

Conference on

# Water Quality, Agriculture and Public Health

Center for Health Effects of  
Environmental Contamination

Proceedings

*Conference held on  
May 14 & 15, 1991,  
in the Iowa Memorial Union  
on the campus of  
The University of Iowa,  
Iowa City, Iowa*

THE UNIVERSITY OF IOWA

# Contents

<b>Preface</b> .....	Page 2
<b>I. Keynote Address: Day 1</b>	
Risk Assessment of Pesticides and Water Contaminants: Regulatory and Public Health Implications .....	Page 3
<i>Anna M. Fan</i>	
<b>II. Exposure Assessment Research</b>	
Twenty-Five Years of Public-Health Based Water Quality Studies in Iowa .....	Page 5
<i>Keith Cherryholmes</i>	
Management System Evaluation Areas: Iowa's Contribution .....	Page 7
<i>Michael Burkart</i>	
Occurrence and Flux of Inert Pesticide Ingredients in Shallow Ground Water .....	Page 7
<i>Michael Liszewski, Keith Cherryholmes</i>	
Biotransformation of Atrazine and Alachlor in Ground Water .....	Page 9
<i>Gene Parkin, Nancy Lynch, Gregory Wilber</i>	
Agricultural Impacts on Ground Water Quality: The Big Spring Basin Study .....	Page 10
<i>Robert Libra, George Hallberg</i>	
<b>III. Health Outcomes Research</b>	
Exposure Assessment Methods for Pesticides .....	Page 11
<i>Burton Kross, William Pependorf, Linda Olgilvie, Leon Burmeister</i>	
Association of Intrauterine Growth Retardation with Source and Constituents of Finished Drinking Water Supplies in Southern Iowa Communities .....	Page 12
<i>Peter Isacson, Ronald Munger, Michael Kramer, William Hausler, Jr., Keith Cherryholmes, Paul VanDorpe, Hua Song, Diane Krishnamurti</i>	
Methods for the Study of Environmental Exposures and the Risk of Birth Defects in Iowa .....	Page 13
<i>Charles Lynch, Ronald Munger, James Hanson, Peter Isacson</i>	
<b>IV. Keynote Address: Day 2</b>	
The President's Water Quality Initiative - Protecting America's Water Resources .....	Page 14
<i>Harry Mussman</i>	
<b>V. Agricultural Chemical Industry Presentations</b>	
Agrichemical Formulations: Inert Ingredients .....	Page 16
<i>Earl Spurrier</i>	
Using Quantitative Risk Assessment to set a Drinking Water Standard for Alachlor .....	Page 19
<i>Dennis Ward</i>	
Atrazine Water Quality Issues: An Industry Perspective .....	Page 23
<i>K. Balu</i>	
<b>VI. Speaker Biographies</b> .....	Page 26
<b>VII. Poster Abstracts</b> .....	Page 28

## Preface

On May 14 & 15, 1991, the Center for Health Effects of Environmental Contamination (CHEEC) held the "Conference on Water Quality, Agriculture and Public Health" at the University of Iowa in Iowa City. This publication contains selected presentations, synopses of other presentations, and poster abstracts from the conference.

Human exposures to drinking water contaminants from point and nonpoint agricultural sources have been a focus of CHEEC research and service activities since the Center's inception in July, 1987. This conference, co-sponsored by the Agency for Toxic Substances and Disease Registry (U.S. Public Health Service) presented exposure and risk assessment research being conducted in Iowa by faculty of the University of Iowa, and by U.S. Geological Survey and Iowa Department of Natural Resources-Geological Survey Bureau scientists.

In addition, representatives of the agricultural chemical industry addressed risk assessment, communication, safety and education programs and industry priorities. The conference provided a forum for reasoned discussion of public health issues related to water contamination by agricultural chemicals. Initial steps toward establishing a common ground for future collaboration between government, academia and industry on water quality issues and prevention efforts were taken.

I would like to thank the members of the CHEEC Executive Committee, including Jim Hanson, Bill Hausler, Peter Isacson, Burt Kross, Chuck Lynch, Jim Merchant, Ron Munger and Jerry Schnoor for their advice, suggestions and support during the planning process.

