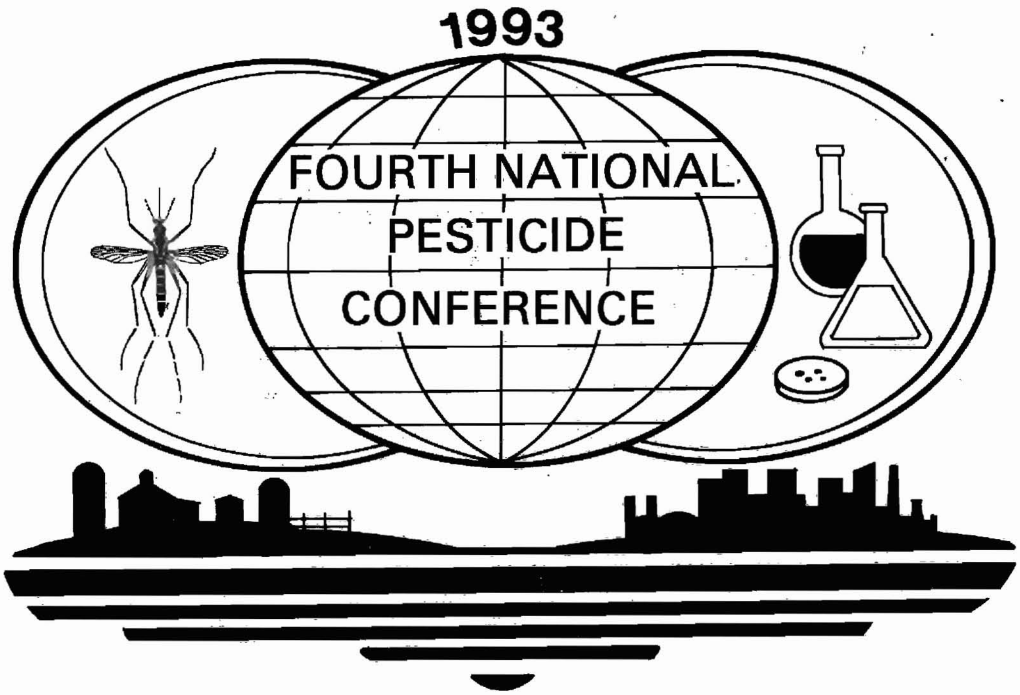
New Directions in Pesticide Research, Development, Management, and Policy



New Directions in Pesticide Research, Development, Management, and Policy

November 1-3, 1993

Program and Presenters' Abstracts

Virginia Water Resources Research Center

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

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Diana L. Weigmann, Interim Director

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COLLECTED ABSTRACTS

of the

FOURTH NATIONAL CONFERENCE ON PESTICIDES

NEW DIRECTIONS IN PESTICIDE RESEARCH, DEVELOPMENT, MANAGEMENT, AND POLICY

November 1-3, 1993

Hyatt Richmond
Richmond, Virginia

Sponsored by

Virginia Water Resources Research Center
Virginia Polytehcnic Institute and State University

SCHEDULE OF EVENTS
AND
TABLE OF CONTENTS

7:30 am	**Registration — Ballroom Foyer**
8:30-9:00 am	**Welcome — Ballroom A** **Mark Schaefer, Assistant Director for the Environment, Office of Science and Technology**
9:00-9:45 am	**Opening — Ballroom A** **Victor Kimm, Acting Assistant Administrator, Office of Prevention, Pesticides, and Toxic Substances, U.S. Environmental Protection Agency**
9:45-10:00 am	**ADJOURN for Session Meetings**

Session Meetings

November 1, 1993

Session A (I): 10:00 am - 12:05 pm
Ballroom C/D

Moderator: Marvin A. Lawson, Office of Pesticide Management, Virginia Department of Agriculture and Consumer Services, Richmond, VA

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Session B (I): 10:00 am - 12:05 pm
Monticello A/B

Moderator: Maureen G. Novotne, Director, Water Quality and Ecology Programs, Water Environment Federation, Alexandria, VA

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LUNCH: 12:05 - 1:45 pm
Ballroom A/B

Speaker: Michael Robinson, Director, National Zoo, Smithsonian Institute, Washington, DC; **Title:** *The Tropics as a Source of New Defenses Against Old Enemies*

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Session A (II): 1:45 - 3:50 pm
Ballroom C/D

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November 2, 1993

Session A (I): 8:30 - 10:10 am
Ballroom C/D

Moderator: Donald J. Lott, Chief, Pesticide Management Section, U.S. EPA, Region III, Phildelphia, PA

BREAK: 10:10 - 10:35 am

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Session B (I): 8:30 - 10:10 am
Monticello A/B

Moderator: Bruce A. Julian, U.S.D.A. Soil Conservation Service, Richmond, VA

BREAK: 10:10 - 10:35 am

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Session A (II): 10:35 am - 12:15 pm
Ballroom C/D

Moderator: Patricia A. Woodson, Virginia Department of Environmental Quality, Richmond, VA

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Session B (II): 10:35 am - 12:15 pm
Monticello A/B

Moderator: John Johnson, Assistant Director of Public Affairs, Virginia Farm Bureau, Richmond, VA

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LUNCH: 12:15 - 1:30 pm
Ballroom A/B

Speaker: Joseph Muldoon, Associate Council, Committee on Agriculture, U.S. House of Representatives, Washington, DC

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Session A (III): 1:30 - 3:10 pm
Ballroom C/D

Moderator: Nancy Malloy, National Center for Food and Agriculture Policy, Washington, DC

BREAK: 3:10 - 3:35 pm

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Session B (III): 1:30 - 3:10 pm
Monticello A/B

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Session B (IV): 3:35 - 5:40 pm
Monticello A/B

Moderator: Betsy Stinson, Wildlife Health Program Manager, Virginia Department of Game and Inland Fisheries, Blacksburg, VA

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November 3, 1993

Session A (I): 8:30 - 10:35 am
Ballroom A

Moderator: Charles Finley, Jr., Virginia Forestry Association, Richmond, VA

BREAK: 10:35 - 11:00 am

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Session B (I): 8:30 - 10:35 am
Ballroom B

Moderator: Jack Waters, former Chair, AWWA, Virginia Section, Chesterfield County Utilities, Chesterfield, VA

BREAK: 10:35 - 11:00 am

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Session A (II): 11:00 am - 1:05 pm
Ballroom A

Moderator: Harry H. Gregori, Jr., Director, Policy and Planning and Public Affairs, Department of Environmental Quality, Richmond, VA

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Session B (II): 11:00 am - 1:05 pm
Ballroom B

Moderator: Joel Artman, Department of Forestry, Charlottesville, VA

Foreword

Across the nation, public dialogues on pesticide and toxic issues have become increasingly polarized. To reach a broad consensus on pesticide issues among groups and individuals with vastly different—but equally firmly held—opinions, we need a communications network for the open and continued exchange of valid data and information.

These abstracts from the fourth national pesticide conference, *New Directions in Pesticide Research, Development, Management, and Policy*, are representative of the Virginia Water Resources Research Center's continuing efforts to facilitate the synthesis and interpretation of scientific data by policymakers, researchers, scientists, practitioners, manufacturers, and public interest groups, and to promote improved communications and the resolution of pesticide issues. The stimulation for this series of conferences and the published proceedings has been the continued encouragement of participants and the intense interest in pesticide issues in Virginia and nationwide. For each conference, the number of participants and the size of the audience has increased — in 1988, 22 invited speakers participated in *Pesticides: Risks, Management, Alternatives;* in 1989, 52 presenters spoke during the two-day conference *Pesticides in Terrestrial and Aquatic Environments;* and in 1990, *Pesticides in the Next Decade: The Challenges Ahead* had 19 cosponsors and 68 presenters. This fourth national conference and the resulting proceedings will serve as a bench mark for establishing new polices and management guidelines for the safe use of pesticides in the future.

The balancing of risks, benefits, and responsibilities to ensure clean air and water, survival of diverse wildlife species, preservation of parks and wilderness, industrial and agricultural growth, and a high quality of life for future generations requires an integrated, multidisciplinary approach. We hope this fourth national conference and the proceedings provide a portion of the science and technology required to resolve complex pesticide issues and stimulate the needed multidisciplinary and interdisciplinary research and analyses to fill the many remaining gaps in pesticide information.

Diana L. Weigmann, Interim Director
Virginia Water Resources Research Center

Chesapeake Bay Program: Partnership for Basinwide Implementation of Innovative Pesticide Management Programs

W. Matuszeski[1]

The Chesapeake Bay Program is a consensus-based state-federal partnership directed toward restoration and protection of the Chesapeake Bay system. Maryland, Virginia, Pennsylvania, the District of Columbia, and the U.S. Environmental Protection Agency (on behalf of the federal agencies) began implementation of a toxics-reduction strategy for the Chesapeake Bay basin in 1988. Building on an existing base of findings from past studies about potential pesticide impacts on the Bay's living resources, the Chesapeake Bay Program agencies began to build a basinwide consensus for the need for more innovative implementation of pesticide management programs. An overview of the unique pesticide management partnerships being developed through the Bay Program as well as a summary of findings to date regarding the nature, extent, and magnitude of pesticide-related impacts on the Chesapeake Bay system will be presented.

[1]U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Region III, Annapolis, MD 21403

An Overview of Integrated Pest Management and Pesticide-Use Surveys

B. H. Marose[1]

The potential impact of agricultural and non-agricultural pesticide use on surface water and groundwater quality is a major concern of the Chesapeake Bay Program. To better understand the use of pesticides within the Chesapeake Bay basin, a number of surveys were conducted by cooperating federal, state, and local agencies and universities. These surveys encompassed a variety of application sites ranging from agricultural crops to home landscapes and a number of information sources such as pesticide-distributor sales records and end-user questionnaires. Some focused solely on pesticide use, while others concentrated on adoption of integrated pest management (IPM) as a tool to improve pesticide decision-making.

In the pesticide-use surveys, participating states agreed to collect information on a set of key parameters that included: (1) pesticide active ingredient; 2) application rate; 3) application site or crop; and 4) size of area treated. Surveys indicated that the most common herbicides were atrazine, alachlor, and metholachlor. The most common insecticides were chlorpyrifos, terbufos, and carbofuran. Total pesticide use in the Bay Basin was greatest from the agronomic crops, primarily because the acreage planted is extensive. In contrast, pesticide use per acre was significantly higher on pest-prone, high-value commodities such as vegetables and tree fruits.

IPM adoption surveys compared use of pesticides, non-chemical practices, environmental attitudes, and demographic differences between IPM users and non-users. Formal IPM programs in which growers paid a fee per acre for monitoring services were used on less than 5 percent of the acreage within the Bay basin. However, educational programs have enabled the vast majority of growers and their advisors to learn the basic techniques of IPM and to adopt those components most compatible with their operations. Those who fine-tuned their operations with IPM by using a designated person to monitor fields regularly, were able to decrease both the number and rate of some pesticide applications, but needed to increase others. Thus, IPM enabled growers to optimize pesticide use. Those using IPM tended to be younger, better educated, and, as a result of IPM, obtained greater profits per acre than non-IPM users.

With information gathered from the surveys discussed, educators and policy-makers within the Chesapeake Bay basin will be better equipped to assess overall pesticide loading and to target pesticide-related programs such as IPM where the greatest effects can be attained.

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[1] University of Maryland, Department of Entomology, College Park, MD 20742

Meeting Pesticide Challenges in the Chesapeake Bay Watershed
BEST Management Practices

M. E. Setting[1]

In an effort to reduce the potential for atrazine, a corn herbicide, to reach drinking water supplies, and to reduce runoff to surface water, particularly the Chesapeake Bay, a specific best management practices (BMPs) program for Bay-region states has been developed.

Atrazine is the second most widely used pesticide in the Chesapeake Bay watershed. Due to its widespread use and persistence in the environment, it has been named to the Chesapeake Bay Program's Toxics of Concern List. The substances on this list are chemicals that either adversely affect, or have the potential to adversely affect, the Bay.

Surface and groundwater monitoring by several state and federal agencies have detected levels of atrazine throughout the Chesapeake Bay region. Atrazine is one of the most frequently detected pesticides in water quality analysis. In addition, it is one of 23 pesticides that must be monitored in public drinking water supplies under the requirements of the Safe Drinking Water Act, effective January 1, 1993. Effective and careful management of atrazine could reduce potential contamination of water supplies and resources.

The BMP program for growers and commercial applicators recommends landowner evaluation of each farm site to determine if BMPs are in place or are needed to protect groundwater and surface water when using, storing, and disposing of atrazine. While the BMPs focus on atrazine, they are equally effective for other pesticides.

Specific BMPs address proper handling, storage, and disposal of atrazine; use of cultural and tillage practices; maintaining a 50-foot setback from wells when mixing, loading, or using atrazine; implementing a 200-foot application buffer from lakes, reservoirs, and public water supplies; maintaining a 66-foot application buffer from points where field surface water runoff enters perennial or intermittent streams and rivers; and delaying use of atrazine if heavy rains are forecast.

Educational materials, including a BMP brochure, a Farm Site Evaluation, a training video and manual on the use of BMPs, and BMP posters have been developed for distribution to farmers, pesticide applicators, and dealers.

The initial Atrazine Best Management Practices Program was developed through the efforts of an Atrazine Advisory Committee appointed by Robert L. Walker, Secretary of the Maryland Department of Agriculture. The committee is comprised of growers, pesticide dealers and applicators, Extension specialists, pesticide manufacturers, representatives of the Maryland Departments of Agriculture and Environment, and USDA's Soil Conservation Service. CIBA-Geigy, an atrazine manufacturer, helped support promotion and development of the BMP program in Maryland. The states of Pennsylvania and Virginia are developing state-specific atrazine BMPs in an effort to provide regional protection to the Chesapeake Bay.

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[1]Pesticide Regulation Section, Maryland Department of Agriculture, 50 Harry S Truman Parkway, Annapolis, MD 21401

Pesticide Disposal and Container Recycling in the Chesapeake Bay Watershed

D. D. Bingaman[1]

To address specific water quality concerns for the Chesapeake Bay Program (CBP), the state signatories of the Bay Agreement have given priority to pesticide product and container disposal within their state management programs. Based on available funding, each state is developing or implementing these programs to improve environmental safety and promote pollution prevention within areas of concern. Design and implementation strategies should result in significant reductions in potential water quality contamination by promoting the responsible handling and disposal of pesticide products and containers. Each state offers a unique program based on state-specific problems, budget constraints, and available resource persons to implement the programs.

Pesticide disposal is necessary because of historical pesticide use and management that has resulted in the banning or cancellation of pesticide products by the U.S. Environmental Protection Agency (EPA) based on concerns for the environment or human health. While these efforts ensured that product use would no longer continue, few alternatives were offered to remove existing stocks of material from the pesticide user. Additional quantities of pesticides are held by farmers due to the age of the product, loss of efficacy, environmental exposure, and product degradation. Virginia's 1990 collection program identified many pesticides that were not canceled or banned, but just unwanted by farm operators. The transport and disposal of pesticides is often cost-prohibitive for individual farmers and, thus, can be facilitated by government funding.

To provide a cost-free disposal to pesticide users, the Bay states are developing and implementing collection programs at the county level. The Virginia Department of Agriculture and Consumer Services piloted the disposal concept in the Bay Watershed in 1990. Subsequent collections in 1992 completed the collection in eight counties, totaling approximately 90,000 pounds of pesticides. Virginia plans to conduct a 1993 disposal program in four counties to collect an estimated 58,000 pounds of pesticides. A program patterned closely after the Virginia effort collected 30,000 pounds of pesticides from six Pennsylvania counties in 1992. Seven additional counties are currently involved in the 1993 Pennsylvania program serving approximately 10,000 agricultural producers. Products collected in the disposal programs include toxaphene, DDT, chlordane, silvex, dinoseb, carbofuran, and numerous other pesticides. State efforts are anticipated on a yearly basis until all counties have been included. Plans for pesticide disposal in Maryland currently are being developed; however, the lack of state funding for this effort may postpone its implementation.

Recycling efforts in Maryland focus on the Eastern Shore, where containers are collected and inspected by MDA prior to being chipped, pelleted, and recycled into new pesticide containers. Container recycling requires triple rinsing to clean containers prior to acceptance, thus, eliminating potential contamination. Prior to the development of container recycling, Maryland farmers had limited options for used pesticide containers, often resulting in storage problems or improper disposal in unapproved areas. A similar program in Virginia involving the Farm Bureau, Cooperative Extension, and Virginia Department of Agriculture and Consumer Services has resulted in containers being collected from three counties. Virginia, Maryland, and Delaware plan to work cooperatively in 1993 to purchase a chipper through AgChem, Inc., to serve all three states. In Pennsylvania, recycling efforts were initiated in 1993 with a planned collection program in Lancaster County. This recycling effort focuses on the state's largest production county to collect containers from private and commercial applicators.

Efforts in all states are designed to remove unwanted chemicals and containers from targeted watersheds to prevent contamination of surface and groundwater sources and effects on human health. These efforts are targeted to meet prevention goals of the CBP as well as EPA's national priorities. Shared technology, equipment, and program goals have resulted in a unique program that has focused on water quality issues for the major portion of an entire watershed. Future efforts are hoped to continue with the potential that the West Virginia, Delaware, and New York portions of the Bay watershed will initiate similar programs.

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[1]Pennsylvania Department of Agriculture, Bureau of Plant Industry, Division of Agronomic Services, 2301 North Cameron St., Harrisonburg, PA 17110

Pesticide Management through Whole-Farm Planning

N. D. Stone[1]

Successful management of agricultural pesticides in the Chesapeake Bay watershed means developing pest-management strategies that control pests below economically damaging levels while also limiting the risks of pesticide leaching and runoff into waterways that flow into the Bay. As public concern increases over farming practices that potentially can pollute our waterways with pesticides and their derivatives, it becomes increasingly important to explore both the potential for, and the implications of, pesticide management regulations on the farm.

Traditionally, there have been three responses to pesticides that pose an environmental hazard: regulation, modification, and information. Regulation has been used to restrict the use of specific chemical and formulations known to be dangerous to environmental and public health. Modification means the substitution of alternative pest-management practices for pesticides; for example, the use of biological control agents, pest-resistant crop varieties, and mechanical or cultural practices. Information has been used to get farmers to eliminate unnecessary pesticide applications through education about pests, their life cycles, and natural enemies; development of sampling techniques and simple decision rules to determine whether a pesticide spray is economically profitable; and effective management of pesticide resistance.

Pesticide management in the Chesapeake Bay watershed will continue to rely on these three approaches, in addition to surveying and identifying land and practices that increase risk of pesticide contamination of the Bay. However, the future of pesticide management is clearly in its integration into a total resource planning process.

