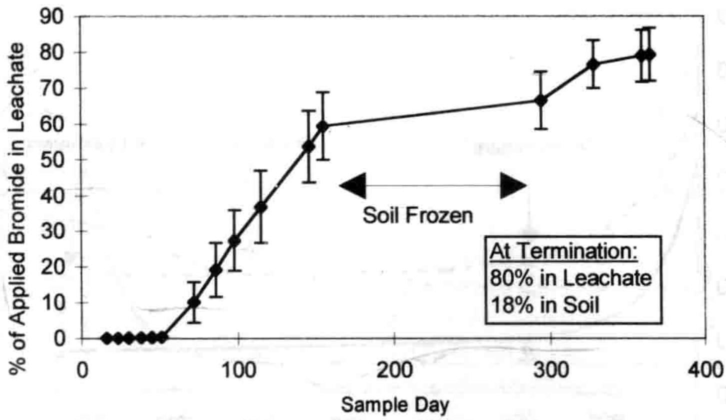

Figure 2 - *Representative Bromide Mass Observed as Leachate*

For two test sites (Iowa and Missouri) the pipe lysimeters were used side-by-side with field plots to study the mobility and dissipation of a radiolabeled test substance. The data generated for these studies (Figures 3, 4, 5, 6) show that the lysimeters match the field plots in terms of mass accountability and degradation. Furthermore, the lysimeters show better replication than the small plots as shown by the small standard deviation between replicates at corresponding time points.

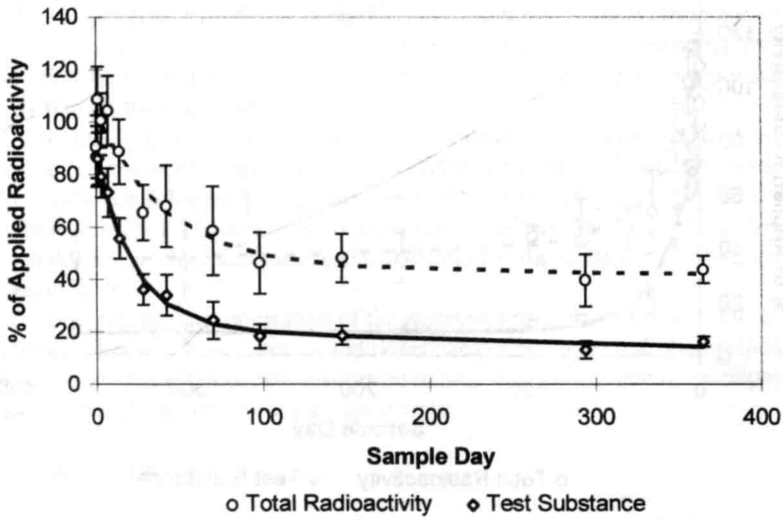

Figure 3 - *Decline Curves from a Radiolabeled Field Dissipation Study in Iowa Using a Typical Small Plot*

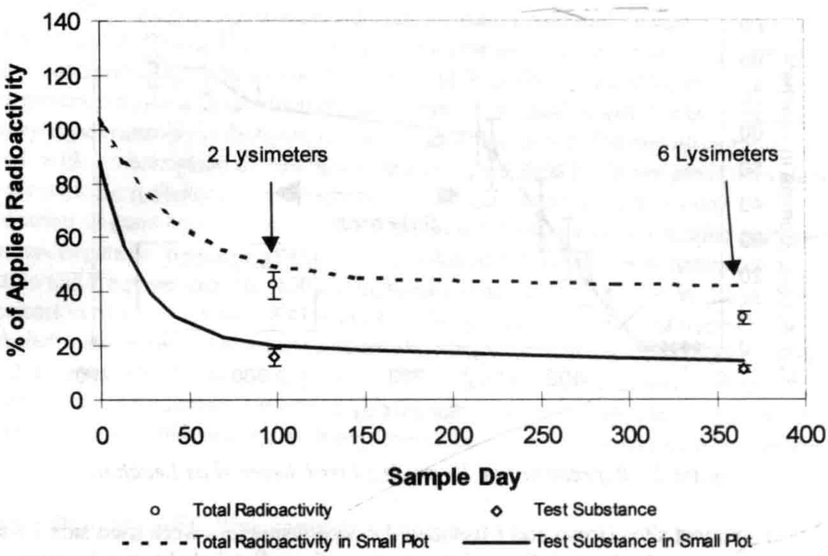

Figure 4 - *Comparison of Lysimeter Time Points to the Decline Curves from a Radiolabeled Field Dissipation Study in Iowa*