Special thanks are extended to Pete Weyer of CHEEC. The original idea for this Conference was his, he wrote most of the proposal, and he was primarily responsible for the planning and execution of the Conference. In short, this Conference would not have happened without Pete's efforts. Special appreciation is also extended to Ted Heald of the University Hygienic Laboratory for poster graphics and design work, and to Lisa Barnes of the University of Iowa Conference Center for management and logistic support.

I would also like to thank Mark Gleaves and Kerry Sesker of CHEEC, and Jane Frank and Anthea Craven of the University of Iowa Department of Civil and Environmental Engineering for their contributions.

Gene Parkin

Director

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## Risk Assessment of Pesticides and Water Contaminants: Regulatory and Public Health Implications

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*(The following is a synopsis of Dr. Fan's talk, based on her slide presentation)*



Following are definitions of permissible levels established for chemicals in drinking water which are used and may lead to the final MCL: MCL =

Maximum Contaminant Level: Maximum

concentration of a contaminant in drinking water allowed by State regulations; technical feasibility and economics considered; public hearing involved. RPHL = Recommended Public Health Level: strictly health-based; if these cannot be met, the water supplier must explain the reasons for not being able to comply and submit a plan to correct the problem. AL = Action Level: an interim guidance level.

Primary drinking water standards are health-based, secondary drinking water standards are based on aesthetic effects (i.e., taste, odor, etc.).

The California Department of Health Services (CDHS) can grant an exemption from the MCL to a city, provided that it finds that the city has compelling reasons which make it unable to comply, and the exemption granted will not result in an unreasonable risk to the health of the water system consumers. The Department shall provide notice and an opportunity for a public hearing.

CDHS has promulgated 53 MCLs, which are re-evaluated every five years. These 53 MCLs may be the same as, or more stringent than, the federal MCLs. A total of 45 RPHLs are being proposed and ALs are established when chemicals without any state guidance levels are found in California drinking water.

Recent public health concerns raised on exposures to nitrate/nitrite in drinking water include infant methemoglobinemia, adverse reproductive effects, possible effects from exposure from breast feeding, exposure during pregnancy and chronic toxicity.

General information on nitrate/nitrite: drinking water standard MCL = Maximum Contaminant Level is 45 mg/L nitrate, 10 mg/L nitrate/nitrogen, 1 mg/L nitrate/nitrogen. URTH = Unreasonable Risk to Health: 45 mg/L: 0-6 months old; 90 mg/L: 7 months and up. The basis for the drinking water standard for nitrate/nitrite comes from epidemiological evidence on methemoglobinemia occurrence, the fact that there are few cases below MCL (in the U.S., there are none below the MCL), and that infants 0-6 months are most sensitive.

### Drinking Water Standards

All units are ppb unless otherwise specified; P is primary drinking water standard; S is secondary drinking water standard, number in parentheses is proposed or draft.

February 1991

Substance Name	Federal MCL	Cal. MCL	Cal. Proposed MCL
(P) Acrylamide	Trmt. Tech.	-	-
(P) Adipates	(500)	-	-
(P) Alachlor	2	0.2(AL)	-
Aldicarb	10	10(AL)	-
aldicarb sulfoxide	10	-	-
aldicarb sulfone	10	-	-
Aldrin	-	0.05(AL)	-
(P) Aluminum	50(S)	1000	1000
(P) Antimony	(10 or 5)	-	-
(P) Arsenic	50	50	5
(P) Asbestos (MFL)	7	-	-
(P) Atrazine	3(2)	3	3
(P) Barium	1000	1000	1000
Baygon	-	90(AL)	-
(P) Bentazon (Basagran)	-	18	18
(P) Benzene	5	1	1
(P) Beryllium	(1)	-	-
(P) Cadmium	5	10	-
Captan	-	350(AL)	-
Carbaryl	-	60(AL)	-
(P) Carbofuran	40	18	18
(P) Carbon tetrachloride	5	0.5	0.5
(P) Chlordane	2	0.1	0.03
(S) Chloride (ppm)	-	250	-
Chloropicrin	-	50(AL)	-
(P) Chromium	100	50	50
(P) Coliforms, total (number/100 mL)	1-4	1-4	-
(S) Color (units)	-	15	-
(S) Copper	1300	1000	-
(S) Corrosivity	-	Relatively low	-
(P) Cyanide	(200)	-	-