Looking at pesticide use and pest management from the whole-farm level opens new avenues for pesticide management. At this higher level, farmers can take pesticide pollution risks into account in farm planning, particularly their choices of crop mix, crop rotation, and pest management strategies. Ideally, they can identify pesticide pollution risks and avoid them altogether, rather than trying to ameliorate the effects of a poor planning decision by alternative pest management tactics later. This presentation discusses the approaches to and tools available for pesticide management in the Chesapeake Bay watershed and highlights a whole-farm planning tool being implemented in Virginia that integrates economic, soil conservation, nutrient, and pesticide management.

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[1]Department of Entomology, Virginia Tech, Blacksburg, VA 24061

PATRIOT — A Methodology and Decision Support System for Evaluating the Leaching Potential of Pesticides

P. R. Hummel[1], J. C. Imhoff[2], J. L. Kittle[1], and R. F. Carsel[3]

The Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT) is a methodology for providing rapid, scientifically sound analyses of groundwater vulnerability to pesticides on a regional, state, or local level. An appropriate measure of groundwater vulnerability is achieved by quantifying the leaching potential of a pesticide in terms of the mass transported to the top of the water table. Reliable assessment of leaching potential requires a methodology that can predict pesticide fate and transport through unsaturated soils to groundwater, making use of site-specific characteristics (i.e., weather, soils, cropping practices, depth to groundwater).

The methodology has been incorporated into a PC-based software package. It is perceived that users of this new tool will need to investigate many combinations of pesticide and unique environmental conditions, and hence, the tool provides analyses within a relatively short time frame (i.e., minutes). Enabling the analyses to be done relatively quickly requires (1) that the data needed to fuel the analysis be provided to the user as part of the tool, and (2) that the tool be made easy to use by effective interfacing of the user with both the data and the analysis model. The software package includes national-scope databases for rainfall, soils geographic occurrence, soil properties, pesticide properties, and cropping practices. The system is housed in a software framework that allows full-screen interaction among databases, the flow and transport model, and ranking procedures. Included in this framework is a comprehensive help environment with hypertext capabilities that allow the user to extract both specific and general background information. PATRIOT contains three types of analysis capabilities:

(1) unit analysis reported as a leaching rate,
(2) area-weighted analysis reported as total mass leached, and
(3) uncertainty analysis using Monte Carlo techniques.

Output capabilities include tables, maps, and graphics that assist the user in database analysis, site characterization, and results analysis.

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[1]AQUA TERRA Consultants, 150 E. Ponce de Leon Ave., Suite 355, Decatur, GA 30030
[2]AQUA TERRA Consultants, P. O. Box 323, Ouray, CO 81427
[3]Environmental Research Laboratory, U.S. EPA, College Station Road, Athens, GA 30613

A Herbicide-Specific Soil Transport Sensitivity Analysis Utilizing Soil Surveys, Screening Models, PRZM, and a Geographic Information System

R. T. Paulsen[1] and K. Balu[2]

The Wisconsin Department of Agriculture, Trade, and Consumer Protection (WI-DATCP) has prohibited or restricted the use of atrazine in some parts of Wisconsin because of groundwater concerns. The objective of this study was to determine, for Wisconsin soils, the sensitivity of atrazine for transport through the root zone using screening models, GIS, and available databases.

The mobility of atrazine in Wisconsin soils was determined using two computer simulation models: CHEMRANK (University of Florida) and PRZM (U.S. EPA Pesticide Root Zone Model). Data for the individual soil series found in Wisconsin were retrieved from the DBAPE database and published soil surveys. The Soil Association maps for all the counties in Wisconsin were digitized and stored in the MAPINFO-GIS. All the soil series in Wisconsin were modeled using CHEMRANK to calculate a retardation factor (RF) for the soils' ability to restrict the movement of atrazine. Soil RF values ranged from 1.69 (extremely low ability to retard atrazine) to 31.0 (extremely high ability to restrict atrazine movement). The retardation factors for each soil series were used to create an overall mobility rank for each of the Soil Associations in Wisconsin. The Soil Association ranks were thematically mapped by using the GIS to produce county scale atrazine mobility maps.

The PRZM model was run for all soil series with low RF values. Each simulation modeled atrazine, surface applied, at a rate of one pound per acre, to conventionally tilled corn. A three-year precipitation scenario including normal, wet, and very wet year precipitation was constructed for each county in Wisconsin using the climate data from climate stations across the state. The results of the PRZM modeling were used to further investigate the soil sensitivity suggested in the low RF values. PRZM results confirmed that soil series with low RF values generally resulted in atrazine being transported to at least a 1-meter depth in the soil column during one of the three years simulated. These data were used to confirm the county scale soil sensitivity maps.

The results of the screening model and GIS mapping phases compared well with the delineation of atrazine management areas constructed by WI-DATCP based on groundwater detections of atrazine. This screening model approach identified parts of Columbia, Green, Iowa, Lafayette, Rock, Sauk, and St. Croix counties as being sensitive to the transport of atrazine. The models also suggested that almost all of Dane county would be sensitive. The WI-DATCP has designated all these areas as atrazine management or prohibition areas. The combination of screening models and

GIS techniques provides a valuable management tool for the safe and effective use of pesticides.

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[1]The Paulsen Group, Suite 114, 3262 Superior Lane, Bowie, MD 20715
[2]Ciba Plant Protection Division, Ciba-Geigy Corporation, 410 Swing Road, Greensboro, NC 27419

Relation of Travel Time and Persistence to the Distribution of Pesticides and Nitrate in an Unconfined Aquifer in the New Jersey Coastal Plain

Z. Szabo[1], D. E. Rice[1], T. Ivahnenko[1], and E. F. Vowinkel[1]

The unconfined Kirkwood-Cohansey aquifer system, composed of quartzose sand, is a major source of potable water in the southern coastal plain of New Jersey. Agricultural chemicals (nitrate and pesticides) are present in groundwater in the western part of the aquifer system, where agricultural land use is common. Nested monitoring wells with five-foot-long screened intervals were installed in this area at five active or historically active agricultural sites. The monitoring wells are located near groundwater divides, where the predominant flow direction is vertical, to study the vertical distribution of agricultural chemicals in the aquifer. The typical site design consists of a shallow well, a medium-depth well, and a deep well, with the bottom of the screen set 10 to 15 feet, 20 to 50 feet, and 60 to 85 feet below the water table, respectively.

All the wells were sampled in spring 1991; results of resampling at two sites in late fall showed that little change in water quality had occurred. Pesticides were detected in samples of shallow water from four of the sites, but were absent in water from the deepest well at all sites. The pesticides detected were alachlor, atrazine, bromacil, carbofuran, metolachlor, metribuzin, simazine, and terbacil; concentrations ranged from 0.1 to 2.8 micrograms per liter. Only atrazine was detected at more than one site. Nitrate was detected in water from all the monitoring wells (maximum concentration, 23 milligrams per liter); concentrations were about an order of magnitude smaller in the deeper wells than in the shallower wells.

Results of simulations of groundwater flow in the study area indicate that the travel time increases with depth, ranging from about 1.5 to 5 years for the shallow wells, about 10 to 25 years for the medium-depth wells, and about 30 to 50 years for the deep wells. The simulations showed that, over time, persistent agricultural chemicals are dispersed both vertically and horizontally in the aquifer along groundwater flow paths whose orientations are determined by hydrogeologic variables. The maximum depth at which a pesticide (bromacil) was detected is 45 feet below the water table; terbacil and atrazine were detected at a depth of 20 feet below the water table. Although the remaining pesticides were detected only in shallow groundwater, some were found at a site where pesticide application had ceased. Because partitioning of pesticides onto organic matter is limited by the low organic-carbon content of the soil and aquifer material, the pesticides are mobile. Nitrate was found at greater depth than were pesticides, probably as a result of the longer application history of nitrogen-based fertilizers, as well as the conservation transport of nitrate and the persistence of nitrate in oxygenated groundwater.

Hydrogeologic factors must be considered in any evaluation of the vulnerability of groundwater to contamination by pesticides and nitrate. Results of this study show that distribution of agricultural chemicals in groundwater is determined by the travel time of the groundwater and the persistence of the compounds in the environment, in addition to the application of the compounds at land surface, the orientation of groundwater flow paths, and retention of the compounds on aquifer material.

[1]U.S. Geological Survey, 810 Bear Tavern Road, Suite 206, West Trenton, NJ 08628

Evaluation of Groundwater Vulnerability to Pesticides in the Thomas Jefferson Planning District, Virginia

S. Shukla[1], S. Mostaghimi[1], V. O. Shanholtz[1], and M. C. Collins[2]

This paper will cover the use of a pesticide mobility index to assess the vulnerability of groundwater contamination to pesticides in the Thomas Jefferson Planning District in Virginia. The mobility index attenuation factor (AF) is defined as the proportion of surface-applied pesticide that reaches groundwater. The AF model requires soil, hydrogeologic, climatic, and chemical information as input data. Soil properties include bulk density, field capacity, and organic carbon fraction. Chemodynamic properties of pesticides required for AF calculation are sorption coefficient (Koc), Henry's constant, (Kh) and degradation half life (t½).

Hydrogeologic information needed for the model are groundwater recharge, and depth to the groundwater. Climatological input data include precipitation, evapotranspiration, and mean monthly temperature. Groundwater recharge is calculated using a water balance model, which further requires estimation of runoff and evapotranspiration. Runoff is calculated using the Soil Conservation Service (SCS) curve number technique. Evapotranspiration is estimated using the Thornthwaite method. Over 2000 well completion report data points were digitized, and static water levels were entered in a separate database. A software program is used to create a regularly spaced grid pattern from irregularly spaced data for every 1/9th-ha area. The soil properties needed for AF calculation were weighted for a particular depth for which information was available in the soil survey report. Spatial (digital maps) and nonspatial (relational table) databases were built to the support screening modeling procedure. Spatial databases include land use, soils, groundwater recharge, and groundwater-table depth. Relational tables include chemical properties database, soils database, and a SCS curve number.

More than 100 pesticides were ranked and the results are displayed highlighting groundwater susceptibility in the Thomas Jefferson Planning District using the GIS technique. Pesticide vulnerability maps are produced to show areas that could be contaminated in the future due to a particular pesticide if this pesticide applied. Vulnerability maps are produced by running the AF model for the entire county area. Apart from vulnerability maps, another set of maps also are created and are called critical area maps. Critical area maps represent the areas where the particular pesticide is actually in use. Vulnerable and critical areas are further categorized into very unlikely, unlikely, moderately likely, and likely, based on AF value. The results of this study will provide information about the potential threat to groundwater contamination by pesticides to the citizens and decision makers in the region. Such information would provide a basis for better land-use planning to protect the valuable groundwater resources.

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[1]Agricultural Engineering Department, Virginia Tech, Blacksburg, VA 24061
[2]Thomas Jefferson Planning District, Charlottesville, VA

A Summary of Government Agency Data on the Occurrence of Pesticides in Indiana Groundwater

M. R. Risch[1]

In 1991, more than 26.5 million pounds of corn and soybean pesticides were applied to 11.6 million acres of Indiana cropland. Nearly 60 percent of Indiana's population depends on groundwater, including half of the state's public water-system customers and most rural residents; accordingly, there is concern about the effect of pesticides on groundwater quality.

The U.S. Geological Survey (USGS), in cooperation with the Indiana Department of Environmental Management, computerized the available pesticide and pesticide metabolite data for Indiana groundwater. The data were collected during 6 statewide surveys, 9 regional studies, and 14 localized investigations by the Indiana Department of Environmental Management, the Indiana Department of Natural Resources, the U.S. Environmental Protection Agency (EPA), and the USGS. Groundwater samples were collected from 535 sites in 82 of 92 Indiana counties, including 179 public supply wells, 318 domestic supply wells, 36 observation wells, and 2 springs. Forty-one percent of all sites were sampled more than once. Thirty-seven wells in 12 counties were sampled in response to alleged groundwater contamination with pesticides. Results of analyses of 1,215 samples were summarized for the period August 1984 through August 1992.

Of 105 pesticides and 10 metabolites analyzed, 30 pesticides and 6 metabolites were detected in 82 samples of groundwater from 39 domestic wells, 10 community-system wells, 5 observation wells, 4 noncommunity-system wells, and 2 springs. Detections associated with complaints of groundwater contamination from pesticide storage, handling, or application occurred at eight domestic wells. Eighty-six percent of all the pesticide detections were in water from wells completed in unconsolidated materials; the average depth of these wells was about 74 feet, but well depths ranged from 12 to 260 feet.

The highest frequency of occurrence was observed for the most commonly used herbicides — atrazine, alachlor, dicamba, the atrazine metabolite de-ethylatrazine 2,4-D, and metolachlor. Also reported in Indiana groundwater were eight insecticides whose registration had been canceled by the EPA prior to their detection in Indiana — EBD, DBCP, aldrin, dieldrin, lindane, heptachlor, DDT, and endrin.

More than one pesticide was present in 22 of the 82 samples, for a total of 133 individual pesticide detections. Concentrations of the detected pesticides ranged from .02 to 460 micrograms per liter. In about 21 percent of the 133 detections, the concentration of 10 pesticides — alachlor, aldrin, atrazine, chlordane, chlorpyrifos, dieldrin, EDB, heptachlor, simazine, and terbufos, plus the metabolite heptachlor epoxide — exceeded either the EPA's Maximum Contaminant Level or adult lifetime Health Advisory.

Statewide inferences about the occurrence of pesticides in groundwater cannot be based solely on this data compilation. Used alone, these data can help researchers select those locations and pesticides in Indiana that merit more detailed scientific investigation. With further analysis, these data could be useful in the design of a statewide groundwater monitoring network for pesticides.

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[1]U.S. Geological Survey, 5957 Lakeside Blvd, Indianapolis, IN 46278

Pesticide Monitoring in the Chesapeake Bay Watershed

D. L. Murphy[1]

Historically, with the exception of fish and shellfish tissue monitoring programs, monitoring of pesticides has not been performed on a routine basis. Sampling of both groundwater and surface water has been performed, periodically, as part of special projects. States in the region, as well as federal agencies such as the United States Geological Survey (USGS), academic organizations, and private pesticide manufacturers have sponsored such studies. A few miscellaneous studies have focused on pesticides in fog, rainfall, and treated drinking water.

The tissue monitoring programs have been performed largely by state agencies and date back, in some cases, to the 1960s. The pesticides targeted in these programs are primarily the organochlorine pesticides.

Groundwater studies have monitored such pesticides as atrazine and alachlor with nitrate, the analyte that traditionally has been targeted in agricultural areas. The pesticide analytes of a recent national survey of groundwater, which included sites in the Chesapeake Bay basin, covered all major pesticide classes. The only locations at which any of these substances have been found at levels in exceedance of human health protection levels were sites where poor management activities were taking place. Several of the state agencies in the Chesapeake Bay watershed and the USGS have groundwater monitoring efforts currently underway. Those will be used in some cases to assess the effectiveness of best management practices in minimizing groundwater impact.

Over the last 20 years, several studies have been performed to investigate levels of a few pesticides in some surface waters of the Chesapeake Bay watershed. These efforts, which primarily have been limited to a few water bodies, have focused on many of the same pesticides as have been emphasized in groundwater projects (e.g., the triazines, alachlor, and metolachlor). In the last few years, several surface water monitoring projects have been performed in the Bay watershed that either included several pesticides among their other analytes or concentrated exclusively on pesticides. The sponsors for these projects have included both federal and state agencies. A recent emphasis in the monitoring of pesticides is urban watersheds. An effort to gauge the importance of residential and commercial pesticide use in the areas is currently being performed by the Maryland Department of the Environment.

Several aquatic sediment monitoring programs recently have included some of the more highly used, as well as the more persistent, pesticides among their lists of analytes. Another media in which emphasis has recently been placed is finished drinking water. The Safe Drinking Water Act has imposed substantial monitoring requirements on drinking water supply programs. Among the required analytes are several classes of pesticides.

A result of these many varied efforts is that we have more information available regarding pesticide contamination of waters, tissue, and sediments. More important than that, communication regarding this topic is increasing both among the projects and between monitoring programs and pesticide regulation programs.

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Groundwater Protection Will Provide Improved Water Quality for the Chesapeake Bay

M. A. Lawson[1]

The states surrounding the Chesapeake Bay share a unique responsibility to protect the Bay from pesticide contamination. It is widely accepted that some pesticides enter the Bay and tributaries feeding the Bay from surface runoff. However, pesticides may enter the Bay through groundwater hydrologically connected to surface waters of the Bay or its tributaries. In October 1991, the U.S. Environmental Protection Agency issued the Pesticides and Groundwater Strategy. The strategy emphasizes preventing contamination of the groundwater resource for current and future generations, and fostering federal-state partnerships that allow states significant flexibility in developing State Management Plans to tailor pesticide use to localized risks. Maryland, Pennsylvania, and Virginia have elected to develop Generic Pesticide and Groundwater Management Plans. The District of Columbia does not plan to develop a Generic Pesticide Management Plan; however, it will address pesticides under its Comprehensive State Groundwater Protection Program. Although each state may express a slightly different philosophy, each promotes a policy of anti-degradation to protect the state's groundwater resources. This paper will discuss how the states surrounding the Chesapeake Bay have dealt with critical issues, such as groundwater hydrologically connected to surface water, detection triggers, response to detections, and monitoring, as they developed plans to protect the vital groundwater resources in this ecologically sensitive region. This regional view will highlight the diverse hydrogeology and pesticide use in the watersheds feeding the Chesapeake Bay.

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The Role of Education in Managing Pesticides in the Chesapeake Bay Watershed

A. E. Brown[1]

Pesticide education is an integral part of programs aimed at preventing pollution of the Chesapeake Bay watershed. Pesticide applicators must be educated about the potential benefits when pesticides are used judiciously, potential environmental hazards of pesticides, and methods to maximize the former while minimizing the latter. States use different strategies to present pesticide education according to needs. Differences in commodity (crop, landscape, structures), site (agricultural vs. urban setting), and audience (applicators, users of commercial pest control services, the general public) dictate different approaches. In addition, staffing requirements and availability of funds influence the methods and, thus, the teaching materials used.

The author will review educational strategies in the Bay region, covering both agricultural and urban pesticide use. State and federal agencies involved in pesticide education in the Bay watershed will be identified. Successful programs and initiatives will be highlighted. Reference will be made to the methods used, including print media (newsletters, bulletins, fact sheets), radio and television programming, satellite workshops, train-the-trainer programs, and self-study materials. Where available, program evaluations also will be addressed.