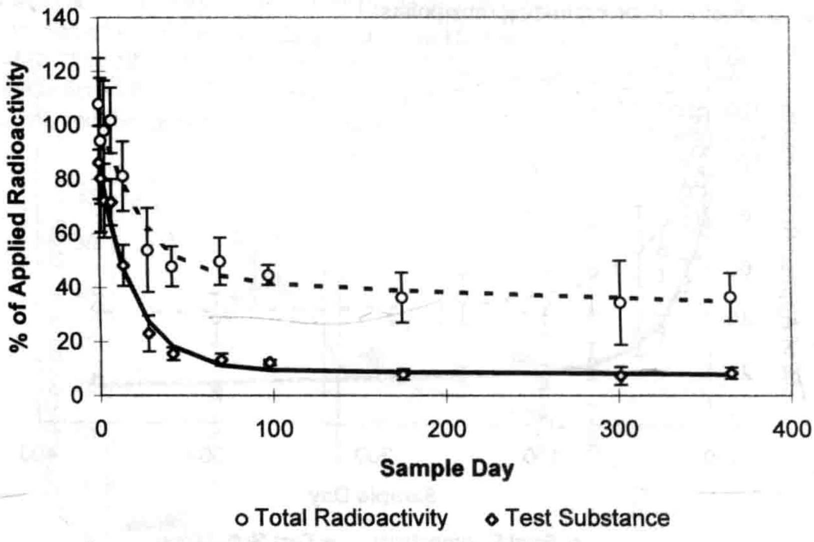

Figure 5 - *Decline Curves from a Radiolabeled Field Dissipation Study in Missouri Using a Typical Small Plot*

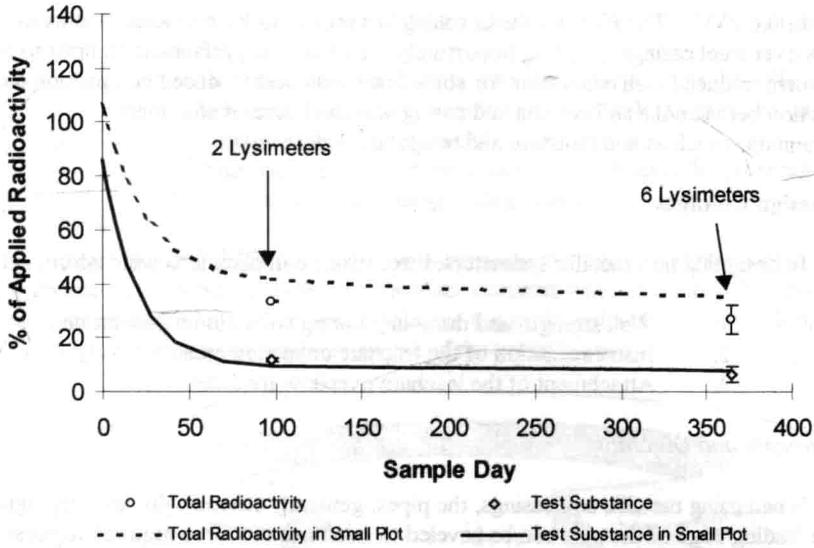

Figure 6 - *Comparison of Lysimeter Time Points to the Decline Curves from a Radiolabeled Field Dissipation Study in Missouri*

These data suggest that pipe lysimeters could be used in place of field dissipation studies while still providing additional information on leaching. Each pipe lysimeter is physically independent, therefore, the sacrifice of a lysimeter within a group has no effect on the remaining lysimeters. Whereas, in a radiolabeled small plot, a sampling event can have an effect on the hydrology of the entire test plot by producing preferred water pathways though the soil column.

The ABC lysimeter design has been instrumented at seven field sites. The seven sites had soil characteristics that ranged from clay to sandy loam. Vertical compaction of less than 1-4% was achieved during instrumentation for all soil types with typical compaction of 1-2% for lighter soils. Sites which contained heavy clay or clay lenses at any depth did not produce adequate leachate illustrating the limitations of the lysimeters use in heavy soils.

In one instance, transportation of the lysimeters from a collection site to a centralized facility has shown that no additional compaction occurred. For purposes of shipment, the instrumented or non-instrumented lysimeters/soil columns are shipped vertically to prevent settling from the casing walls.

Need for Improvement

The previous lysimeter design of ABC Laboratories, Inc. was limited to the use of metallic soil columns, predominately steel and stainless steel. Since metallic soil columns are not always the best choice, due to conduction of heat and/or chemical interactions, the lysimeter design was modified to include the use of non-metallic soil column casing