### List of Chemicals with Proposed RPHL Lower than MCL

all units are ppb unless otherwise specified

February 1991

Chemical Name	EPA MCL	Cal. MCL	Cal. Proposed MCL
Arsenic	50	50	5
Chlordane	2	0.1	0.03
1,2-Dibromo-3- chloropropane (DBCP)	0.2	0.2	0.02
1,2-Dichloroethane (1,2-DCA)	5	0.5	0.3
1,3-Dichloropropene	-	0.5	0.2
Ethylene dibromide (EDB)	0.05	0.02	0.02
Heptachlor epoxide	0.2	0.01	0.007
Tetrachloroethylene (PCE)	5	5	0.7
Toxaphene	3	5	0.06
Trichloroethylene (TCE)	5	5	3
Vinyl chloride	2	0.5	0.015

## Comparison of RPHL with Validated Water Method MDL

MDL is the method detection limit as defined in 52 CFR 25699, July 8, 1987; all units are ppb.

February 1991

Chemical Name	Cal. proposed RPHL	Analytical Method	MDL
Arsenic	5	EPA 206.2 EPA 7061	1
Chlordane	0.03	EPA 505	0.14
1,2 Dibromo-3- chloropropane (DBCP)	0.002	EPA 504 EPA 524.2	0.06
1,2-Dichloroethane (1,2-DCA)	0.3	EPA 502.2 EPA 524.2	0.06
1,3-Dichloropropene	0.2	EPA 8010	0.3
Ethylene dibromide (EDB)	0.02	EPA 504 EPA 524.2	0.02 0.06
Heptachlor epoxide	0.007	EPA 1618 EPA 505	0.02 0.1
Tetrachloroethylene (PCE)	0.7	EPA 502.2 EPA 524.2	0.04 0.05
Toxaphene	0.06	EPA 8080 EPA 505	0.24 1
Trichloroethylene (TCE)	3	EPA 502.2 EPA 524.2	0.01 0.02
Vinyl chloride	0.015	EPA 502.2 EPA 524.2	0.04 0.17

## Twenty-Five Years of Public Health-Based Water Quality Studies in Iowa

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For over twenty five years the University Hygienic Laboratory has been actively involved in public health-based water quality surveys throughout the state of Iowa.

Early studies in the mid-1960s focused on the detection of chlorinated hydrocarbon insecticides in surface waters and aquatic biota. As the use of chlorinated hydrocarbons dropped due to government interventions, the Hygienic Laboratory turned its attention to the occurrence of second and third generation herbicides and insecticides.

A study was undertaken in the spring of 1986 by the Iowa Department of Natural Resources (IDNR) and the Hygienic Laboratory to investigate pesticide contamination in water supplies using surface sources. Samples of treated water were collected from 33 public water supplies which rely on surface water as their sole source or as one of several permanent sources of water. All samples were collected after a rainfall event and thus represented pesticide levels in treated water affected by runoff. At 14 of these public water supplies, concurrent samples were also collected from the surface water sources, prior to treatment. Sampling of water prior to and after treatment provided an indication of the effectiveness of

pesticide removal during the treatment process. Each sample was analyzed for 37 pesticide compounds.

Detectable levels of one or more pesticide compounds were found in 30 of the 33 public water supplies tested. Overall, 10 individual pesticides compounds were detected. Individual pesticides and the number of supplies in which they were detected were: atrazine, 30; cyanazine (Bladex), 26; metolachlor (Dual), 21; alachlor (Lasso), 17; carbofuran (Furadan), 9; metribuzin (Sencor), 4; 2,4-D, 2; and trifluralin (Treflan), butylate (Sutan) and dicamba (Banvel), 1 each.

All the pesticides detected in the treated water samples were identified as those most abundantly used on cropland. With the exception of 2,4-D, the compounds found at the public water supplies are not required to be monitored through the federal requirements in the Safe Drinking Water Act (SDWA). In total, the SDWA only requires monitoring for 6 pesticide compounds in public water supplies using surface water sources. Of those required to be monitored only 2,4-D was detected in the treated water samples. The other pesticides mandated to be monitored according to SDWA regulations have limited or no current usage in Iowa.