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Managing Nonagricultural Pesticides in the Chesapeake Bay Watershed

S. A. Harrison[1]

Studies conducted in the 1970s and 1980s on the Chesapeake Bay indicate that runoff from urban areas contributed significantly to the degradation of the aquatic ecosystem. Pollutants present in urban runoff are diverse and range from atmospheric fallout of industrial stack emissions and auto exhaust particulates to street litter, animal wastes, and organic residues of decaying vegetation. Pesticides used in urban settings have been implicated as contributing to this pollutant complex. In fact, scarce data on currently used nonagricultural pesticides have been reported in published urban water-quality studies. Nonagricultural pesticides are employed for a wide variety of uses, including turfgrass and ornamental landscape management, public health disease vector control, institutional pest management, structural pest control, and stored-food pests. Landscape applications, by nature of their volume and pattern of use, offer the largest potential to be mobilized and affect the watershed. However, the limited data available from university studies suggest that properly managed ornamental landscapes do not generate large quantities of runoff (relative to the impervious portions of the watershed) and that detectable residues of pesticides are seldom a component of such runoff when it occurs. In practice, pesticides may enter surface water systems at any stage of the handling process, from transport and storage through mixing and application, and, ultimately, to cleanup and disposal. Many of these activities, regardless of the application site or target pest, involve the handling of pesticide concentrates on surfaces other than well-managed turfgrass. Individual pesticide-handling activities should be evaluated and prioritized according to the relative risk they pose to surface waters. Cost-effective efforts to reduce pesticide loading to the Chesapeake Bay should be based on such a prioritization of issues.

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Drinking Water Utility Compliance Problems from Pesticides and Herbicides

J. A. Roberson[1]

The use of agricultural chemicals can have a significant impact on drinking water utility compliance with maximum compliance levels (MCLs) under the Safe Drinking Water Act (SDWA) in many agricultural watersheds. MCLs for several pesticides and herbicides were finalized by the U.S. Environmental Protection Agency (EPA) in the Phase II and Phase V regulations. MCLs for atrazine and alachlor, the two most commonly used herbicides in the United States, are included in the Phase II regulations. Additionally, monitoring for pesticides and herbicides in drinking water increased substantially under the new EPA standardized monitoring framework, which began on January 1, 1993.

This paper will present a brief review of the federal regulations for the use of pesticides and herbicides, and how the drinking water regulations fit into these other federal regulations. This paper will review several monitoring studies conducted by the U.S. Geological Survey (USGS), EPA, state agencies, pesticide manufacturers, and drinking water utilities. The results of these studies will be analyzed to make an assessment of the drinking water utility compliance problems with the MCLs for atrazine, alachlor, and other pesticides.

Emphasis will be placed on the difference in the compliance problems for utilities with groundwater sources, lake or reservoir sources, and river sources. The compliance problems for utilities with river sources with a single sample during the spring flush will be analyzed based on these studies. Additionally, the compliance problems for utilities with groundwater, lake, or reservoir sources with continuous high pesticide levels will be analyzed based on these studies.

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Implementation of a Program to Assess the Vulnerability of New Jersey's Drinking Water Supplies to Pesticide Contamination

J. B. Louis[1], P. F. Sanders[1], and P. M. Bono[2]

The recently promulgated Safe Drinking Water Regulations allow states to base their compliance monitoring program for 24 pesticides/pesticide metabolites upon the results of a vulnerability assessment. The assessment is based on a combination of the hydrogeologic susceptibility of the source water, and the amount of a particular pesticide that is used in the proximity of the water supply. For the purpose of this program, New Jersey has divided their public water supplies into three groups: 1) surface water supplies, 2) public community groundwater supplies, and 3) non-transient non-community groundwater supplies.

For the public water supplies, the assessment is being carried out using a two-step process. The first involves an assessment of the vulnerability of the source water to agriculture contributions using a geographic information system (GIS). The second step involves assessing other existing state databases for information on the use of pesticides for aquatic weed control, on golf courses, by right-of-way treatments, and by facilities that directly or indirectly discharge into the watersheds. Based upon this information, NJDEPE will either (1) issue a waiver for sampling for a particular pesticide for water supplies with low vulnerability to pesticide contamination, or (2) for supplies with medium or high vulnerability, will collect a screening sample of the source water. The results of this sampling will either trigger a routine monitoring program for a particular pesticide, or result in a waiver of the monitoring requirement for that pesticide. For the non-transient, non-community water supplies, waivers will be based upon past water quality data.

This paper will discuss in detail the various aspects of NJDEPE's program for evaluating the vulnerability of public water supplies to pesticide contamination, the waiver process, and the data generated from the screening samples collected during 1993 for New Jersey's 45 surface water supplies.

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Method to Estimate the Vulnerability of New Jersey Drainage Basins Used for Public Supply to Contamination by Agricultural Pesticides

D. E. Buxton[1] and D. A. Stedfast[1]

A statistical analysis of pesticide-application data and drainage-basin characteristics derived from a geographic information system (GIS) was conducted to develop a numerical vulnerability index for 45 drainage basins used for public surface-water supply. The vulnerability index can be used to estimate the potential of a drainage basin to exhibit contamination from each of four specific groups of agricultural pesticides: acetanilides, triazines, organophosphates, and carbamates. The three explanatory variables used in the analysis that were found to best predict vulnerability are (1) percentage of agricultural land in the basin, (2) application rate of pesticide, and (3) potential for pesticide loss from the soil. The validity of the index was verified by results of water-quality sampling throughout the crop-growing season in two basins — one with a high vulnerability index and one with a low vulnerability index. The vulnerability index can be used to determine where analysis of intake water for pesticides or additional water treatment may be required.

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Herbicides in Ohio's Drinking Water: Risk Assessment, Reductions, and Communication

D. B. Baker[1] and R. P. Richards[1]

Quantitative data on herbicide concentrations in Ohio's public and private water supplies, coupled with data on the toxicity of these compounds, support the application of relative risk assessment to issues surrounding herbicide occurrence in this state's drinking water supplies. Exposure data indicate that less than 1 percent of Ohio's population consume drinking water containing herbicides at concentrations in excess of drinking water standards. Atrazine and alachlor are the two herbicides most likely to be found at concentrations above drinking water standards. Where standards are exceeded, it is by small amounts. Isolated private water supplies affected by point sources of groundwater contamination generally account for the highest herbicide exposure rates. The largest amounts of exposure, although at lower rates, occur in public water supplies using surface waters derived from intensively row-cropped watersheds.

Since drinking water standards include substantial safety factors, the most likely outcome of efforts to reduce herbicide exposures will be to increase the margin of safety, rather than to improve human health. Given such an outcome, herbicide exposure reduction programs should emphasize those management improvements that (1) have positive economic impacts on farmers, such as avoiding over-application of herbicides, (2) reduce point sources of herbicide contamination, or (3) indirectly reduce herbicide runoff while reducing runoff of sediments and phosphorus, as through adoption of conservation tillage. Since, for the vast majority of herbicides, the gap between exposures and toxicity is even wider than for atrazine and alachlor, concerns regarding synergistic interactions among herbicides appear unwarranted.

To support appropriate regulation and avoid over-regulation of herbicide use, the procedures of relative risk assessment need to be rigorously applied and the results communicated both to the general public and to policy makers. Ideally, these procedures should be applied to as broad a spectrum of possible drinking water contaminants as possible, so that efforts to improve human health by improving drinking water quality can be targeted to those pollutants where the greatest gains can be obtained per unit investment, whether it be in pollution prevention or in treatment.

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Atrazine Exposures through Drinking Water: Three Midwestern Case Studies

R. P. Richards[1] and D. B. Baker[1]

Drinking water exposure assessments for a large population involve dividing the population into segments for which both the water source and the exposure concentration can be expected to be the same, and then determining the population and the exposure concentration for as many of these segments as possible. A population segment might be as small as those people served by an individual water treatment plant, or as broad as those people who use private wells as a water source. The segmentation is usually dictated by the availability of data on which to base an estimate of the exposure concentration, which should be a reasonable estimate of the long-term average concentration to which an individual is exposed. Often, data result from worst-case sampling programs and are unevenly spaced in time; in these cases, a time-weighted average must be used to avoid a biased exposure concentration.

The assessment is conveniently displayed as an exposure concentration exceedency plot, which represents the population segments by rectangles, with width proportional to the population and height proportional to the exposure concentration, arranged in order of decreasing concentration, and color-coded to represent the source of the drinking water. We have developed a Macintosh computer program that converts a data table into such a display.

An exposure assessment for a large area such as a state is bound to require the use of some population segments for which the data is fairly good, some for which it is poor, and some for which it is non-existent. The data gap for the last group can be handled by extrapolation from other related population segments, by modeling, by best professional judgement, or in several other ways. One of the advantages of doing a large-area population assessment is that it identifies the parts of the population that are inadequately characterized. As better data become available, the assessment can be updated and improved.

Assessments have been done for the states of Ohio and Illinois, and for the populations that draw their drinking water from the Ohio-Missouri-Mississippi river system. An assessment of the state of Iowa is underway. Even though worst-case assumptions were made to resolve any points of uncertainty, none of these assessments identified any substantial population blocks that are exposed to atrazine through drinking water at concentrations that exceed the MCL of 3.0 μg/L. In general, groundwater and the Great Lakes are the sources with lowest atrazine concentrations, while rivers draining agricultural watersheds and some reservoirs on these rivers have the highest concentrations.

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Herbicides in Soil and Water at Three Kentucky Farm Sites

B. D. Jacobson[1] and W. W. Witt[1]

The University of Kentucky is monitoring the impact of agriculture on water quality at several sites in the state. Each site comprised a small drainage basin or tile-drained field that represented the various physiographic regions and agricultural practices common to the area. Three of these sites were chosen in the summer of 1992 to investigate the relationship between dissipation of herbicides in soil and their appearance in tile effluent and groundwater. The herbicides that were investigated were atrazine and simazine at site 1, metolachlor at site 2, and metribuzin at site 3. The soil types were a Belknap silt loam, a Karnac silty clay, and a Loring silt loam at sites 1, 2, and 3, respectively. Samples were taken from the upper 15 cm of soil immediately following herbicide application and at several times during the following weeks. The herbicides were extracted with methanol and analyzed with gas chromatography. Water samples were collected from tile drains and wells of various depths. Samples either were extracted with methylene chloride and analyzed with gas chromatography or analyzed with enzyme-linked immunosorbent assays.

At site 1, the half-lives of atrazine and simazine in soil were 30 days. The concentration of these two herbicides in tile effluent remained negligible until heavy rains caused the concentrations of both to rise above 30 $\mu g\ L^{-1}$ 18 days after application. Concentrations returned to below 3 $\mu g\ L^{-1}$ by 35 days after application. Both herbicides appeared in 1.5- and 3.0-m wells 40 days after application at concentrations less than 3 $\mu g\ L^{-1}$. Neither herbicide was found in 4.5-m or deeper wells. The half-life of metolachlor in soil was eight days at site 2. Metolachlor concentrations in tile effluent were as high as 10 $\mu g\ L^{-1}$. Metolachlor was found in wells as deep as 4.5 m soon after application. At site 3, the half-life of metribuzin in soil was seven days. The field was not tile-drained, and no metribuzin was detected in the 8.2-m well. At all sites, herbicide dissipation followed first-order kinetics. At sites 1 and 2, herbicide concentration peaks in tile effluent did not have corresponding sudden losses of herbicide from the soil. This indicated that the herbicide in tile effluent was a relatively minor portion of the herbicide applied to the field.

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Alachlor Movement in a Coastal Plain Soil

W. F. Ritter[1], A. E. M. Chirnside[1], R. W. Scarborough[1], and G. Salthouse[2]

The potential for alachlor movement in sandy coastal plain soils was evaluated in laboratory and field studies. The objectives of the research were to:

1. Evaluate degradation rates and adsorption of alachlor in a sandy loam soil,

2. Evaluate the leaching of alachlor from fields planted to corn as influenced by tillage systems, and

3. Evaluate the role of cereal grain (rye) cover crop in reducing leaching of alachlor.

Alachlor degradation and adsorption were studied in an Evesboro loamy sand soil in the laboratory . The movement of alachlor in an Evesboro soil under irrigated corn was studied for three years from 1989 to 1991. Four large plots (0.25 ha) were used. Groundwater was sampled at depths of 3.0 and 4.5 m. Treatments used in the field study included conventional tillage and no-tillage along with a rye cover crop and no cover crop. Groundwater samples were collected on a monthly basis, and soil samples were taken four times a year to a depth of 150 cm.

During the first year of the study, alachlor was leached to the groundwater by heavy rains shortly after it was applied (Table 1). Concentrations ranged from 0.6 to 4.4 μg/L. By July, alachlor was below detectable levels in the groundwater. In 1990, alachlor was detected in several of the monitoring wells shortly after it was applied. In 1991, no alachlor was detected in the groundwater. There were no major differences in alachlor movement between conventional and no-tillage.

The laboratory degradation studies showed degradation rates were greater at field capacity than at lower moisture rates. Degradation rates were greater in the A horizon than the B and C horizons. The adsorption data fit Langmuir isotherms. Adsorption was greater at a pH level of 4.0 than 6.0.

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Table 1. Alachlor concentrations in groundwater in May and June 1989

Treatment	Days from application	Well depth (m)	Concentration (µg/L) Average	Range
NT-Cover	20	3.0	2.5	1.4-4.4
NT-Cover	20	4.5	1.2	0.8-1.5
NT-No Cover	20	3.0	0.9	0.6-1.2
NT-No Cover	20	4.5	2.3	1.8-3.4
CT-Cover	20	3.0	1.5	1.4-1.6
CT-Cover	20	4.5	1.8	1.7-1.8
CT-No Cover	20	3.0	1.5	1.3-1.7
CT-No Cover	20	4.5	1.9	1.7-2.1
NT-Cover	57	3.0	1.4	1.4
NT-Cover	57	4.5	1.1	0.9-1.3
NT-No Cover	57	3.0	1.5	1.0-1.9
NT-No Cover	57	4.5	3.6	1.3-7.5
CT-Cover	57	3.0	1.3	0.8-2.0
CT-Cover	57	4.5	1.7	0.8-2.8
CT-No Cover	57	3.0	1.2	0.5-1.7
CT-No Cover	57	4.5	1.5	1.1-1.9

Tillage Effects on Atrazine and Metolachlor Leaching in a Virginia Coastal Plain Soil

C. D. Heatwole[1], S. Zacharias[1], S. Mostaghimi[1], and T. A. Dillaha[1]

The fate and transport of atrazine, metolachlor, and bromide as a tracer, were characterized through surface runoff monitoring and soil core sampling on no-till and conventionally tilled field plots planted with corn. A rainfall simulator was used to generate a surface runoff event within 48 hours of pesticide application. In comparison with the conventional tillage plot, the no-till plot yielded 32 percent of the runoff volume, 8 percent of the sediment, and 50 percent of the pesticide mass. Total losses of atrazine and metolachlor in surface runoff ranged from 0.5 to 1.5 percent of the amount applied, with the greatest percentage losses associated with conventional tillage. Significant precipitation in the early stages of the study resulted in rapid leaching of the chemicals in both plots. Statistical tests show that chemicals moved deeper in the no-till plot as compared to the conventional tillage plot in the first two weeks after application. However, statistical analysis in the remaining period showed no consistent differences in pesticide concentrations in the soil profile based on tillage practice. Atrazine dissipation was higher in the no-till plot, and there was a significant carryover of the pesticide in both plots at the end of the 157-day period.

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Evaluation of a Pilot Monitoring Project for 14 Pesticides in Maryland Surface Waters

R. Kroll[1], D. Murphy[1], and M. J. Garrels[1]

A pilot pesticide project was conducted by the Maryland Department of the Environment (MDE) during calendar year 1992. Surface waters from three regions of the state were monitored for the presence of 14 pesticides. The list of analytes was compiled from the results of a risk-screening effort by MDE and recommendations from the Chesapeake Bay Program (CBP) Toxics Sub-Committee. The pesticides selected by MDE were alachlor, atrazine, carbofuran, chlorpyrifos, cyanazine, metolachlor, and simazine. The pesticides recommended by the CBP Toxics Sub-Committee were those identified on the Toxics of Concern list (atrazine and chlordane) and several pesticides for which data was lacking or limited (alachlor, aldrin, dieldrin, diflubenzuron, fenvalerate, metolachlor, permethrin, and toxaphene).

All sampling stations except one were judged to be probable recipients of nonpoint source agricultural or urban run-off. The remaining station (the project's control) was surrounded by a buffer zone of state and municipal park lands. Sampling was performed seasonally. In addition, a partial sampling was performed at one station during a substantial rain event in the late spring.

The project resulted in the following observations and conclusions:

- Ambient water from all ten stations suspected of receiving nonpoint source run-off demonstrated the presence of at least one pesticide. Only the control station's water failed to demonstrate analytically detectable levels of at least one pesticide.

- Several pesticides (aldrin, chlordane, fenvalerate, permethrin, and toxaphene) were not detected in any sample from any station.

- The highest levels for two of the pesticides (11.27 ppb atrazine and 7.4 ppb metolachlor) occurred in a sample taken during the rain event. The highest mean levels of other pesticides (0.74 ppb alachlor, 1.5 ppb carbofuran, 0.023 ppb chlorpyrifos, 2.99 ppb cyanazine, a trace of diflubenzuron, 6.50 ppb simazine) occurred during the spring and summer. These data indicate that pesticides receiving prominent agricultural use in Maryland, such as alachlor, atrazine, cyanazine, and metolachlor, affect water quality on a seasonal basis; the levels were lowest in the winter and fall, and highest in the spring and summer.

- The levels at which pesticides were observed throughout the year were not of toxicological concern for human health. Because of the data variability and the lack of information concerning exposure and duration, it was difficult to determine the significance of the levels of chlorpyrifos and atrazine to aquatic life. The need for further monitoring to better characterize the severity of pesticide contamination is suggested.

- The experience gained from this project demonstrates to environmental managers the value of the use of risk-screening techniques to identify appropriate pesticides for surface water monitoring programs.

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Impact of Copper, Chromium, Arsenic, and Pentachlorophenol on Aquatic Macroinvertebrates in a North Georgia Forest Stream

M.A. Callaham[1], P. B. Bush[2], D. G. Neary[3], R. A. LaFayette[4], and J. W. Taylor, Jr.[5]

The impact of copper, chromium, arsenic, and pentachlorophenol was assessed on aquatic macroinvertebrates within the first-, second-, and third-order drainages of a forest stream in the upper Piedmont of Georgia. Movement of the chemicals from a wood treatment plant into the headwaters of Nancytown Creek caused acute toxic concentrations of copper and pentachlorophenol. Chromium and arsenic concentrations did not exceed acutely toxic levels, but may have presented chronic problems. A series of beaver ponds and an artificial impoundment reduced the extent of downstream chemical movement. The presence of the wood preservative chemicals significantly reduced aquatic macroinvertebrate diversity, number of taxa found, and numbers of organisms collected.