Results from samples collected prior to and after treatment indicate that conventional water treatment systems are ineffective at substantially removing or eliminating pesticide compounds. Thirteen of 14 water supplies sampling both treated and untreated water had detectable levels of pesticide compounds in the untreated water source. All 13 of these supplies had detectable levels of one or more pesticide compounds in their treated water samples. Although the water supplies tested provided results from a wide range of conventional treatment systems, evaluating the effectiveness of any one type of treatment system was beyond the scope of this study.

Pesticide concentrations in treated water samples at 21 of the 33 supplies exceeded preliminary lifetime health advisory concentrations (MCL Goals). A number of study factors, including the small number of supplies sampled, variability among sites on amounts of rainfall and rainfall occurrence with respect to pesticide application, precluded the development of any concrete recommendations. Furthermore, the frequency at which lifetime health advisory concentrations in those water supplies is exceeded could not be established.

In 1986 the seventy-first Iowa General Assembly passed House File 2303. This legislation required the IDNR to develop and implement a one-time, finished water testing program of public and privately owned water systems for pesticides and synthetic organic contaminants (SOCs). The Hygienic Laboratory provided the analytical services. The testing was conducted from November 1986 to November 1987. The testing, on a voluntary basis, was also available to privately owned water systems.

Eight hundred and fifty-three (853) public water systems were tested; 122 tested positive for one or more pesticides. Five hundred and forty-eight (548) tested positive for one or more SOC. No measurable concentrations of pesticides or SOC were found in 279 systems. Nine water systems had pesticide or SOC levels that exceeded U.S. EPA Health Advisory Levels or federal maximum contaminant levels. Contaminant levels high enough to cause an acute health risk were not observed in this study.

The pesticides most commonly found were atrazine, Bladex, Lasso, Dual and 2,4-D. The most frequently found SOC belongs to a group of compounds called trihalomethanes (THMs). THMs are formed during disinfection when chlorine reacts with organic matter in the water.

The most significant findings drawn from this project were:

- 1) surface water systems have the greatest potential for pesticide contamination;
- 2) the shallower ground water sources have a greater potential for contamination by pesticides and SOC;
- 3) a seasonal trend in pesticide occurrences in water sources was not observed; and
- 4) the frequency of appearance and concentration of THMs in ground water systems was unexpected.

Significant recommendations drawn from this project were:

- 1) Modify IDNR's statutory authority so that in the absence of federal regulations, the Department may adopt monitoring and drinking water standards for public water supplies for pesticides and SOC commonly used in Iowa and found in drinking water (i.e., atrazine, Bladex, Lasso, Dual, benzene, carbon tetrachloride, methylene chloride, 1,1,1-trichloroethene, o-xylene and p + m-xylene).
- 2) The THM formation process would appear to limit their presence in ground water. However, the study results indicate the potential for ground water systems to exceed the THM maximum contaminant level. Therefore, encourage and support studies to determine the source and significance of THMs in ground water supplies.
- 3) The THM monitoring requirement and standard, which are currently applicable to systems serving more than 100,000 people, should be extended to include all surface water supplies regardless of size.
- 4) Conduct additional controlled studies to correlate the significance of pesticide and SOC contamination in finished drinking water and ground water sources.
- 5) Educate water suppliers with vulnerable water sources (e.g., surface and shallow ground water sources, and water sources in close proximity to commercial or industrial use, disposal or storage of SOC and pesticides) of the possible contamination pathways and encourage the development of economical and innovative methods to protect water sources.
- 6) Encourage and support studies directed at developing innovative and economical treatment techniques for the removal of pesticides and SOC.
- 7) Adequate funding should accompany sampling projects of this nature to insure that follow-up and data analysis activities can be conducted.

## Management System Evaluation Areas: Iowa's Contribution

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### Summary

**I**nteragency collaborative research is being conducted to improve understanding of where and how water resources are degraded by selected agrichemicals in the mid-continental United States. Mass balance and multiscale research approaches are being applied to develop improved agricultural systems to protect water quality. Local-scale research is being conducted in five primary and five satellite Management Systems Evaluation Areas (MSEA) representative of the range of hydrologic settings in the region. MSEA research is being conducted to determine the effects of existing agricultural technology on water quality and to study processes by which agrichemicals are transported, transformed or stored in the hydrologic system. Research at the regional scale

was initiated to define the occurrence of agrichemicals in streams, precipitation and shallow aquifers. Representative stream basins, wells and precipitation chemistry sites are being sampled to determine the temporal and spatial distribution of agrichemicals in these parts of the water resources. A study of historical nitrate in ground water and nitrogen-fertilizer application rates shows a positive correlation between the two variables but only in some subregions. Identification of such subregions provides opportunities to implement land-management changes where improvements in water quality have the greatest potential for short-term success. In these subregions it will be possible to extrapolate the results of local-scale research to larger segments of the landscape.

## Occurrence and Flux of Inert Pesticide Ingredients in Shallow Ground Water

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**T**he use of pesticides in all states with agricultural production was between 400 and 500 million pounds of active ingredients in 1987. More than 56 million pounds of active ingredients were used in Iowa in 1979. In addition to the active ingredients, all pesticides currently in use contain ingredients that are referred to on the product label as inert ingredients. These ingredients may constitute more than 90 % of some product formulations. Some of the inert ingredients are priority pollutants and therefore should be given extra consideration when evaluating the effect of these chemicals on the environment. Currently, a need exists for more information on the occurrence and flux of inert ingredients both in soil and ground water.

Inert ingredients are used as fillers or as components to enhance or activate the active ingredients of the product. Volatile organic compounds comprise the most common class of chemicals used in inert ingredients. Many of the

volatile organic compounds are listed as priority pollutants by the Environmental Protection Agency (EPA) and are regulated through the primary standards of the Safe Drinking Water Act (SDWA).

A March 1987 EPA publication contains two lists of specific inert materials of concern. One list is identified as "inerts of toxicological concern" and names 57 chemicals. The other list noted as "inerts with a high priority for testing" contains 62 chemicals. Two compounds on the EPA lists, chlorobenzene and chlorotoluene, have been found at percent levels in the raw pesticide formulations of alachlor and trifluralin, respectively, by researchers at the University Hygienic Laboratory. These two compounds are not used extensively as industrial solvents or in petroleum-derived motor fuels and therefore are suitable for making correlations between environmental occurrences and pesticide application. Although volatile in nature, these two compounds have relatively low vapor pressures and can be expected to leach into ground water when applied directly to the land surface. Howard (1989) estimates that



environmental releases of chlorobenzene are due, in part, to losses associated with its use as a solvent in pesticide formulations. Furthermore, chlorobenzene has been found in association with alachlor in drinking water supplies in shallow aquifers in Iowa (Cherryholmes and others, 1989). Other chemicals classified as inert ingredients were found during a reconnaissance study conducted in Iowa during the 1989 and 1990 field seasons. This reconnaissance indicates that these chemicals may have contaminated some shallow ground water aquifers, but the source and flowpaths for these chemicals could not be determined.

A regulation to require pesticide manufacturers to register toxic ingredients with the State has passed the Iowa legislature. Other agricultural states may implement similar legislation. The EPA currently is implementing a pesticide in ground water protection program. As part of this program, all 50 states will need to develop a State Management Plan for pesticides in ground water. The information obtained from this project may be important in formulating ground water protection plans related to pesticide inert ingredients.

The University Hygienic Laboratory and the U.S. Geological Survey are undertaking a study that addresses the following objectives: 1) to determine the occurrence of selected volatile organic compounds contained in selected corn and soybean herbicides in the unsaturated zone immediately after application, 2) to determine the seasonal and vertical distribution of pesticide inert ingredients in the unsaturated zone and the upper saturated zone, and 3) to show the relationship between the occurrence and movement of pesticide inert ingredients and hydrologic and pedologic factors.

The project is being conducted at the Iowa Management System Evaluation Area (MSEA) study sites. The Iowa MSEA is representative of a significant part of the Midcontinent corn and soybean growing region and the findings of the project should provide an indication of the significance of inert ingredient contamination of ground water in shallow aquifers in this region. The project is to be completed in three years.