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Pilot Development of a Freshwater Molluscan Sediment BioAssay for Pesticides

H. L. Phelps[1]

Research was conducted to develop a freshwater molluscan sediment bioassay procedure for pesticides using Atrazine® as a model because of its role as a Toxic of Concern in the Chesapeake Bay. Radiolabelled Atrazine® was used to establish sediment sorption parameters with fresh sieved (74μ) sediment, and to conduct toxicity assessment of the sorbed Atrazine® with *Corbicula fluminea* (Asiatic clam) larvae and *Anadonta imbicilis* (common river mussel) larvae. *Corbicula fluminea* pediveliger larvae were obtained from adults collected from the Potomac River; *Anadonta imbicilis* larvae were raised in tissue culture to the pediveliger stage. The sorption of Atrazine® by suspended sediment increased with Atrazine® concentration in water up to the solubility maximum of 33 mg/l. The highest sorbed atrazine concentration of 1.27 mg Atrazine®/gm sediment took place with the maximum Atrazine® water concentration of 33 mg/L and the lowest suspended sediment concentration of 2.4 mg/ml. Initial sediment sorption of Atrazine® reached a maximum at 10 minutes with some desorption by 30 minutes. The bioassays with *Corbicula* larvae found a limited and variable relationship of larval mortality to sediment-sorbed Atrazine® up to the maximum of 1.27 mg Atrazine®/gm sediment. There was no effect of sediment-sorbed Atrazine® up to 0.54 mg/gm sediment on survival of either species of mollusk pediveliger larvae.

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Pesticide Use Surveys in Arizona — What Do They Show?

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Pesticide-use surveys were conducted on seven commodities grown in Arizona over the three-year period of 1990-1993. These surveys were conducted on alfalfa and potatoes (1990), apples, grapes, and wheat (1992), and barley and corn (1993). The four-page questionnaires were mailed to commodity growers identified by the Arizona Agricultural Statistics Service. A week later a "Thank You"/reminder was mailed, and if necessary, a follow-up phone enumerator was used to record grower responses to the questionnaire.

The survey consisted of questions regarding acres planted, harvested, and treated with agrichemicals, application rates, methods of application, and cost of application. We also asked questions regarding production practices such as, "Did you use IPM practices?", "Did you adjust planting dates for pest control?", "Did you have your soil tested?", and "Did you allow biological control organisms to develop?" Some surveys were coded for use in Lotus 1-2-3 database files for analysis, while others used the General Services Administration (GSA) Questionnaire Program Language for analysis by Statistical Packaging for Social Sciences.

In the two major commodities, alfalfa and wheat, over 55 percent of the respondents used no agrichemicals at all. In addition, nearly 34 percent of the respondents indicated that they attempted to protect naturally occurring beneficial organisms. If chemicals were used, the chemical class most frequently mentioned as insecticides (>60%), followed by herbicides (>35%) and fungicides (<1%). The use of nematicides was never reported on any commodity. Small-acreage commodities, such as apples and grapes, received limited applications of agrichemicals, usually only one application per season. In the wheat survey, BMPs had a higher response rate (41%) than did IPM practices (24%). In general, pesticide use on the seven commodities reported here was significantly less than the authors anticipated.

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Pesticide Use in Virginia: Results of the 1991 Statewide Surveys

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Mail surveys of Virginia growers were conducted in January and March 1991 to assess pesticide-use patterns in economically important commodities in the Commonwealth. This study was undertaken to address the need for information on pest control methods in general, and in specific, on the types, amounts, and locations of pesticides currently used by Virginia farmers. The crops surveyed were corn, potatoes, small grains (barley, oats, and rye), soybeans, tobacco, tomato, and wheat. Growers surveyed were selected randomly from the mailing list of the Virginia Agricultural Statistics Services, which also determined the sample size by crop and county. A total of 6155 questionnaires were mailed to farmers and 3184 were returned, resulting in a response rate of 52 percent. Of the responding farmers, 32 percent applied pesticides on their 1991 surveyed crop. Herbicides were applied by 91 percent of the responding growers using pesticides, while insecticides and fungicides were used by 43 and 41 percent, respectively. Only 7 percent of the responding farmers reported the use of alternative pest control methods.

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A Nine-Year Comparison of Pesticide Use in New Jersey

G. C. Hamilton[1] and R. Meyer[2]

In 1986, the New Jersey DEPE-Pesticide Control Program and Rutgers Cooperative Extension conducted a cooperative program to collect pesticide-use data from New Jersey growers. Growers were asked, via a mail-in survey, to provide information regarding the pesticides they applied to their crops during the 1985 growing season. The information collected included the crops treated, the materials and amount applied, and the total area treated. Once collected, additional information, such as amount of active ingredient (a.i.) applied and its chemical classification, were developed. In 1986 this program was highly effective (>90% return rate) and represented the majority of the pesticides applied to New Jersey crops in that year. Due to the successful nature of the 1986 program, it was conducted again in 1989 and 1992. The availability of this type of data, collected over a nine-year period, presents a unique opportunity to observe the changes and trends in pesticide use by New Jersey growers. This is important due to the numerous pesticide issues, such as groundwater contamination and food safety, that have developed since 1986. By examining these data, inferences as to whether growers respond to pesticide issues can be made. The results of these three surveys revealed that, in each of the survey years, vegetables and tree fruits received the highest overall levels of application. The materials applied, however, differed for each crop within the three major classes of materials used, i.e., insecticides, fungicides, and herbicides. Differences in usage also were seen within each of these three classes. A similar trend was seen for field crops, especially as it pertains to herbicide usage. These contrasting patterns and the possible reasons for them will be examined. Changes in usage patterns due to groundwater contamination problems and reduced alachlor usage, or increases in pyrethroid insecticide usage due to worker safety issues, etc. will be discussed.

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Assessing Pesticide Use in New Jersey by Means Other Than Amounts

C. R. Brown[1] and L. W. Meyer[1]

Currently, the face of agricultural pesticide use in New Jersey has been judged mainly on the poundage (or tonnage) of pesticides used. A decrease of pesticide use based on amount, however, may not realistically indicate a decrease in the hazards associated with pesticides. Likewise, an increase of pesticide-use may not realistically indicate an increase of those same hazards. Using three agricultural pesticide use surveys for the state of New Jersey spanning nine years, a *weighing* system was created to determine the increase or decrease of undesirable repercussions associated with the varying pesticide use from survey to survey. Three parameters were *weighted* in connection with the pesticide survey amounts: acute toxicity, using the oral toxicity class assigned by the U.S. Environmental Protection Agency (EPA); carcinogenicity, using EPA's carcinogenicity classification system; and groundwater leachability, using an in-house potential leaching classification. Pesticide use repercussions over the nine years were looked at by pesticide type (herbicides, insecticides, fungicides) and by selected crops. The *weighing* system presented in this paper could be used to gauge the hazards associated with pesticide use from year to year and alter pesticide management programs as required, not only on a state level, but on a county or even farm level as well.

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Automated Solid Phase Extraction for Pesticides and Herbicides in Large-Volume Water Samples

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Traditionally, water samples being analyzed for organic pollutants were extracted by liquid/liquid techniques. Most liquid/liquid extraction methods used today were developed during the 1950s. These methods are designed using a separatory funnel to perform the extraction. Some years later, automation was applied to liquid/liquid extraction in the form of a continuous liquid/liquid extractor. Both methods are labor intensive and involve using large quantities of extraction solvent.

During the late 1970s, laboratories started experimenting with liquid/solid extraction techniques. This technique, also known as solid phase extraction (SPE), provides the same efficiency of extraction as liquid/liquid extraction, but with a ten-fold reduction in the amount of solvent consumed. The equipment used to perform SPE is a vacuum manifold. The advantage of reduced solvent use is of great benefit to laboratories and the ozone layer, but the vacuum manifold method is still technique-sensitive and has a limited capacity for samples containing suspended solids.

A new device has been developed for SPE that automatically conditions the SPE cartridge, loads the sample onto the SPE cartridge, and elutes the SPE cartridge without operator intervention. Samples are delivered to the SPE cartridges by positive pressure pumps allowing higher loading pressures than a vacuum system. By incorporating a microprocessor into the unit, precise sample load rates can be attained. This ensures that the interaction between the sample and stationary phase is kept constant. This consistency helps maximize analyte recoveries.

This paper will discuss the operation of the device and provide recovery data from water samples.

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Monitoring Atrazine After Turf Application Using Immunoassays

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Pre-emergent herbicides have been detected in groundwater, well water, and surface water runoff. In the analysis of pesticides, immunoassays afford efficient and economical screening and monitoring. Only a small volume of aqueous sample (<1 ml) is necessary for detection in the parts-per-billion (ppb) concentration range.

The herbicide atrazine was applied in the spring of 1992 to experimental turf plots in sandy loam soil at the labeled rate of two pounds of active ingredient per acre. Atrazine was monitored in rain-induced leachate samples collected from several field lysimeters for eight subsequent months.

For pesticide detection and quantification, a commercially available immunoassay kit for atrazine and related triazines was used. The detection level of the assay for atrazine is about 0.05 ppb, as compared to the Practical Quantitation Level (U.S. Environmental Protection Agency) of 1 ppb, and the minimum quantification limit for groundwater samples of 0.24 ppb (National Pesticide Survey).

Samples were taken before and after pesticide applications from April to September. Pre-application atrazine concentration levels were below the limit of detection. After application and with water recharge events, lysimeter atrazine concentration levels were found to increase to approximately 4 ppb. Seven months after treatment, atrazine was still detected at about 1 ppb. Lateral movement of atrazine into adjacent untreated turf plots was not detected.

The use of immunoassays has several significant benefits. It allows for direct aqueous analyses of small-volume samples. For many samples, immunoassay use eliminates sample preparation, pre-concentration, and interference removal procedures. Immunoassays may be an efficient tool in assessing the efficacy of pollution prevention measures, such as agricultural best management practices (BMPs). Immunoassays are being evaluated for applicability to a state-wide targeted pesticide monitoring plan under the Pesticides and Groundwater State Management Plan.

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Extraction of Pesticides from Soil, Plant, and Water Samples by Classical and Supercritical Fluid Methods

R. G. Frazier[1] and G. Winnett[1]

The Cohansey aquifer located in south-central New Jersey, the Pine Barrens, consists of sandy loam soil with an acidic pH—ideal conditions for the culture of blueberries. As part of normal cultural practices, herbicides and insecticides are applied to the field prior to, during, and after the harvest. After the application, it is important to ensure the safety of the crop for public consumption and to investigate possible contamination of the water table, which, in this case, can be only three feet below ground.

The location for the study was chosen, among other things, because of the detailed records kept by the Rutgers Blueberry and Cranberry Research Station on precipitation, temperature, irrigation, and pesticide application schedules. The pesticides investigated were diazinon, malathion, captan, norflurazon, devrinol, and guthion. Samples of leaf, berry, soil, groundwater, and surface water were examined for residual pesticides.

Water samples were immediately extracted by classical liquid/solvent extraction, and analyzed by gas chromatography using an electron capture detector. Soil and plant samples were extracted by two techniques to improve the efficiency of analysis. Supercritical fluid extraction (SFE) using carbon dioxide with a hexane modifier was used for most of the samples due to the extraction efficiency and rapidity with which samples can be processed. Samples also were extracted by Soxhlet extraction to confirm extraction. Results indicated that SFE is as reproducible and effective as Soxhlet extraction in recovering pesticides. Additionally, it is 20 times faster and is less detrimental to the environment due to a 90-percent reduction in solvent use. Samples extracted by SFE were more specific for pesticides and had lower limits of detection than duplicates extracted by Soxhlet. The SFE method further benefitted from the inherent variability of the system in that the extraction parameters could be modified easily depending on the nature of the samples and analytes to be extracted. Leaf and blueberry samples were prepared by milling with dry ice, and then mixed with Hydromatrix (Varian) to control the high water level in plant material. Recoveries of the pesticides in the study were good.

SFE is a viable substitute for Soxhlet extraction of pesticides from soil and plant samples, with a reduction of time and solvent, and with analyte recovery as complete as that by confirmed methods. The information gained in this study contributed to the knowledge of farming in a sensitive region such as the Cohansey aquifer.

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Significant Improvements in Multiresidue Pesticide Analysis

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The United States Food and Drug Administration (FDA) often has been criticized for failure to adequately monitor the food supply for pesticide residues. Much of the problem is that many pesticides are not amenable to analysis by gas chromatography and, thus, can not be included in a multiresidue protocol. For pesticides that can be analyzed by gas chromatography, reliance on packed-column chromatography and the use of several element-specific detectors contribute to a labor-intensive, time-consuming process that could use improvement. Over the past few years, we have developed methods based on the use of capillary gas chromatography coupled with an ion trap mass spectrometer operated in the chemical ionization mode. These changes translate into faster pesticide analyses at, in most cases, lower limits of detection as well as elimination of the need to separately confirm the presence of many pesticides. Currently, the FDA District Laboratory in Los Angeles is evaluating this new methodology in the expectation of replacing 22 separate gas chromatographs with just two ion trap mass spectrometers. The savings in time and manpower will be used to analyze those pesticides that cannot be analyzed with gas chromatography techniques. Because of the potential changes in the way in which multiresidue pesticide analyses will be conducted in the near future, an explanation of the methodology and its underlying philosophy will be provided. We also will give examples of how these procedures have been used to analyze for a variety of pesticides in air, water, and soil, as well as food.

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Concepts for a National Synthesis of Pesticides in Major River Basins and Aquifer Systems

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The National Water-Quality Assessment (NAWQA) Program is designed to describe the status and trends in the quality of the nation's groundwater and surface water resources and to provide an improved understanding of the natural and human factors that affect the quality of these resources. The program has two major work elements: (1) hydrologic investigations of large river basins and aquifer systems, referred to as study units, and (2) national synthesis projects focused on water-quality topics of regional and national interest. Current national synthesis efforts are focused on the occurrence and distribution of pesticides and nutrients in major river basins and aquifer systems of the United States. The unique characteristic of the NAWQA Program that lends itself to national synthesis is the coordinated application of comparative hydrological studies at a wide range of spatial and temporal scales. This approach is intended to simultaneously provide new insights into the status and trends of water quality and, more importantly, improve our understanding of physical, chemical, and biological processes and causal relationships.

Some of the questions that will be addressed as part of the pesticide synthesis include: (1) Which pesticides are detectable in surface water and groundwater, and where and how frequently do they occur? (2) What are the seasonal patterns of pesticide concentrations, and do detectable concentrations occur only during periods of significant use? (3) What are the relations between pesticide occurrence in surface water and groundwater and various natural and anthropogenic factors? (4) Do concentrations of pesticides found in water pose a threat to the health of humans or aquatic life? (5) Does current knowledge of the sources and behavior of pesticides in hydrologic systems indicate the need for changes in management practices or regulations?

The approach to the national synthesis will be an iterative process involving four elements that correspond to the sources of information to be used: (1) review of existing information, (2) development and analysis of ancillary geographic and hydrologic data, (3) NAWQA study-unit investigations, and (4) regional synoptic studies.

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Canadian Water Quality Guidelines for Pesticides

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The Canadian Council of Ministers of the Environment (formerly CCREM, now CCME) published the first edition of the Canadian Water Quality Guidelines in 1987 to harmonize guidelines recommended for the maintenance and protection of designated water uses (CCREM 1987). These guidelines define acceptable water quality for a number of chemical, physical, biological, and radiological parameters. The major water uses addressed are (a) raw water for drinking water supply, (b) recreational water quality and aesthetics, (c) agricultural uses, including irrigation and livestock water, (d) industrial water supplies, and (e) water to support and protect freshwater and marine aquatic life.

CCME water quality guidelines are national in scope, and are being accepted by all provinces and territories and used in their respective water quality management programs. Guidelines do not constitute values for uniform national water quality, as their use will require consideration of local conditions.

In 1987, the CCME task force compiled a priority list of pesticides urgently requiring water quality guideline development. This list was amended in 1989 and 1990 with newer priorities following further consultation with task force members.

Guidelines are based on public documents, which contain a detailed review of all the published information currently available regarding: production and registered uses, physical and chemical properties, sources and pathways for entering the aquatic environment, environmental concentrations, fate and persistence, bioaccumulation, toxicity to aquatic biota, non-target corps, livestock, and related biota, and a review of available guidelines/objectives/criteria from other jurisdictions. When sufficient information is available, maximum numerical concentrations or narrative statements that will protect and maintain water uses in Canada are recommended.

Canadian Water Quality Guidelines have been prepared for 21 priority in-use pesticides to date, including aldicarb, atrazine, bromoxynil, captan, carbofuran, chlorothalonil, cyanazine, dicamba, diclofop-methyl, dinoseb, dimethoate, endosulfan, glyphosate, lindane, metolachlor, metribuzin, picloram, simazine, triallate, trifluralin, and 2,4-D.

Data gaps for the aquatic life and agricultural guidelines have been identified as being:

1) Long-term chronic studies using sensitive lifestages or full/partial life cycles of native fish and/or invertebrate species (captan, cyanazine, glyphosate, metolachlor, metribuzin, picloram, simazine, trifluralin, dicamba)

2) Short-term acute toxicity studies on sensitive native invertebrate and/or fish species (dinoseb, metolachlor)

3) Laboratory/field acute and chronic dose response studies on native aquatic plants (macrophytes and algae) (cyanazine, glyphosate, metolachlor, picloram, trifluralin)

4) Long-term studies (ingestion) on livestock receptors (ungulates and fowl) including bioaccumulation (all in-use pesticides)

5) Studies on sensitive crop species, preferably studies employing irrigation water exposures (all in-use pesticides).

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The Challenge of Planning Ahead: A Case Study in the Development of Virginia's Generic Pesticides and Groundwater Management Plan

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In 1987, Virginia affirmed its anti-degradation policy to treat all groundwater resources the same. The cornerstone of the U.S. Environmental Protection Agency's (EPA) pesticide and groundwater protection strategy is the development and implementation of state management plans (SMPs) for pesticides posing a significant risk to groundwater resources. The EPA has encouraged the states to develop generic management plans and will require pesticide-specific management plans to protect the groundwater resource from highly leachable pesticides. Development of such plans may permit the continued safe use of certain pesticides. An inter-agency task force, which went beyond state agencies to include agricultural and groundwater interests, was formed to draft Virginia's Generic Management plan. The inclusive approach of using a task force, mediated by a facilitator, promoted greater cross-program, cross-media agreement and cooperation among participating parties. This process also exploited the existing capabilities of several agencies to assess vulnerability and to monitor groundwater, while effectively using limited resources to advance groundwater protection.

During the early stages of its deliberations, the task force developed a concept outline that incorporated the 12 elements sought by the EPA into a plan comprising 7 chapters. The final chapter, which provides direction for proceeding from the generic plan to pesticide-specific plans, is unique in Virginia's approach. This paper will discuss how, in the development of the generic SMP, Virginia has addressed and handled critical groundwater issues, such as: clarifying the difference between groundwater and surface water, treating groundwater hydrologically connected to surface waters, establishing detection triggers and appropriate responses, and establishing baseline monitoring. The lessons learned from this experience should prove useful to any state in developing future SMPs, where the crunch will be on and the potential pressures will be heightened.