At the Iowa MSEA, where the proposed project will be conducted, related research will be performed by the Agricultural Research Service, the Cooperative State Research Service, and the U.S. Geological Survey. The objective of the interagency research at the MSEA sites will be to study the effect of varied farm practices on water quality. Farm practices will be controlled at selected field plots, and information on the types and amounts of agrichemicals will be documented. A network of wells will be established, instrumented and monitored by the MSEA research team to analyze the ground water movement beneath the field plots. The MSEA field plots will provide an opportunity to evaluate sampling results for a variety of pesticides on two crop types, a variety of application rates, and to maintain quality control of the amounts and timing of applications. The proposed project will be coordinated with other MSEA research objectives and will benefit from the expertise of associated researchers from other institutions and government agencies. The access to controlled field plots with a network of instrumented wells will provide an ideal environment for the study of inert ingredients. A combination of laboratory and field measurements will be performed to determine the source and presence in the environment of selected volatile organic compounds contained in herbicide products. Volatile organic compounds that are routinely analyzed as part of water supply monitoring will be the targeted class of organic compounds because of their prevalence as inert components and their designation as regulated drinking water toxics. The sampling strategy will consist of collecting samples of the herbicide mixtures applied to the corn and soybean plots prior to or during application to determine the source and types of selected volatile organics that may be present in field samples. Both raw and diluted samples will be analyzed by gas chromatography mass spectrometry. Samples will also be obtained from the plots prior to application as a quality assurance procedure. Soil gas, pore water, and shallow ground water samples will be collected and analyzed using a portable gas chromatograph and laboratory methods. Samples of soil gas and shallow ground water will be collected within 72 hours of application to be analyzed for target substances. Additional samples will be collected during the spring and summer months to determine the flux and degradation of detected substances.

The analyses of the herbicide mixtures will be compared with soil gas and ground water samples collected to determine the occurrence and transport of inert ingredients after application.

Additional samples collected during the growing season will be used to determine the seasonal and vertical distribution in the unsaturated zone and upper saturated zone. The sampling process will be repeated the following year to verify the information obtained during the first year and to evaluate the effects of variable climatic and hydrologic conditions on the flux of inert pesticide ingredients. Additional samples from the shallow aquifers will be collected from selected wells throughout Iowa. This reconnaissance will provide additional information on the geographic variability of any observed contaminants.

## **Biotransformation of Atrazine and Alachlor in Ground Water**

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There has been growing concern about the presence of pesticides in ground water supplies. Several water quality surveys, both national and specific to the Midwest, have shown that many of the commonly used pesticides are present in raw ground water supplies and in finished drinking waters. Evidence suggests that both the number of wells showing pesticide contamination and actual concentration levels are increasing. Two of the most commonly used and detected pesticides are the triazine herbicide atrazine and the acetanilide herbicide alachlor. Because of potential health concerns, the EPA has issued proposed maximum contaminant levels (MCLs) of 3 micrograms/liter for atrazine and 2 micrograms/liter for alachlor. Although there is some information in the literature about the fate and transport of atrazine and alachlor in ground water environments, additional information is needed, especially concerning the effect of redox (electron acceptor) conditions.

A research program was initiated to investigate the fate of atrazine and alachlor under conditions similar to those found in Iowa ground water. The objectives of this research program were: 1) to assess the transformation of atrazine and alachlor under four terminal redox (electron acceptor) conditions: aerobic, nitrate reducing, sulfate reducing and methanogenic; 2) to assess the

The information collected will provide baseline information on the occurrence of inert ingredients under differing agricultural practices and at different times of the year. The results will be used in correlation procedures for determining the hydrologic and pedologic factors that affect contaminant fate and transport.

### **References**

Cherryholmes, KL, Breuer, GB, Hausler, WJ: "One time testing of Iowa's regulated drinking water supplies"; University Hygienic Laboratory, Iowa City, 1989.

Howard, HH: "Handbook of environmental fate and exposure data for organic chemicals, Volume 1"; Lewis Publications, 1989.

First published in the *Iowa Groundwater Quarterly*, Vol.3, No. 3, September, 1991 (Author: Cherryholmes)

kinetics of atrazine and alachlor biotransformation under these four terminal electron acceptor conditions; 3) to develop and test a vertical, one-dimensional mathematical model for the transport of atrazine and alachlor under these four terminal electron acceptor conditions; and 4) to assess in a preliminary fashion the production of metabolites of atrazine and alachlor as a function of the four terminal electron acceptor conditions.

Four Plexiglas columns, one for each terminal electron acceptor condition, filled with glass beads were used. Temperature was controlled at 16 degrees C. and the hydraulic detention time was varied from 17 to 68 hours. Media designed to resemble the oligotrophic conditions of ground water were used. Acetate was added as a primary growth substrate. Atrazine and alachlor were fed to the reactors at a concentration of 100 or 300 micrograms/liter.

Alachlor was degraded under all four electron acceptor conditions studied (aerobic respiration, nitrate reduction, sulfate reduction, methanogenesis). When atrazine and alachlor influent concentrations were below 200 micrograms/liter, they were most readily degraded under sulfate-reducing conditions. Atrazine was much less readily transformed than alachlor. The strictly anaerobic conditions appear to have the greatest capacity to perform these transformations.

When the detention time of the aerobic column was 17 hours, no removal of atrazine occurred. When pesticide influent concentrations were near 300 micrograms/liter, acetate utilization was partially inhibited and pesticide transformation was completely inhibited in the sulfate-reducing reactor. One of the products of alachlor transformation under both sulfate-reducing and methanogenic conditions was the reductive dechlorination product, "nochlor-alachlor".

Alachlor is transformed in an abiotic reaction with bisulfide. The second-order rate constant for this reaction was found to be 0.0015 L/mg [HS<sup>-</sup>]-hr.

Evidence was found indicating that the continuous presence of the primary substrate (acetate) is required to maintain continuous transformation of the secondary substrate (pesticides), particularly in the sulfate-reducing system.

In general, increased contact time between biomass and secondary substrates resulted in greater degrees of transformation, which is

indicative of a biological reaction. This increase, however, appeared to be tempered by a possible loss of degradative capacity within some of the cultures due to a decrease in primary substrate loading when detention time was increased.

A time-variable mathematical model coupling biomass growth and decay with primary substrate utilization was very sensitive to changes in the kinetic parameters of microbial decay rate and maximum substrate utilization rate. A steady-state model in which the measured biomass concentrations were used to predict secondary substrate transformation along each column had some successful applications. A significant difficulty was encountered with regard to using protein as an indicator of an actively degrading biomass. It appeared that in some instances the protein assay was measuring inactive parts of the culture incapable of transforming a secondary substrate. Thus, it appears that accurate measurement of active biomass, those organisms responsible for mediating the biotransformations, is a major limitation of existing models.

## **Agricultural Impacts on Ground Water Quality: The Big Spring Basin Study**

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The Big Spring Basin Demonstration Project (BSBDP), located in northeast Iowa, is designed to track the fate of farm chemicals in a major ground water basin and its watershed.

Primarily, the project seeks to follow these chemicals, devising methods to prevent or reduce their movement to surface and ground water while still maintaining profitability for the farmer.

The basin is significant because it provides a natural field laboratory for the study of how surface activities, specifically farming, affect ground water. Nearly all of the ground water exits at Big Spring, enabling scientists to easily measure the effects of farming activities on ground water quality. In addition, agriculture is the only basin industry, simplifying the study of impacts to water quality. No cities, towns, manufacturing plants, commercial industries, nor municipal waste treatment facilities contribute contaminants.

Water quality monitoring data gathered as early as 1981 showed elevated levels of nitrate. In addition, collaborative analysis of water samples collected from wells in the basin suggested widespread nitrate contamination of ground water,

according to Iowa State University Extension Service. After many years of high nitrogen fertilizer applications, the nitrate moving into ground water was in relative equilibrium with the water flux: the more water that moved through the soil and into the ground water, the higher the nitrate content of the water. Prompted by these alarming data in 1983, local citizens groups joined existing organizations and agencies to establish a working task force known as the Iowa Consortium on Agriculture and Water Quality.

Pesticides first appeared in basin ground water samples in early spring 1982 and have appeared ever since. According to researchers at the Iowa Department of Natural Resources, by 1986 only one insecticide, fonolos (Counter) had been detected in the Big Spring Basin ground water. Between 1981-1985, however, numerous herbicides appeared at various concentrations, including atrazine, alachlor, cyanazine, 2,4-D, metolachlor and metribuzin.