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Agrichemical Groundwater Quality Protection in Idaho: Management and Policies

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Agriculture ranks as the number one industry in Idaho. In 1991, agriculture accounted for 36 percent of the state's economy. An industry of this size has the potential to impose several demands on the natural resources of a state. One of these resources, groundwater, is in the forefront of environmental issues in Idaho due to several recent findings of groundwater contamination by pesticides. Agrichemicals serve an important need of growers for pest control in Idaho. Consequently, preventing groundwater contamination from pesticides is a major challenge and concern for Idaho's agricultural industry.

Two groundwater quality protection plans currently are being developed for the state of Idaho to address the prevention of, and response to, groundwater contamination from agricultural chemicals. These plans include the Idaho Agricultural Groundwater Quality Protection Program (AGQP) and the State Pesticide Management Plan (SMP). The former is being developed by the Agricultural Chemicals Subcommittee of the Groundwater Council and is intended to be a supplement to the Idaho Groundwater Quality Plan. The SMP is U.S. Environmental Protection Agency directed, as part of the Pesticides and Groundwater Strategy, and will be a separate document developed by the Idaho Department of Agriculture in conjunction with other state and private entities. The policies and management strategies of both documents will be consistent.

Development of the AGQP is based on the agrichemical and nutrient management policy of the Idaho Groundwater Quality Plan. Several sources of potential groundwater contamination resulting from agriculturally related activities, as well as the possible causes for such contamination, are identified. The agrichemical sources include: storage and handling, mixing and loading, disposal, and application.

Three protective strategies have been chosen for managing the potential agrichemical sources. These include: 1) information and education; 2) best management practices (BMPs); and 3) regulations. All three strategies will be used in both a preventative and response mode.

The preventative mode is initiated for those instances where contamination of the groundwater has not occurred. It consists of determining the appropriateness of applying BMPs for a given agricultural activity. The criteria used for this determination include the chemical characteristics of the agrichemical, groundwater susceptibility/vulnerability, schedule for BMP development/implementation, chemical transport modeling, and quantity and areal extent of agrichemical use. A "not appropriate" determination leads to a regulatory approach.

The response mode is initiated when agrichemicals are detected in the groundwater. The extent, degree, and cause of the contamination determine the protective strategy chosen to remedy the situation.

BMPs are implemented via a BMP Feedback Loop (FBL) process. The BMP FBL consists of four steps: 1) BMP development/improvement, 2) onsite implementation/ maintenance, 3) effectiveness evaluation, and 4) goal(s) assessment. Onsite maintenance continues when the goals of the BMP(s) are being met.

The SMP addresses 12 components regarding the protection of groundwater from agrichemicals. The prevention and response components will be similar to those presented in the AGQP. Unlike the AGQP, the SMP will be pesticide-specific and part of the label requirement for the pesticide.

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Pesticide Contamination of Targeted Household Water Supplies

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The water requirements of the vast majority of rural homes and farms throughout Virginia are met by individual water supply systems. The water needs of approximately 1.5 million Virginians are met by private wells and springs. Nuisance problems with quality of household water supplies are frequently encountered raising curiosity about the possible presence of health-related contaminants that do not lead to sensory symptoms.

Public awareness and concern have been heightened through extensive publicity about water supply contamination occurrences such as the identification of several U.S. Environmental Protection Agency (EPA) Superfund groundwater sites in Virginia. Local governments have acted to support investigations of the vulnerability of their jurisdictions to groundwater contamination and the effect of land-use activities. Few investigative studies, however, have been conducted to examine the possible contamination of household water supplies by pesticides in Virginia. The likelihood of pesticide contamination is relatively uncertain since little documented information is available because Virginia does not record pesticide usage, and, until recently, well construction standards were not enforced. The widespread use of pesticides, inadequate well construction, and reliance on numerous shallow, dug wells, as well as soil, climate, and hydrogeologic conditions favoring pesticide movement to groundwater all combine to create a real potential for pesticide contamination of household water supplies in many areas of Virginia.

To examine the potential for pesticide contamination in Virginia's household water supplies, pesticide analysis was integrated into an ongoing series of countywide water quality educational programs that have been conducted in seven Virginia counties since 1989 by the Virginia Tech Department of Agricultural Engineering and Virginia Cooperative Extension. The objectives of this program were to provide rural household residents with information about water quality, leading to an improvement in their individual and family quality of life, as well as to create a groundwater quality data inventory for assisting local governments in land-use and groundwater management planning.

The foundation of this educational effort was a two-phase diagnostic water testing program offered on a first-come, first-serve basis to any interested county resident using an individual, privately-owned household water system. Phase 1 analysis included approximately a dozen nuisance and health-related water quality parameters, such as iron, hardness, nitrate, and coliform bacteria. Upon collection of water samples, information about the location, type, and characteristics of the water supply, as well as details about its proximity to potential pollutant sources, was obtained.

After the completion of Phase 1 of the water testing program, suspicion of more serious contamination, as indicated by Phase 1 test results, along with the above water supply information, was used to select participants for Phase 2 testing for pesticides and other chemical compounds. The number of participant samples analyzed under Phase 2 testing ranged from 10 to 60 per county and totaled more than 200. Based on the above information and history of pesticide use in each county, a target list of most-likely contaminants to be found in the water supplies of each county was developed for analysis. As a result, a high risk scenario resulted that was likely to reveal any incidence of pesticide contamination, if it existed.

Of more than 30 pesticides and other chemical compounds tested, few incidents of a concentration exceeding EPA's maximum contaminant level or health advisory limit were noted, among those being atrazine and chlordane. However, more than 20 different compounds were detected in measurable quantities in one or more samples. Nearly half of the samples had detectable concentrations of one or more compounds.

This paper will examine the relationship between contaminant levels and the various criteria used in the selection of the pesticide analysis subsample. The actual risk of pesticide exposure to household water users, such as those participating in the educational program, will be explored in the context of the risk implied by the targeting criteria used.

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Well Vulnerability and Nitrate Contamination: Assessments from a Voluntary Well Testing Program

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The Heidelberg College Cooperative Private Well Testing Program is one of the largest voluntary monitoring programs of its type in the United States. It is designed to address water-quality issues in private rural wells. Through local organizations in 335 counties and 14 states, 37,000 individuals have submitted water samples to be tested as part of the program. The average nitrate-nitrogen concentration in these wells is 1.62 ppm, and 3.9 percent of the wells exceeded the drinking water standard. A concentration of 1 ppm was exceeded in about 30 percent of the wells.

The data set provides useful information regarding those factors of well vulnerability that correlate with high and low nitrate concentrations. An information sheet, completed by well owners and submitted along with their water samples, provides data on factors such as well depth, well age, well type, soil type, and proximity to cropland, feedlots, or chemical mixing sites. The data indicate that nitrate concentrations are higher in shallower wells, in older wells, in dug or driven wells, in wells located close to cropland (within 20 feet), in wells located in sandy soils, and in wells close to either feedlots or chemical mixing sites. Where wells combine the most vulnerable alternative for two or three factors, the probability of contamination by nitrate increases dramatically. For example, 27 percent of the shallow wells located in sandy soils near crops contained nitrate in excess of the drinking water standard of 10 ppm. In contrast, for deep wells in clay soils, away from cropland, nitrate-nitrogen concentrations exceeded 10 ppm in only 0.8 percent of the samples.

A mapping component of the well testing program frequently reveals spatial patterns of nitrate contamination that reflect geological factors. River valley aquifers, sandy soils with high water tables, karst areas, and reef structures with surficial expressions are all reflected in county maps that are developed as part of the program.

While voluntary programs do not necessarily provide a random sample of wells, they nevertheless provide much useful data to support local groundwater protection and education programs. In the Heidelberg program, the investments individuals make to have their own well water tested and the voluntary efforts of local agencies to facilitate the testing program are linked to the development of detailed local databases. Even though individual results remain confidential, the mapping component is adequate to support targeting groundwater protection programs.

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Evaluation of the Vulnerability of Water from Public Supply Wells in New Jersey to Contamination by Pesticides by Use of a Geographic Information System

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The vulnerability of groundwater from the 2,300 public supply wells in New Jersey to contamination by pesticides is being evaluated by using a geographic information system (GIS) in conjunction with a multivariate statistical model. The vulnerability of water from each well will be determined from the (1) sensitivity of the hydrogeologic system, (2) well-construction and groundwater-quality characteristics, (3) land use and intensity of pesticide use near the well, and (4) chemical and physical characteristics of the pesticides. The model will be used to rank the public supply wells as having high, medium, or low vulnerability to contamination by pesticides. The validity of the model will be tested by sampling water for pesticides from a stratified subset of the public supply wells from each vulnerability group and then comparing predicted and observed results. The GIS database and statistical model can be used by water managers to determine whether water-supply companies can receive waivers for analyses of pesticides in water samples from those wells determined to have low vulnerability.

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Pesticide Degradates in Groundwater: Implications of Available Studies for Regulatory Policy

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For the majority of pesticides, degradates are much less toxic to the target pests than the parent active ingredient, and in the past the environmental significance of degradates was largely ignored. This has begun to change with the establishment of health advisory or regulatory action levels in recent years. Calculation of these levels often is based on modes of action in mammals unrelated to the action on the target species. The level triggering regulatory action may be set very low after the appropriate safety factors are built into the calculations. Recent studies with triazine and acetanilide herbicides have demonstrated that quantities of degradates in groundwater may exceed the quantities of the parent compound. For example, in a survey of rural drinking water wells in Iowa, the combined residues of the two monodealkylated degradates of atrazine were, on average, greater than the residues of atrazine parent. A study of Wisconsin wells also found that there are additional degradates of atrazine and other triazine herbicides that can be present in significant quantities. These residues appear to be persisting for many years and will likely be considered for inclusion in future regulatory standards at the federal and state level. Most of the major preemergent herbicides, which are the most commonly found pesticides in groundwater, will undoubtedly come under increased scrutiny as groundwater monitoring studies begin to focus more on the total residues including degradates. This is likely to significantly increase the rate of non-compliance of drinking water wells with these standards and force decisions on whether to restrict the areas in which many pesticides can be used.

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Induced Systemic Resistance — A Non-Pesticide Technology for Disease Control in Plants

J.A. Kuc[1]

The use of pesticides in plant protection is becoming increasingly restricted at the same time that the profitability and competitiveness of U.S. agriculture must increase. Aside from considerations of health and quality of life, the generation of new pesticides is becoming more difficult and expensive. Resistant strains of pathogens rapidly develop to many newly developed systemic pesticides and the development of environmentally safe pesticides has increased their cost and reduced the number that are available. Many recommended pesticides are being removed from the market, and others can be used only on particular crops. The consumer is becoming increasingly concerned about pesticide use and residues on food products, but at the same time, pesticides continue to make a major contribution to the increased crop yields and quality of modern agriculture.

Induced systemic resistance (ISR) is a technology developed to reduce our dependence on pesticides. ISR uses genetic information for resistance mechanisms present even in plants susceptible to a disease. In susceptibility, the information is not expressed quickly and strongly enough to control the infectious agent. By inoculating plants with nonsystemic pathogens or some nonpathogens, resistance can be induced systemically to a broad spectrum of diseases caused by viruses, bacteria, and fungi. Several putative chemical signal compounds have been isolated from induced plants that cause the production of or enhance systemically some defense compounds, (e.g., chitinases, β-1, 3-glucanases, and peroxidases.) The putative signals also sensitize the plant to respond rapidly to infection by producing other defense compounds at the infection site, (e.g., phytoalexins, hydroxyproline-rich glycoproteins, lignin), and enhance further the systemic defense compounds mentioned earlier. A nontoxic group of environmentally safe compounds has been developed in our laboratory that causes the release of the signals when sprayed on plants. The signals and compounds that release signals increase the ability of the plant to protect itself.

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Development of Environmentally Safe Chemicals as Inducers of Disease Resistance in Crop Plants

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It is possible to induce high levels of disease resistance in plants by localized inoculation with nonsystemic plant pathogens, but this approach is often impractical for production agriculture. As an alternative to plant pathogens, we are investigating the potential of environmentally compatible chemicals as inducers of disease resistance. A common feature of resistance induced by pathogens is the gradual development of chlorosis and/or necrosis in the plant tissues inoculated. Certain herbicides were found to cause such symptoms and to induce systemic resistance; however, these herbicides are not ideal candidates for field application, due to the hazards they pose to farm workers and the environment.

We have subsequently identified a number of nonhazardous chemicals that can induce disease resistance. These chemicals are inexpensive and readily biodegradable. The most promising of these materials are being studied with respect to their modes of action and efficacy against diverse pathogens.

Greenhouse tests indicate that chemically-induced resistance resembles that induced by pathogens with respect to the activation of multiple plant defenses and effectiveness against a broad spectrum of pathogens. Some of the plant defenses that are activated in induced resistance to pathogens have been implicated in plant tolerance to environmental stresses, and we are intrigued by the possibility that protection from environmental stresses may be an added benefit of induced resistance to pathogens.

We also are developing formulations of inducers with additives that will maximize effectiveness while minimizing damage to treated leaves, and evaluating seed treatments that may induce disease resistance. We envision that induced resistance will find optimal application as a component of integrated strategies for disease control, including judicious use of conventional pesticides.

Induced resistance should enhance the effectiveness of pesticides for plant disease control, as does resistance introduced by plant breeders. Induced resistance may permit substantial reductions in the dose and/or frequency at which pesticides must be applied to provide economic control of plant disease. Reductions in pesticide use due to induced resistance would help protect the environment, reduce hazards to human health, increase farm profitability, and extend the useful life of conventional pesticides.

Much research is needed to determine the extent to which induced resistance can control plant diseases and influence pesticide usage. We would welcome the cooperation and assistance of others in testing the performance of compounds we have developed in the field and in commercial greenhouses to determine their effectiveness and reliability under varying climatic, geographic, and cultural conditions.

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Higher Plant Products as Natural Pesticides

A.K. Mishra[1], N. Kishore[1], and N. K. Dubey[1]

Keeping in mind the side effects of synthetic pesticides, a screening program has been conducted in our laboratory to find out the bioactivity of some higher plant products as natural pesticides so as to exploit them as biodegradable, non-pollutive, renewable, and nontoxic alternative sources of pesticides.

Some groups of higher plant products have been isolated and standardized by physico-chemical properties and chromatographic and spectral studies. These products have been tested against some storage fungi *Aspergillus flavus, A. versicolor,* and storage insect pests *Trogoderma granarium, Tribolium castaneum* and *Sitophilus oryzae*, causing severe biodeterioration of different food commodities during storage. The essential oils of *Ocimum canum, Cymbopogon citratus,* and 4-naphthylnaphthoquinone, a compound isolated from *Prunus persica* leaves, exhibited absolute bioactivity. The lethal dosages, biotoxic spectrum, thermostability, and shelf-life of these products have been determined. The products being nonphytotoxic in nature exhibited nonanimal toxicity on albino rats when the treated feed was fed to these animals. The practical applicability of these products was observed as fumigants. These plant products exhibited their capability to protect some food commodities and fruits from insects as well as fungi when used as fumigants.

In another set of experiments, the essential oils of *Hyptis suaveolense, Lippia alba, Chenopodium ambrosioides*, and Zerumbone, a sesquiterpine of *Zingiber cassumunar*, showed their potential control of damping-off diseases of seedlings of some vegetables when used in seed treatments.

Thus, these plant products may be exploited as alternative pesticides of higher plant origin in plant protection in place of synthetic chemicals.

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The Insecticidal Activity of Floral and Root Extracts of *Tagetes minuta* and *Tagetes patula* (Marigolds, Family-Asteraceae) Against Mexican Bean Weevils, *Zabrotes subfasciatus* and Nontarget Organisms, Fish *(Gambusia affinis)* and a Beneficial Insect, the Pirate Bug, *Xylocoris flavipes*

S. Sriharan[1], A. Wright[1], P. Singh[1], F. V. Dunkel[2], D. C. Richards[2], W. Bertsch[3], and C. Wells[3]

The potential use of botanical derivatives for insect control is gaining attention in recent years because of the concerns over the environmental consequences of the application of nonselective and persistent pesticides. In addition, the development of insecticide resistance by target species has brought about intensified efforts to search for alternative pest-control strategies.

This paper deals with a program developed for obtaining natural substances easily and inexpensively for control of major storage pests in Rwanda, East Africa. The results of extraction procedures developed in the study and bioassay against the target and non-target organisms are presented.

Marigolds, *Tagetes* spp., (*T. minuta L.* and *T. patula*) known as intercrop in agriculture, were selected to prepare the extracts by simultaneous steam distillation using methylene chloride. The target storage insects, Mexican bean weevils, *Zabrotes subfasciatus* and nontarget biocontrol agents, a pirate bug, *Xylocoris flavipes*, mosquitofish, *Gambusia affinis* (Baird and Girard) were exposed to the steam-distilled oil from marigolds. The 24 hour LC_{50} values ranged from 138 $\mu g/cm^2$ for males to the root extract (most susceptible) to 803 $\mu g/cm^2$ for females of *Z. subfasciatus* to the foliar extract (least susceptible). The LC_{50} (24 hour) for nontarget adult *X. flavipes* was 240.3 $\mu g/cm^2$. However, exposure of nontarget predatory mosquitofish, *G. affinis*, to marigold extract showed no mortality even in the range as high as 1000-2000 ppm in water. Therefore, marigolds are promising botanical resources for isolating insecticidal components for stored-product insect management.

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Summary of CIBA/State Groundwater Monitoring Study for Atrazine and Its Major Degradation Products in the United States

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A large-scale groundwater monitoring program is being conducted by CIBA Plant Protection in cooperation with state agencies in approximately 20 states in the United States. This program was initiated in 1992 and will take two to three years to complete. Approximately 50-100 wells are being selected in each state in hydrogeologically vulnerable settings characterized by high atrazine use. The states proposed for monitoring include California, Florida, Hawaii, Illinois, Indiana, Iowa, Kansas, Louisiana, Maryland, Minnesota, Mississippi, Missouri, Nebraska, North Carolina, Ohio, Pennsylvania, Texas, Virginia, West Virginia, and Wisconsin. Analyses are being conducted for atrazine and the major degradation products, including deethyl atrazine, didealkylated atrazine, diaminochloro atrazine, and hydroxy atrazine.

This paper will describe the details of the field phase, including the criteria for well selection, training of personnel GLP requirements, and sample shipment. Details of the analytical phase of the study using GC/MS and LC/MS procedures will be described. Summary of the data collected to date will be provided, including analyses of the ratios of parent/degradates and mapping of the monitoring data using a geographic information system (GIS).

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General Discussion of the 1988 EPA Draft Guidance for Groundwater Monitoring Studies and Recommendations for Modification of the Small-Scale Prospective Design Based on Field Experience

I. W. Buttler[1], K. Balu[2], and P. W. Holden[3]

Elden et al. prepared a draft guidance document for groundwater monitoring studies in 1988 that has been used by registrants and their contractors to perform such studies. The original document described specific requirements of three study types: a small-scale prospective groundwater monitoring study; a small-scale retrospective groundwater study; and a large-scale retrospective groundwater study.

The EPA has determined that the small-scale prospective study is generally the most useful design from a scientific and regulatory perspective. This paper will describe in detail the design elements of the small-scale prospective study and recommend modification of the original design based on actual field experience in a number of states around the country. The strengths and shortcomings of the study design will be discussed, with suggestions offered to improve the overall utility of the study.

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Validation of Enhancements to the Pesticide Root Zone Model: Metabolites, Irrigation, and Vadose Zone Transport

J. M. Cheplick[1], W. M. Williams[1], K. Balu[2], and R. F. Carsel[3]

The Pesticide Root Zone Model, PRZM, has been validated against a number of field studies since its inception in 1984. The latest release of PRZM, PRZM-2, provides the following enhancements: the ability to simulate pesticide metabolites, various irrigation algorithms, and improved hydraulic transport in the vadose zone based on constitutive relationships between pressure, water content, and hydraulic conductivity. These specific enhancements in PRZM-2 are tested and validated against field data collected from a prospective groundwater monitoring study conducted for pesticide registration. This paper presents the configuration of the model to site conditions, calibration under environmental conditions observed during the study, and applications to predict concentrations under a greater range of climatological conditions. PRZM-2 is capable of simulating the behavior of bromide tracer, pesticide parent, and two metabolites as observed over a two-year period, and is found to be a superior simulation model for this case study compared to earlier versions of PRZM.

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Application of PRZM-2 to Predict the Fate and Transport of Forest Site Preparation Herbicides on Clear-cut Sites

A. K. Shahlaee[1], P. B. Bush[2], W. L. Nutter[1], J. W. Taylor[3], and Y. C. Berisford[2]

This study presents results of using PRZM-2, the latest version of Pesticide Root Zone Model, to predict the fate and transport of picloram, imazapyr, hexazinone, and triclopyr on three clear-cut forest sites on the U.S. Department of Energy Savannah River site. One of the improvements in PRZM-2 over its original version is the use of Richard's equation to simulate movement of water in the unsaturated zone below the root zone. Another major improvement in PRZM-2 is the probabilistic treatment of input values and the relevant output variables, such as solute concentration, by taking account of variability in the natural systems and uncertainty in system properties and processes. Sensitivity tests of major hydrologic, soil-crop and pesticide parameters were made. Following sensitivity tests, the model was calibrated and used to simulate the water balance of the study area over a 20-year period using the daily precipitation and mean temperature data. The model's output includes herbicide mass balance summary partitioned as total soil decay, total runoff, herbicide mass leached below root zone, and herbicide mass leached below core depth, as well as herbicide mass adsorbed, dissolved, or in gaseous form for each compartment. The simulations predicted that, of 124 cm of average annual precipitation, 50 percent is evapotranspiration, 2 percent is runoff, and 46 percent percolates below the root zone. Herbicide loss in deep percolation ranged from 0 percent (for imazapyr) to 15 percent (for picloram) of their respective application rates (1.12 kg/ha for imazapyr to 2.24 kg/ha for picloram). Herbicide residues in soil cores ranged from almost 0 percent (for triclopyr) to 8 percent (for imazapyr), and the loss in runoff ranged from 0 percent (for hexazinone) to 2 percent (for imazapyr) of their respective application rates.

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Predicting the Safety of New Pesticide Registrations to Man and the Environment Using Artificial Intelligence and Computer Knowledge Base Techniques

T. C. McDowell[1]

The utility of pesticide regulation by prediction via groundwater simulation modeling for potential water quality contamination is summarized with correlations to historical real-life pesticide detections in Florida. In a hazard assessment, a matrix decision procedure to analyze new pesticides based on relative groundwater leaching potential and chronic toxicity is presented. This matrix analysis is extended to interrelate risks to endangered species and worker protection by including bioaccumulation and acute (oral and dermal) assessments. The relative risk of a pesticide in Florida compared to some 12,000 state pesticide registrations is formulated by estimations of the total pounds of active ingredient that can and are most likely to be applied to actual acreage of the crop sites listed on the label.

In addition to the how, when, where, and how much of the pesticide application process, experts in the fields of pesticide environmental fate factors, toxicology, geohydrology, ecology, and worker protection have provided weighting values to the presented parameters which include Koc, Kow, soil degradation half-life, volatility, bioaccumulation, and carcinogenicity factors (both chronic and acute) including oral and dermal exposures. This knowledge base then is used in standard artificial intelligence program techniques to rank relatively pesticides as to total risk. In this manner, selection of chemicals in a prioritized manner is possible to subjectively choose regulatory options under budgetary constraints. The codification and acceptance of these knowledge base techniques by interagency groups provide a means for decision-making in a governmental unit for pesticide regulation.

Such decisions include initial screenings for tiered data requirements, (based on areal usage and sales information from manufacturing companies), the monitoring of usage areas, small- or large-scale prospective or retrospective field-study requirements, and conditional registrations based on label restrictions to include soils, usage areas, conditional best management practices, or even rejection of registration. The high use of pesticides in Florida's subtropical climate presents a worst-case scenario with world-wide applicability for registrations that may affect public health and the environment.

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A Fate and Transport Model to Evaluate and Manage Agrochemical Runoff from Rice Paddies

W. M. Williams[1], J. M. Cheplick[1], R. Layton[2], and J. G. Arnold[3]

Rice production in the Mississippi embayment presents a unique problem with respect to agrochemical runoff because of the high seasonal rainfall, water management, and proximity of cropland to surface water bodies in this regional area. Existing pesticide transport models are not configured to simulate the flooding conditions, overflow, and controlled releases of water that are typical under rice production. A fate and transport model, RICEWQ, was developed to simulate water and chemical mass balance associated with these unique governing processes. Water balance accounts for precipitation, evaporation, seepage, irrigation, and overflow from various paddy outlet configurations, and controlled drainage prior to harvest. Chemical balance accommodates application; dilution; advection; volatilization; partitioning between water/sediment; foliar washoff; decay in foliage, water, and sediment; burial in sediment; and resuspension from sediment. This paper describes in detail the model development, calibration procedures, and application in investigating the fate and transport to surface waters of agrochemicals used in rice production. Also described are applications of the model in developing and evaluating the effectiveness of alternative agricultural best management practices (BMPs) for environmentally-sound chemical use.

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Movement of the Pyrethroid Insecticide Bifenthrin in a Georgia Piedmont Pine Seed Orchard

P. C. deGolian[1], Y. C. Berisford[2], P. B. Bush[2], J. W. Taylor[3], and W.L. Nutter[1]

Bifenthrin (Capture 2EC®) was aerially applied to a loblolly pine (*Pinus taeda* L.) seed orchard in the Georgia Piedmont at a target rate of 0.197 kg a.i./ha (0.176 lb a.i./ac). Applications were made to a forested area and a bare soil area within a single watershed on June 21, August 9, and September 6, 1991. The mean level of bifenthrin deposited on the bare soil site was 48 - 67 percent of the application level. The mean level of bifenthrin deposited on the forest floor was 26-58 percent of the application level.

Offsite movement of the pesticide was monitored by collected surface water and sediment samples from a pond and an intermittent stream originating in the watershed. Movement within the soil matrix was measured by sampling soil in 15-cm increments to a depth of 90 cm. Soil samples were collected on the day of application and at scheduled intervals thereafter. Groundwater samples were collected on a monthly basis from three monitoring wells.

Bifenthrin was not detected in the surface and groundwater samples. The insecticide was detected in sediment samples only after the August application. Bifenthrin was only detected in soils collected from the bare soil area. Average soil concentrations ranged from 0.026 to 0.075 μg/g dry soil.

The models PRZM and GLEAMS were used to predict the movement of the insecticide within the watershed. Model simulations predicted little or no movement of bifenthrin from either of the two monitored areas, nor below the top 15 cm of the soil profile on either site. The models also predicted no surface runoff of bifenthrin into the stream or lake systems.

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Control of Pesticide Movement with Stormflow Detention Ponds

D. G. Neary[1], P. B. Bush[2], W. L. Nutter[3], and J. W. Taylor, Jr.[4]

A stormflow detention pond was constructed to hold storm runoff from a Piedmont pine seed orchard treated with up to 19 kg/ha of carbofuran. The pond was designed to hold low-volume stormflows, which, in the spring, after carbofuran applications, can produce LC_{50} concentrations for fish. The 2,500-cubic-meter detention pond was constructed with 2 subdrains filled with large gravel and covered to a depth of 30 cm to allow slow drainage into the lake. Agricultural limestone was disked into the Bt horizon soil material that formed the pond floor to enhance carbofuran degradation. Stormflow from a 2-ha watershed above the detention pond was sampled at an H-flume weir during 11 runoff events in the winter-spring period of 1983 and 1984. Outflows from the subdrains into a narrow bay head of the lake were sampled with automatic discrete samplers. Stormflow contributions to the detention pond of 6580, 3500, and 1000 μg/L were reduced to <2, 1500, and <2 μg/L, respectively, in pond discharge. The efficacy of detention ponds and situations for their use are discussed.

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Monitoring of Pesticides on Golf Courses in New Jersey

L. W. Meyer[1] and C. Brown[1]

Over the past few years, pesticide use on golf courses has been questioned as contributing to surface and groundwater contamination and causing a number of fish kills. State regulatory agencies are now faced with evaluating pesticide use and the associated potential impact. Municipal and other local authorities, in an attempt to address the concerns of citizens, require monitoring programs for pesticides without any guidance as to program design or interpretation of results.

The New Jersey Department of Environmental Protection and Energy (NJDEPE) is developing a set of guidelines for golf courses. As part of this effort, the Pesticide Control Program is conducting a monitoring program for pesticides on golf courses. The first phase was to accumulate data from a pesticide-use survey sent to over 200 operating golf courses in New Jersey. The survey provides information on the amount, site of application, and types of pesticides used on courses in the state, and will allow a variety of geographic comparisons by use of a geographic information system (GIS).

The second phase is an ongoing monitoring program that will seek to evaluate the use, accumulation, and runoff of pesticides from golf courses. Application records will be examined to determine peak pesticide application periods. Samples of surface water, groundwater, and soil/sediment will be obtained during these peak application periods, especially just after a significant rainfall, if possible. Background sampling was conducted on three courses during 1992, with at least six courses scheduled for seasonal monitoring during 1993.

The data collected will be used to assess the potential risk posed by the pesticides and to aid in the development and refinement of guidelines and management practices for pesticide applications on golf courses. This information is critical if intelligent, informed decisions are to be made by a variety of regulatory agencies and golf course developers and superintendents regarding golf course construction, management, and operation.

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The Potential Roles of Herbicide Resistant Crops in the United States

L. P. Gianessi[1] and C. A. Puffer[1]

Biotechnology has expanded the range of possibilities in the development of new crop varieties. Traditional plant breeding limited the range of characteristics that could be imparted to a new cultivar to traits conferred by the genetic material of the same species or a closely related species. Methods developed from biotechnology now allow genetic material from different species to be incorporated into the genes of a crop variety, conferring new characteristics to the plant. Currently, there are new varieties of crops under development that have been biologically engineered to resist or tolerate herbicides to which the crop has been susceptible. This development opens up new uses for herbicides where use had been prevented due to crop damage.

As the introduction of these crops into the marketplace draws closer, controversy is growing over the impact of herbicide-resistant crops on the future direction of agricultural weed control, and whether this new technology will promote or hinder practices in keeping with sustainable agriculture and decreased pesticide use. Private companies can be expected to invest in the development of herbicide-resistant plants for crops with significant acreage such as corn, soybean, cotton, and wheat. Although there are already many herbicides available for these crops, there are certain weed-control problems for which herbicide-resistant crops would offer solutions. For example, there are no herbicides available for broadleaf weeds that are not phytotoxic to cotton plants. The development of a bromoxynil-resistant cotton plant would allow for the substitution of a low rate per acre herbicide that would replace several older herbicides that are used at higher rates per acre with the constant threat of crop injury.

The development of herbicide-resistant plants for low-acreage vegetable crops is being supported in a few instances by private commodity groups and university research. There are no guarantees that commercial enterprises will register herbicides for low-acreage herbicide-resistant crops even if research proves successful, and even if the herbicide-resistant plants would offer significant benefits for weed control. In some cases, herbicide-resistant plants would represent an increase in herbicide use. For example, for some vegetable crops, hand labor is used for weed control. If herbicides replaced the hand labor, it would represent a significant decrease in costs but with the associated increase in herbicide use. In all cases, herbicide-resistant crops will have to compete with all other available weed control practices in terms of costs, safety, ease of application, and weed-control efficacy.

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Cutinases as Natural Adjuvants for Increasing the Uptake of Agrichemicals

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Developing more efficient delivery systems for pesticides would decrease the amount of chemicals applied to plants, and lessen the potential for contamination of water and agricultural products.

The primary barrier to the uptake of foliarly applied pesticides is the plant cuticle, composed of cutin (insoluble polymer composed mainly of hydroxy and epoxy hexa- and octadecanoic acids linked by ester bonds) and cuticular waxes. The addition of cutinases (cutin-degrading enzymes) to agrichemical formulations may allow increased uptake, and bacterial cutinases are more heat stable than fungal cutinases. To test the idea, that these enzymes could be useful for field applications, over 200 bacterial strains of filamentous and non-filamentous bacteria were screened for their ability to produce cutinases when grown in the presence of apple vs. Golden Delicious cutin. Extracellular cutinase activity was monitored using a novel HPLC technique (alleviating the need to use radiolabelled cutin) developed for the separation and quantification of released hydroxy fatty acids. Cutin monomer identity was confirmed by GC-MS analysis. Seven bacterial strains (three *Pseudomonas aeruginosa* and four *Streptomyces*) produced high levels of cutinase activity.

Partial purification of the cutinases was initiated using *P. aeruginosa* DAR41352. The supernatant fluids of 4 L of culture were treated with ammonium sulfate at 60 percent. The precipitated protein was then treated batchwise with DE 52 cellulose. The supernatant was dialyzed, applied onto a QAE-Sephadex column and eluted with a linear gradient of 0 - 1.0 M NaCl. Active fractions were collected and subjected to gel filtration on a Sephacryl S200 column. The estimated molecular weight by this technique was 120,000. By SDS-PAGE, the estimated molecule weight of the cutinase was 60,000, indicating that the enzyme is a dimer.

Several industrial lipases also were found to possess limited cutinase activity. A well-characterized fungal cutinase from *Nectria haematococca,* partially purified in our laboratory by ammonium sulfate precipitation at 50 percent, and an industrial lipase were used in plant uptake studies. Initial evaluations of cutinases on uptake of the broad-spectrum herbicide glyphosate showed that plants treated with enzymes absorbed as much as 600 percent more herbicide than did controls.

*Mention of brand or firm names does not constitute an endorsement by the USDA.

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Environmental Risk Reduction in the Cranberry Industry

T. J. Bicki[1]

Environmental risk reduction in the cranberry industry is a management initiative undertaken by Ocean Spray Cranberries, Inc. (OSC), targeted at the approximately 1000 cranberry growers in North America. OSC's corporate program is meant to reduce potential non-point sources of pollution from cranberry agriculture without significantly impeding successful economical production. Our efforts focus on grower education, supported by sound scientific research. Because cranberries are a minor agricultural crop, government support for cranberry research and educational efforts is somewhat limited. The goal of OSC's environmental management/policy is to reach as many cranberry growers as possible, both OSC cooperative members and independent cranberry growers, with environmentally sound, cost-effective production practices. Research efforts have focused on a number of innovative approaches, such as: parasitic nematodes for insect control; evaluation of insect disease and weed control efficacy with reduced pesticide rates; pesticide risk/benefit analysis; activated carbon treatment of surface water to reduce occurrence of pesticide residues; and wildlife habitat enhancement. Educational efforts have focused on a number of components: publication of an IPM newsletter and growers environmental notebook; bog-side, hands-on IPM workshops; on-site environmental assessments; and production of an IPM training video on scouting. This innovative program can serve as a model for agricultural commodity involvement in environmental stewardship. Specific successes, such as the first successful commercial use of nematodes on a commodity in the United States and experiences with other programs will be presented.

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Opportunities and Obstacles for Proper Application and Management of Pesticides

H. E. Ozkan[1]

As part of the ongoing pesticide educational programs in Ohio, a survey was conducted in 18 counties to learn more about current pesticide application and disposal practices. The survey also provided information related to applicators' attitudes toward reducing pesticide waste.

Survey results based on the 1380 responses received are summarized in this paper. Over two-thirds of the respondents calibrate their sprayers at least once a year. Approximately 10 percent said they never calibrate. Over 90 percent of the respondents always rinse empty pesticide containers; however, only 71 percent follow acceptable rinsing procedures. About 3 percent indicated they do not rinse containers at all. Burning was the number-one method of pesticide container disposal used by applicators. Although over two-thirds of the applicators feel well-informed about pesticide container disposal practices, the number of improper disposal methods identified by the respondents indicate that educational programs are needed to help applicators choose the most environmentally sound disposal practice. In general, the pesticide applicators expressed a positive attitude toward reducing pesticide waste.

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A Comparison of the Pesticides Used in Conventional and IPM-Grown Eggplant

G. C. Hamilton and J. Lashomb[1]

Each year, New Jersey is a major producer of vegetables in the United States. Of the 11 major vegetables grown, eggplant represents a constant 900 planted acres each year and yields approximately 140 cwt per acre. Based on this level of production, eggplant ranked third in total dollar value per acre ($2,431) in 1990. In light of eggplant's value as a crop in New Jersey, the use of pesticides is correspondingly high (ca. 6,381 pounds a.i. of product in 1988). This usage represents primarily insecticides and fungicides applied to control two principal pests, Verticullium wilt and the Colorado potato beetle (CPB). Each pest, when left untreated, can result in significant crop losses. Control of these pests is accomplished via field fumigation or crop rotation for Verticullium, and the use of a calendar spray schedule for CPB. Unfortunately, these types of control programs have resulted in resistance development in CPB to many of the materials developed or to the heavy use of field fumigation for Verticillium control. During the 1980s, an IPM program targeting the control of CPB in eggplant was developed and implemented. This program uses an egg parasite of CPB, and has resulted in significant reductions or changes in the number and type of sprays applied. One drawback to this program, however, has been the lack of a comparison between this program and conventional control practices. This study proposed to make this comparison during the 1993 growing season. To accomplish this, ten growers from each of the two regimes were used. Data collected from these farms included the total acreage planted, pests encountered, pesticides used to control these pests (timing, number of applications, method of application, rates, acreage treated, etc.), and total yield. Following the collection and analysis of these data, additional data was developed on economics involved with each program. The differences found between the two programs will be presented.

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A Review of Surface-Water Monitoring for Atrazine in the Chesapeake Bay Watershed (1976-1991)

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In January 1991, the U.S. Environmental Protection Agency (EPA) promulgated primary drinking water standards for 38 synthetic organic chemicals (SOCs) and inorganic chemicals. These final rules required maximum contaminant levels (MCLs) for a number of chemicals, including the herbicides alachlor, atrazine, and 2,4-D. The rules were issued pursuant to 1986 amendments to the Federal Safe Drinking Water Act (SDWA) and mandate that water utilities monitor finished water prior to its entering the distribution system and set compliance with each chemical's specific MCL based on an annual running average. Since atrazine historically has been, and currently is used on corn crops in the Chesapeake Bay drainage basin, there is interest in assessing its occurrence and levels in tributary bodies to the Bay.

This report provides an assessment of the historical surface water monitoring data for the herbicide atrazine in the Chesapeake Bay drainage basin. Atrazine levels from nine surface-water studies conducted from 1976 to 1991 are discussed in relation to the SDWA MCL and Health Advisory Levels (HALs) for this chemical. Monitoring has occurred primarily on large river systems (e.g., downstream areas of the Potomac, James, and Susquehanna) and, to a much lesser extent, in the smaller tributaries where the majority of public water supply intakes are located. Smaller tributaries were included only in a study of Maryland public water supplies; however, the largest population is served by utilities in the larger river systems.

Detectable levels of atrazine (>0.10 ppb) were reported in a high percentage of samples in practically all studies (72% average). However, concentrations in only three samples exceeded the SDWA atrazine MCL of 3.0 ppb out of over 600 samples analyzed between 1976 and 1991. The maximum atrazine concentration was 5.89 ppb. This is below the 7-year HAL for children and adults (50 and 200 ppb, respectively). Concentrations averaged over each annual period (time-weighted mean) rarely approach 1.0 ppb and are generally below 0.3 ppb, or 10 times lower than the MCL. Based on historical monitoring, annual atrazine concentrations in the future are not expected to exceed the MCL.

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Groundwater Transport of Pesticides to Surface Waters and Estuaries on the Eastern Shore of Virginia

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This research investigated the submarine groundwater discharge and transport of five pesticides from coastal-plain groundwater to the inland waterways of the Chesapeake Bay on Virginia's Eastern Shore. Groundwater, estuarine water, seepage water, upland soil, and offshore sediment samples were collected on nearly a monthly basis from April 1992 until February 1993 from four agricultural and one non-agricultural site. Approximately 30-40 samples were taken on each sampling date. Concentrations of atrazine, cyanazine, alachlor, metolachlor, and carbofuran were determined in the samples by two methods: 1) liquid-solid phase extraction followed by GC-ECD and/or GC/MS analysis; and 2) pesticide-specific immunoassay using RaPID Assays® developed by Ohmicron. Use of two techniques for determining pesticides allowed for a methods-comparison study and also provided lower detection limits as the immunoassay methods tend to have detection limits about a factor of 10 lower than that of traditional extraction/gas chromatographic methods. Determinations of nitrite, nitrate, ammonia, and dissolved inorganic phosphorus were performed on the water samples using calorimetric analyses.

Pesticides were identified most often in soil samples, occasionally in groundwater samples, infrequently in seepage water samples, and never in the off-shore sediment samples. Nearly half of the almost 30 upland soil samples were positive for pesticides. Alachlor and metolachlor were detected in soil samples at concentrations ranging from 10 to 400 μg/kg; atrazine, cyanazine, and carbofuran were not detected in these samples. None of the 26 off-shore sediment samples contained detectable levels of pesticides. Over 500 water samples were analyzed, and pesticides were detected in less than 10% of the samples at concentrations generally below 1 μg/L. Atrazine and alachlor were the two pesticides most frequently detected in aqueous samples; carbofuran was detected most infrequently.

Nutrient measurements performed on water samples indicated that fertilizer nutrients were moving from the groundwater to the surface water. Evidence for this was higher nutrient concentrations in seepage water samples compared to nutrient concentrations in estuarine samples taken from Chesapeake Bay water. However, the

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same trend was not observed for the pesticides, indicating that adsorption to soils or degradation/biotransformation was occurring, and that this limited groundwater transport.

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Temporal and Geographic Distribution of Herbicides in Precipitation in the Midwest and Northeast United States, 1990-91

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Triazine and chloroacetanalide herbicides were detected in precipitation throughout the Midwest and Northeast United States during late spring and summer of 1990 and 1991. Weekly accumulations of rainfall and snow from 81 sites operated by the National Atmospheric Deposition Program/National Trends Network were analyzed to determine the occurrence, distribution, and deposition rates of herbicides. Nearly 6,000 precipitation samples collected during March 1990 through September 1991 were screened for triazine and chloroacetanalide herbicides using an enzyme-linked immunosorbent assay (ELISA) analysis. Samples with detectable concentrations of herbicides (0.1 - 0.2 μg/l) and with a minimum of 60 ml of water also were analyzed by gas chromatography/mass spectrometry (GC/MS) for 13 herbicides and metabolites. GC/MS - ELISA regression models were used to estimate atrazine and alachlor concentrations in samples not analyzed by GC/MS. Weekly deposition rates were determined from herbicide concentrations and measured amounts of precipitation.

Herbicides were detected in at least one sample from all 23 states in the study area, including samples from remote areas such as Maine and Isle Royale in northern Lake Superior. Detections were most frequent and concentrations were highest during May and June, following herbicide application to cropland. For several weeks during this period in both 1990 and 1991, herbicides were detected at nearly three-fourths of the sampling sites. During the remainder of the year, herbicides generally were detected at less than 20 percent of the sites. Atrazine was the most frequently detected herbicide followed, in order, by alachlor, desethylatrazine (an atrazine metabolite), and metolachlor. Herbicide concentrations and frequency of detection were much higher in the Midwest, where large quantities of herbicides are used in the production of corn and soybeans than elsewhere. Precipitation-weighted concentrations of atrazine and alachlor of 0.2 - 0.4 μg/L were typical at sites in this area during May and June. Weighted concentrations as large as 0.6 - 1.0 μg/L occurred at a few sites. Atrazine and alachlor concentrations of 1 - 3 μg/l were measured in a few individual samples representing small amounts of precipitation. Concentrations of alachlor often were slightly higher than atrazine, but persisted for a shorter period of time. The temporal distribution of herbicides in precipitation in the Midwest is similar to the pattern in Midwest streams. At a few sites, concentrations of herbicides in rainfall during May and June were similar to those recently reported in large rivers such as the Ohio and upper Mississippi.

Wet deposition of herbicides was highest in an area extending from eastern Nebraska across northern Iowa, southern Minnesota, and the northern half of Illinois and Indiana. Deposition rates for both atrazine and alachlor were estimated to be more than 100 μg per square meter per year for much of this area. However, the total amounts of atrazine and alachlor deposited each year in precipitation represents less than 1 percent of the amounts applied to crops. Additional unmeasured amounts of herbicides may be deposited as dryfall during periods of no precipitation. Deposition rates in much of the Northeast where herbicide use is low were less than 10 μg per square meter per year. The geographic pattern of herbicide deposition provides evidence for long-range atmospheric transport.

Results from this study indicate that the use, concentrations, and annual deposition of atrazine and alachlor in precipitation are similar in the Midwest. In contrast, a recent study of herbicides in surface water indicates that, in the Mississippi River basin the concentrations and annual mass transport of alachlor in streamflow are typically only 10 - 30 percent of that for atrazine. These results indicate that considerably more alachlor is transported into the atmosphere and redeposited in wet deposition in the Mississippi River basin than is transported out of the Mississippi River basin in streamflow, whereas the opposite is true for atrazine.

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Relations Between Agricultural Chemical Use and Annual Transport of Agricultural Chemicals in Midwestern Rivers, 1991-92

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About 80 percent of the corn and soybeans produced in the United States are grown in the Midwest, which comprises much of the Mississippi River basin. Agricultural chemicals (pesticides and nutrients) are used extensively in this region to increase production of crops. It is estimated that about 110,000 metric tons of pesticides and 6.3 million metric tons of nitrogen fertilizer were applied to cropland in the Mississippi River basin in 1991.

Relationships between estimates of the mass of agricultural chemicals applied (kilograms of active ingredient applied per county) and the mass of chemicals transported in rivers are investigated for the Mississippi River and its major tributaries using a geographic information system (GIS). Estimates of herbicide and nitrogen use by county are developed into a series of GIS thematic data layers and used to estimate the mass of agricultural chemicals applied within specific drainage basins. Data from water samples collected about once per week and daily mean streamflow data are used to estimate agricultural chemical masses transported out of specific drainage basins. These two data sets are used to develop linear regression models that estimate annual agricultural chemical transport as a percentage of estimated annual agricultural chemical use for rivers in the midwestern United States.

The relationship between use and load are investigated for 13 agricultural chemicals: atrazine, alachlor, butylate, cyanazine, EPTC, metolachlor, metribuzin, propazine, propachlor, pendamethalin, simazine, trifluralin, and nitrate-N. Preliminary results for the year studied (April 1991 through March 1992) indicate significant correlations between annual applications and annual transport for atrazine, metolachlor, cyanazine, alachlor, and nitrate-N.

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A Review of Historical Surface-Water Monitoring for Atrazine in the Mississippi, Missouri, and Ohio Rivers, 1975-1991

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The U.S. Environmental Protection Agency (EPA) promulgated primary drinking water standards for 38 synthetic organic chemicals (SOCs) and inorganic chemicals in January 1991. The final rules established maximum contaminant levels (MCLs) for these chemicals, including the herbicides alachlor, atrazine, and 2,4-D. The rules were issued pursuant to 1986 amendments to the Federal Safe Drinking Water Act (SDWA) and mandate that water utilities monitor finished water prior to its entering the distribution system. The rules also set compliance for each chemical's specific MCL based on an annual running average. Atrazine historically has been, and currently is, used on corn crops. The major corn production states are located predominantly in the Mississippi River drainage basin, including the two major tributary rivers, the Missouri and Ohio.

This report provides a review of the historical surface water monitoring data for atrazine in the Mississippi, Missouri, and Ohio Rivers. Annual monitoring data collected between 1975 and 1991 are discussed in relation to the SDWA MCL and Health Advisory Levels (HALs) for atrazine. Monitoring data from 13 Mississippi River locations, as well as 6 Missouri River and 3 Ohio River sites are provided. The Ohio and Missouri Rivers have annual data available for 8 years of the 17-year period (1975-91), while monitoring data are available for each of the 17 years at various sites on the Mississippi River.

Atrazine presence was detected in 94 percent of the samples of the sites. The maximum atrazine concentration was 17.5 ppb. The spring mean (May-July) atrazine concentration ranged from 0.45 - 5.0 ppb. Individual and spring mean atrazine values were well below the EPA HALs for 1- and 10-day and 7-year exposure periods.

Annual mean atrazine concentrations ranged from 0.38-3.77 ppb. Annual mean atrazine levels were less than the atrazine MCL of 3.0 ppb for 98.5 percent of the sites. Annual means were lowest on the Ohio River (less than 1.0 ppb). No annual mean exceeded 2.02 ppb on the 13 Mississippi River sites. The Missouri River had one site exceeding the MCL at 3.77 ppb.

When possible, multi-year means were obtained at specific sites. These reflected the yearly variability. The lowest five-year mean (0.56 ppb) was observed on the Ohio River. A six-year mean of 1.01 ppb occurred on the Lower Missouri River. The Mississippi River had four sites with multi-year means: Greenville, MS (1.17 ppb), Vicksburg, MS (0.70 ppb), St. Gabriel, LA (1.21 ppb), and Venice, LA (1.10 ppb).

These data indicated the annual atrazine mean concentrations in the Mississippi, Missouri, and Ohio Rivers have been reliably and consistently below the MCL over the 17-year period (1975-91). Community water supplies for the years monitored would have been in compliance if the SDWA standard for atrazine had been in place throughout this period. It is expected future monitoring under the SDWA will continue to confirm this observation.

A current population of 10.4 million individuals are provided with drinking water from these rivers. The atrazine concentrations noted to date are not expected to pose any acute or chronic health risks to these populations.

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Survey of Acaricide Use in Georgia's Managed Honey Bee Colonies

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In the 1980s, two new parasitic mites of honey bees were introduced into the United States. By 1990, two acaricides were registered by the U.S. Environmental Protection Agency for controlling honey bee mites. Because beekeepers are relatively new pesticide users, I surveyed Georgia's beekeepers to learn their miticide use habits, the alternative controls they use, and their estimates of yield changes from alternative controls.

In 1990, an estimated 32,007 Georgia bee hives were treated with menthol to control tracheal mites, and 20,771 hives were treated with Apistan® to control *Varroa* mites. In 1990, Georgia beekeepers spent at least $122,343 on miticides. If Georgia beekeepers had to rely solely on nonchemical controls against mites, they predict state-wide losses of hives and hive products of at least $5,748,091. Survey respondents represented 51,608 bee hives, which were 46.5 percent of the hives in Georgia at the end of 1990.

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Scotchgard® Effects on Pesticide Removal from Farmers' Work Clothing During Laundering

S. L. Prior[1], D. A. M. Sterling[2], and G. H. Frazer[2]

Dermal exposure to pesticides is the major route of pesticide intoxication for farmers. While protective clothing is available, farmers prefer to wear 100% cotton denim work clothing during spraying for reasons of comfort and launderability. Use of a consumer-applied soil repellent, Scotchgard®, as a possible method of enhancing pesticide removal during laundering was investigated. Untreated fabric swatches and those treated with Scotchgard® were contaminated with either alachlor or atrazine, and later laundered in a manner simulating home washing. Remaining pesticide residues were extracted from the swatches and measured. Statistical analysis revealed no significant evidence that Scotchgard® enhanced removal of atrazine residuals, but confirmed a highly significant interactive effect between Scotchgard® and alachlor. Based on the results, the application of Scotchgard® may not be a viable method for enhancing pesticide removal from cotton work clothing during laundering, and may, in some instances, cause greater retention on the clothing than no treatment.

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Development of Oxidative Stress and Induction of Oxidative Stress-Related Genes and Proteins in Lung, Heart, Liver, Kidney, Intestine, and Brain following Intratracheal Administration of Polyhalogenated Cyclic Hydrocarbons

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Recent studies indicate that toxic effects of many polyhalogenated cyclic hydrocarbons (PCH) are at least in part due to the development of oxidative stress. This study was designed to examine the mechanism of the oxidative stress induction due to PCH toxicity. Sprague Dawley rats of 250 gm body weight were given chlorpyrifox, fenthione, and lindane orally, and twenty-four hours after the exposure of the insecticides. Rats were injected intravenously with one mM salicylate to trap any hydroxyl radical and then sacrificed to obtain the vital organs (i.e, lung, heart, liver, kidney, intestine, and brain). In another set of experiments, vital organs were removed without injecting salicylate. Hydroxyl radical was assayed as hydroxylated benzoic acids by HPLC using an electrochemical detection technique. Lipid peroxidation also was estimated with HPLC by detecting malonaldehyde formation. Oxidative stress inducible proteins were detected by 2-D polyacrylamide gel electrophoresis. Expression of stress inducible genes was monitored by Northern Analysis using specific cDNA probes for heat shock proteins, HSP 27, HSP 70, and HSP 89, as well as probes for oncogenes, c-fos, and c-myc.

The results of our study indicated the presence of hydroxyl radical in all the organs tested. The development of oxidative stress also was confirmed by the presence of significant amounts of malonaldehyde in the test organs. HSP 70 was induced in the liver, whereas HSP 27 was induced in the lung. In the brain, both HSP 70 and HSP 27 were induced. c-Fos oncogene was expressed in all the organs tested; c-myc oncogene was expressed only in the lung. The results of this study indicate that different organs respond differently to the stress developed from the insecticides suggesting differential gene expression in the organs due to the oxidative stress developed by these PCH compounds.

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Human Health Risk Assessment from Chemically Contaminated Fish and Shellfish: A National and State Perspective

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Over the past several years, concerns have been raised over the presence of toxic substances (heavy metals, pesticides, and other organic pollutants such as PCBs) in the aquatic environment and the potential health risks from consumption of chemically contaminated fish and shellfish. Federal and state governments share responsibilities for protecting human health by regulating and controlling chemically contaminated food. The primary mechanism used by the states to alert consumers (recreational or subsistence fisherman and other public, especially young children and women of child-bearing age) about health risks associated from consumption of chemically contaminated fish or shellfish is the fish consumption advisory. A majority of states, including Indiana, use FDA action levels for developing the fish consumption advisories, but some states issue health advisories derived from the U.S. Environmental Protection Agency's (EPA) risk assessment methodology using either cancer potency factor (CPF) or reference dose (RFD). Differences and inconsistencies also exist in selecting not only portions of fish used (e.g., whole fish, fillet with skin on or skin off, whole shellfish, or eatable portion of shellfish), but also in the kinds of priority pollutants that are analyzed and used in the development of fish consumption advisories. Comparison of health risks derived using FDA action levels and those derived using the EPA's risk-based analysis method have been made and presented here in predicting the human health risks associated with consumption of chemically contaminated fish and shellfish.

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Methodology for an Integrated Evaluation of All Scientific Evidence Relating to the Safety of the Herbicide 2,4-D

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Some epidemiological studies have suggested that exposure to the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) might increase the risk of soft-tissue sarcoma, Hodgkin's disease or non-Hodgkin's lymphoma. Since 2,4-D is an inexpensive herbicide used widely by farmers, foresters, and gardeners, correctly assessing its risks is a serious public health matter. The epidemiological data do not agree with information from other scientific disciplines, however. Toxicological studies demonstrate no known biological basis for 2,4-D to cause such malignancies. Metabolic data show that 2,4-D is quickly excreted, primarily unchanged. Exposure information indicates that little exposure to 2,4-D is sustained not only by the general public, but also by the populations studied epidemiologically.

In an attempt to reconcile the apparently contradictory epidemiological data with the other scientific disciplines, we have reviewed the literature on 2,4-D in a new way, emphasizing integration of the multidisciplinary data throughout the evaluation. This review on 2,4-D is unique in that the approach taken was to integrate data from worker exposure studies, whole-animal toxicology, metabolic tests, and other relevant laboratory studies with the epidemiological findings to assess the extent to which there is scientific support for the hypothesis that 2,4-D exposure is associated with an increased risk of human cancer. Our review focused on cancer, but we also have considered the weight of the scientific evidence on 2,4-D exposure and other chronic conditions, such as neurological toxicity, immunotoxicity, and reproductive toxicity.

The available data indicate that the potential public health impact of 2,4-D, including the risk of human cancer, was negligible in the past and would be expected to be even smaller in the present and future under revised label directions limiting exposure. Prompted by the epidemiological data, the U.S. Environmental Protection Agency decided to assemble an expert panel to review the safety of 2,4-D, but they chose to make the panel multidisciplinary. Our published review (Munro et al. (1992) *Journal of the American College of Toxicology* 11(5): 559-664), along with the other relevant literature, was provided to the panel members. A report by the panel is forthcoming.

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Remediation of Alachlor-Impacted Soil Using the White Rot Fungus *P. chrysosporium* in a Solar Heated Bioreactor

M. J. McFarland[1], E. Baiden[1], and D. Wray[1]

Composting of soils impacted by hazardous organic compounds using the white rot fungus *Phanerochaete chrysosporium,* is an innovative low-cost biotreatment process that is being evaluated for the remediation of alachlor (2, chloro-N-(2,6-diethylphenyl)-N(methoxy methyl) acetamide) contaminated soils. Fungal inoculation to laboratory scale soil compost reactors was observed to increase the pesticide removal rate from 2.2 to 4.8 mg alachlor/Kg soil-day during the 42-day incubation period. The first-order removal rate constants varied from 0.022 day^{-1} (for soil-only system) to 0.05 day^{-1} (for fungal-inoculated system). Pretreatment of the compost organic amendments was observed to have a negligible effect on alachlor removal rates.

Although removal was enhanced with fungal inoculation, the fate of the transformation products and, hence, the effect of treatment on soil toxicity is unknown. Transformation processes such as volatilization, humification (i.e., irreversible adsorption) and mineralization currently are being quantified using a chemical mass balance with radiolabeled alachlor in soil.

Reactor scale-up efforts have focused on development of a pilot-scale solar-heated chamber that can operate year round with minimal operational management. Evaluation of the solar-heated bioreactor demonstrated that temperatures as high as 45°C could be maintained within the system during the fall months when ambient air temperature was below 25°C. During the same time period, the maximum moisture loss was observed to be 2.6 mm of water per day. The fact that this evaporative loss was less than 50 percent of the moisture loss observed from a free water surface suggested that desiccation of soil during the treatment process may not be of major concern. Present pilot-scale testing efforts are focusing on: 1) monitoring alachlor removal within the solar-heated chamber during subzero ambient temperatures, 2) estimating the depth of penetration of the white rot fungus within the soil profile, and 3) establishing management criteria for the solar-heated chamber to maximize solar energy receipt at the soil surface as well as optimum air circulation for efficient water-vapor transport.

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Biodegradation of Alachlor and Atrazine in Soil as a Function of Concentration

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Biodegradation of alachlor and atrazine was studied in a clay loam and a sandy loam soil under laboratory conditions following treatment with high concentrations to simulate levels commonly found with accidental spills or misuse. Biodegradation of alachlor in soil following treatment with concentrations ranging from 10 to 10,000 mg kg^{-1} ^{14}C-alachlor showed similar biodegradation patterns in both soils, and persistence was prolonged as concentration increased. Soil microbial activity as indicated by soil respiration decreased at high concentrations. At the 10,000 mg kg^{-1} alachlor level, after five months, only 0.3 percent was mineralized, 5 percent was nonextractible, and 90 percent of the originally applied herbicide was recovered as parent compound. High concentrations of alachlor may have inhibited soil microorganisms, thereby increasing persistence. Atrazine degradation was monitored at levels ranging from 5 to 5,000 mg kg^{-1} ^{14}C-atrazine. In a clay loam soil, extensive degradation occurred at all concentrations. Following an initial lag phase at the 5,000 mg kg^{-1} concentration, 51 percent of the atrazine was mineralized to CO_2 and less than 10 percent remained as atrazine after 20 weeks. Microbial activity as indicated by soil respiration was stimulated at high atrazine concentrations. In contrast, in a sandy loam soil, atrazine degradation decreased with increasing concentration, and no stimulation of microbial activity at high concentrations occurred. It appears that soil microorganisms capable of degrading atrazine at high levels can be induced or enriched under certain conditions and have potential as biological remediation methods for decontamination of soils. Results from field leaching and degradation studies also will be discussed.

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Containment Spray Systems for Apples

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This project had three primary objectives: (1) Develop spray delivery systems that minimize drift and collect excess spray; (2) Evaluate the adequacy of these systems to provide the crop protection required to produce high-valued fruit; and (3) Operate the spray system with less than 23 kW of tractor power based on equipment needs of intensive orchard production.

A spray containment system was developed for dwarf apple production using an over-the-row chassis (OTRC) and two spray containment hoods. The OTRC was designed and constructed for use on plantings with 3.66-m row spacing. The wheels are mounted on walking beams with a distance of 3.1 m from the walking beam pivot to the drawbar ball hitch. The chassis tongue supports the 378-L tank and spray pump. The hoods are supported by two electric winches that control height and across-the-row leveling. Across-the-row leveling is controlled from the tractor seat, whereas height adjustment is made from the chassis.

Spray hoods were designed and constructed for the European three-wire trellis and T-trellis plantings. The spray hoods are lined with embossed aluminum, corrugated roofing panels. Spray solution is delivered from the tank to the top center of the hood and applied to both sides of the tree by hollow-cone nozzles attached to square steel tubing. Horizontal collection pans extend underneath each hood, and excess spray is pumped back to the tank.

Containment spray systems were evaluated during 1991 and 1992 at the Kearneysville Experiment Farm and compared to a FMC Economist airblast sprayer. Spray deposit was quantified on the top and bottom surface of leaves in the periphery and center regions of five tree replicates/test at a height of 0.6 to 1.2 m. For each test, the same set of five trees was sprayed from both sides with FD&C blue no. 1 (containment spray systems) and FD&C yellow no. 6 (FMC sprayer) dye.

For the three-wire trellis, the containment spray system delivered dye deposits equal to and greater than that of the airblast sprayer on the top surface of leaves. However, the containment spray system delivered less dye deposit to the bottom of the leaves. On the T-trellis, the quantity of dye deposit was similar for both spray systems, except on the bottom surface of leaves in the tree periphery, where airblast sprayer deposit was excessive. The containment spray systems had from >3-fold to 15-fold less spray drift than the airblast sprayer in adjacent row trees.

Future studies will examine any detrimental impacts on control of insects and diseases from the less-uniform deposit of the spray containment system in three-wire trellis planting. If control is determined to be unsatisfactory, future modifications will be necessary to improve deposit distribution on the containment spray system. In addition, monetary costs and benefits will be evaluated for containment versus airblast spray systems to determine apple producers' profit incentive for adoption of containment spray systems.

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Ropes and Bands for Pest Control

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This report describes several methods of accomplishment in pest control, all based on a general idea which uses chemically treated ropes or bands. These ropes or bands are covered with glue to block the movement of crawling or climbing animals, such as snails, on their way to plants or stored foods. These chemically treated ropes and bands provide protection to plants, fodder, and stored foods for a duration of six months. In terms of quantity and cost, the preparation is 80 - 90 percent more cost-effective than the previous methods because its application is specific and serves as a barrier that the animal cannot overrun.

After the natural deactivation of the active chemical layer or upon discontinuance of use, the chemically treated ropes or bands are placed in plastic bags and recycled; thus, care of the environment is ensured.

The method offers several techniques for protection of plants and stored food from destructive animals. The technique integrates several chemical methods leading to new technology in the phytopathology practice that is more cost-effective than any other approach to date.

In future applications, it will be necessary to manufacture bands coated in advance on one side with a thin layer of poisonous granules. These bands can be made either in rolls or as straight bands in different lengths and packaged in layers like boards, or one band over another, with paper providing insulation between them. For this purpose, we have two different machines to manufacture such bands. A third presentation would be to sprinkle the band with a chemical preparation when gluing it. For this purpose, we have a container with a dispenser that spreads the chemicals evenly over the upper surface of the band.

Without any doubt, the three methods will find many applications in pest control. Ropes coated with poison will be developed and their manufacturing will be automated easily. The proposed methods ensure 100 percent more clean water and environment.

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Pesticide Litigation

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Historically, pesticide litigation has involved allegations of damages to land or crops of neighbors by farmer sprayers. Increasingly, pesticide litigation has involved allegations of personal injury. This paper will focus on both aspects of pesticide litigation including: injury to land, injury to persons, legal theories of liability, defenses, and proving causation of injury. Trends will be reviewed where possible.

Theories for recovery from pesticide damages include strict product liability in tort, negligence, negligence per se, strict liability for ultra-hazardous activities, nuisance, trespass, and warranty. Defenses will include the sophisticated-user defense, the bulk seller defense, the state-of-the-art defense, statute of limitations, preemption doctrine, contributory negligence, and assumption of risks.

Causation is often the most difficult and interesting aspect of a pesticide injury case. Recent court cases reviewing issues such as qualifications of experts, use of facts and data, and probative value of evidence will be presented.

The material will focus on national trends, issues, and concerns. As appropriate, a section will be developed under each topic on how Virginia law is the same or different from the national trend.

The issue is timely and of interest to the academic, chemical, environmental, and user communities. Damages are mere recompense for wrong doing, but the threat of liability also can change and direct user activity by being a deterrent to environmentally harmful conduct and by reducing the profitability of unauthorized use of or improperly used pesticides.

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Importance of Pesticide Science in University IPM Curricula

J. All[1]

Pesticide science has become a secondary priority in the curricula of many state universities, despite the fact that public concern probably has never been greater for safe and effective use of chemicals for pest control. Undergraduate and graduate training have diminished in subject areas concerned with the chemistry and physical properties of pesticides, toxicology to pests and nontarget organisms, resistance to pesticides, application technology, and the safety, disposal, and environmental fate of pest control chemicals. Courses concerned with the concept of integrated pest management (IPM), which emphasize the use of a combination of chemical and nonchemical pest control techniques to manage insects, often do not provide sufficient detail in any single pest control discipline to provide students with sufficient training to make informed decisions in professional situations.

IPM should be a capstone course built on a foundation of training in specific disciplines (such as pesticide science, biological control, host resistance, etc.) concerned with pest control. A practical pesticide science course for IPM curricula should cover major chemical groups, toxicological characteristics, and safe, effective methods for use. Students should obtain hands-on experience with pesticides in class laboratories concerned with efficacy, application technology, and safety methods. Pesticide science education could be encouraged at state universities by increasing lobbying efforts by professional organizations concerned with pesticide science, by increasing funding opportunities for pesticide research and education, and by establishing a pesticide science accreditation or certification program.

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Vegetation Management with Environmental Stewardship

R. A. Johnstone[1]

Vegetation management of Delmarva Power's electric transmission and distribution rights-of-way was converted from brushhog mowing to herbicide management during the 1980s. This change was achieved in one of the most environmentally sensitive areas of the United States, and under the watchful eye of Washington's politicians and regulators.

The various techniques used for herbicide treatment are demonstrated and compared with those used for mechanical and manual cutting of vegetation. Superior benefits of herbicide management compared to mowing, for reasons of safety, aesthetics, wildlife management, environmental protection, and economics, are discussed. The proper use of herbicides in managing wetlands and endangered species is reviewed.

This paper endorses a proactive public relations policy to educate the general public and policy makers as to the positive aspects of judicious herbicide use. It also emphasizes the importance of communication and cooperation with environmental organizations, regulators, and politicians.

This philosophy has resulted in Delmarva Power becoming a partner with organizations such as The Nature Conservancy, ornithological societies, garden clubs, Greenway commissions, state Heritage Programs, and wildlife managers.

It concludes by advising managers in all aspects of vegetation management to learn the needs of other interested parties, adjust techniques to accommodate where possible, and promote wise environmental stewardship through proper herbicide use.

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BayScapes Project

B. W. Mills[1]

The BayScapes project is a conservation education initiative under development by the Alliance for the Chesapeake Bay (ACB) and the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office. The BayScapes program advocates environmentally-sound landscape management for Bay region homeowners and residents, and is designed to involve these constituents in the regional restoration effort for the Bay. Homeowners and residents throughout the Bay region make thousands of decisions involving the significant use of fertilizers and pesticides, and represent an opportunity for behavioral change that could result in significant impacts in favor of the Bay. BayScapes will provide educational materials to help homeowners make alternative decisions about landscaping, chemical use, and other issues related to management of the home landscape.

The Alliance initiated the BayScapes project in 1992 by holding two pilot interactive workshops in Washington, D.C. and Richmond, Virginia. These workshops provided an opportunity for program planners to generate important feedback from urban target audiences, and to gauge participants' reactions to proposed BayScapes messages and themes. During the first year, ACB developed a draft program brochure, draft fact sheets, and a draft slide presentation. These products currently are being circulated for review, refinement, and editing, and for the purpose of incorporating the feedback from the urban workshops.

In 1993, the Alliance proposes to hold BayScapes workshops and activities in Maryland and Pennsylvania, as well as follow-up activities in Virginia. Seven BayScapes fact sheets will be written for printing and distribution in the Bay region: three developed during 1992, and four scheduled for 1993. A professional quality BayScapes slide presentation will be completed, as well as a Presenters' Guide of annotated slide scripts for use by message-sharers for widespread dissemination to diverse audiences. The result of this effort in 1993 will be that the BayScapes program will move from its current development phase to implementation in the field. The alliance anticipates that the fully developed BayScapes project will provide essential training materials and methods for ready dissemination throughout the Bay region.

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The Problem of Pesticides

R. Williams[1]

Wes Jackson (1980) restated problems *in* agriculture as "the problem of agriculture." He said agriculture itself is the ecological problem, not its component technologies, per se. Generally, investigators have reduced problems to fragments to handle them with scientific methods. Systems approaches have increased recently. These uses have often deemphasized significance of emergent properties in the systems modeled.

Pesticides are a problem in agriculture. With Jackson's conception, research to solve pesticide problems becomes problematic, because such research minimizes the importance of emergent properties of ecosystems and cultures. Such second-order problems of analysis are problems of assumption and inference, arising at philosophic levels of thought, as well as in ecological, technological frames. To redress this epistemological tangle, I discuss all levels of consideration in the problem of pesticides.

Philosophically, pesticide questions stem from scientific logic defined by Bacon and from the division of mind and nature of Descartes. Scientific proof does not negate alternative, additive, or synergistic factors. The mind-nature dichotomy dismisses mind as agent in natural phenomena. Epistemological and ethical aspects of pesticide use involve questions of values, rights, privileges, and responsibilities in ecosystem exploitation. These imply need to explore secular, religious, and spiritual motivations in pest management and in agriculture. At the root of these are basic concerns — *how* we know and how we *frame* what we know.

Ecological considerations in the pesticide problem range from individual/population scales to ecosystem/biosphere levels. Across all positions, we must remember "the map is not the territory"; our models are not the real world. What we *think* we do and what we *do* are different things. In ecosystems, actions influence loop-style processes, and activities of minds, through human actions, affect those loops in counter-intuitive fashions. Humans are keystone in managed ecosystems; removals of people result in degradation (arrested succession). This places burdens of self-judgement, questioning the validity of claims of objectivity. Ecosystem management through pesticide use suggests we must better incorporate principles of ecology.

The pesticide problem necessarily raises technological inquiries. Epistemologically and practically, technique and technology are distinctive, yet interactive. Assumptions allowing use of "improved" and "advanced" in describing new technologies are questionable, economically and morally. Technology is, finally, metaphor — what determines meaning of mind-environment interaction. Use of pesticide technology highlights similarities and differences of minds and ecosystems, their structure and change. These arguments affect how we handle the problem of pesticides, in terms of benefits and risks. What most limits their value is unintended effects, those unrecognized, unexpected, or discounted in reasoning (economically, externalities). All of the newer approaches to pest control, especially recombinant-DNA methods, have distinctive, but no less significant, sets of limitations.

Final considerations link the problem of pesticides and issues of sustainability. Sustainability is a resolution of economic and ecological realities. The preeminence of ecological determinants cannot be ignored. Sustainability is primarily conceptual. The meaning and symbolism arising with pesticide use are what become most significant. The metaphor implied by that use is most basic in uncovering the value of those materials, environmentally and culturally.

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Frequency of Chromosomal Aberrations of Ascorbic Acid on Dimethoate in Human Lymphocyte Cultures

D. Geetanjali[1] and P. P. Reddy[1]

Dimethoate is an organophosphorus pesticide extensively used in India to control pests in agriculture and known to cause mutagenic effects in various test systems. Ascorbic acid (vitamin C) is a water-soluble vitamin and found to be an anticarcinogenic/antimutagenic agent in lower and higher systems. The mutagenic potential of dimethoate is evaluated in the presence of ascorbic acid in human lymphocyte cultures.

Groups of cultures were treated with 1-percent dimethylsulfoxide (solvent control) or 0.25, 0.50, and 1.0 μg/ml of ascorbic acid with or without concurrent administration of 0.15 ug/ml of dimethoate. After 72 hours, the cultures were terminated and slides were prepared as described by Moorehead et al. (1960).

A significant increase in the incidence of chromosomal aberrations in lymphocytes treated with dimethoate was observed when compared to the control group. However, the frequency of chromosomal aberrations was reduced in cells treated with dimethoate in combination with ascorbic acid and indicates the protective role of ascorbic acid.

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Regulating Pesticide Use in Developing Countries: Problems and Suggestions

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Even in developing countries like India, the existing and potential hazards of improper use of pesticides are acknowledged, and the need to regulate indiscriminate pesticide application is accepted and advocated. However, the efforts made by government agencies and users in this direction are inadequate and do not counter the gravity of the situation.

The damage takes root when the farmer in a developing country ignores the initial attack of a pest population, thereby allowing the infestation to become severe. Soon, panic sets in and an excessive dose of the pesticide is applied as a quick-fix solution. Once the pest population is reduced considerably, the vigil is relaxed, which results in the pest population rebounding to its previous dimensions in a short period of time. Once again, excessive pesticide is applied and the cycle continues.

Instead of reacting massively and belatedly to a large pest population, steps must be taken to accelerate mortality by minimum use of pesticide to lower the population to a safe asymptotic level. Next, suppress natality by other control measures and practices to maintain the safe asymptotic level.

To achieve this objective, toxicological research in developing countries must take on responsibilities in addition to its traditional job of determining pesticide doses. A coupled approach consisting of short-term and long-term control measures for different groups of pests should be investigated. Under short-term measures, a specific, effective dose of a pesticide, sufficient to bring down the population to a desired safer level, should be determined. Under long-term measures, other control measures including best management practices, which suppress natality and curb population growth, should be developed. At the onset of infestation, the short-term control measure may be applied and later long-term measures may be implemented. to maintain the safe level. If population increases, short-term control measures followed by long-term control measures may be repeated. Such coupled control measures should be developed for different groups of pests and passed on to the farmers in developing countries.

Such an approach will go a long way in satisfying illiterate and ignorant farmers and other users of pesticides. The pest infestation will be controlled in a short period of time and, thereafter, safer levels of the pest population will be maintained. At the same time, the use of pesticides will be regulated, leading to reduced hazards.

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