Through on-farm demonstrations the project illustrated the potential to reduce tillage and chemical use, improve nutrient and fertilizer management, improve pest management, reduce soil erosion, and reduce overall application costs. Between 1984 and 1987, fifty-two percent of farmers reported reducing nitrogen fertilizer, and

twenty-three percent reduced pesticide use. Yet they also report higher crop yields, with application costs on the average farm in the area dropping some \$3,000 to \$4,000 per year.

Summary from *EPA Nonpoint Source News-Notes*, February, 1990

## Exposure Assessment Methods for Pesticides

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### Summary



The National Cancer Institute is sponsoring a methodologic investigation to evaluate and improve procedures for estimating or measuring occupational exposure of farmers to pesticides. The study was performed by researchers at the University of Iowa Institute of Agricultural Medicine and Occupational Health.

The linkage of cancer risk to pesticides is critically dependent upon an accurate, reliable exposure assessment method for pesticides in a farm setting. Chronic (drinking water, food residuals, environmental drift) exposures and acute (mixing, application, accidents) conditions contribute to the overall exposure assessment model. The primary objectives of this investigation were:

- to evaluate the comparability, reliability and representativeness of several methods typically used to estimate pesticide exposure;
- to simultaneously implement the following pesticide exposure assessment procedures in representative farm settings:
  - interview/questionnaire methods based on recall of farmers
  - independent verification of pesticide use from purchase records
  - industrial hygiene measurements of pesticide exposure in air and dermal contact

- industrial hygiene measurements of indirect pesticide exposure in the home from residuals on work clothing and environmental drift
- chronic exposure to pesticides from drinking water
- biologic monitoring of blood and urine samples from farmers and families for pesticide residuals or metabolites
- to recommend improvements in pesticide exposure methodologies based on comparisons of existing approaches to pesticide exposure assessment, and
- to evaluate the credibility of study results (particularly interview/questionnaire data) through the use of a panel of experts in agricultural practices, pest management, toxicology, and exposure assessment.

The study began in July, 1989, with a pilot field data collection occurring in the spring of 1990. Results of the pilot study were presented at the CHEEC Conference. Detailed field and survey investigations of farmer pesticide exposures were performed during 1991.

## Association of Intrauterine Growth Retardation with Source and Constituents of Finished Drinking Water Supplies in Southern Iowa Communities

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### Summary

**R**ates were determined for low birth weight (LBW - less than 2,500 grams), intrauterine growth retardation (IUGR - LBW for gestational age), and prematurity (PM - less than 37 weeks gestation) per 100 singleton live births to all white females from 10 to 50 years of age residing in incorporated municipalities in Iowa for the years 1984 through 1990. The rates by individual municipality were statistically related in an aggregate analysis to sociodemographic factors including population, income, percent females in labor force, population, and education; smoking during pregnancy; amount of prenatal care at varying periods of gestation, failure to record the last menstrual period, age of mother, and parity. Also included in the analyses were the source of the municipal water supply (alluvial, drift, bedrock aquifer, or surface), water treatment methods, and composition of the finished water supply from a statewide testing of each of Iowa's 865 municipal supplies in 1986 to 1987. The survey included 35 pesticides used in Iowa and 35 other volatile organic contaminants, including the trihalomethanes.

For all incorporated Iowa municipalities, the association between rates of these adverse pregnancy outcomes and socioeconomic, lifestyle, smoking, and medical care variables were comparable to those previously reported from other areas of the country. When the birth outcomes were related to the source of water supply, a significant elevation of rates of IUGR was noted in fourteen communities in southern Iowa supplied by a single rural water association which obtained the water from an impoundment reservoir. It was also found that this supply

contained elevated levels of the pesticides atrazine and bladex throughout the year 1986-87 and the levels remained elevated in 1990 and 1991. Multiple linear regression analyses for all Iowa municipalities revealed that atrazine levels appeared in the best model fit. Since the communities were small and were all located in the southern tier of Iowa counties, further analyses were restricted to municipalities within the southern third of Iowa counties and a population of less than 2,500 persons. In this stratification multiple linear regression again showed atrazine levels to be significantly associated with IUGR rates with an effect comparable to that of other non-water variables, and analysis of residuals after removal of other associated variables showed the linkage of atrazine with IUGR to persist. While the statistical association of IUGR was strongest with atrazine levels, a separate effect of bladex could not be ruled out.

Because of the aggregate nature of the study and the impossibility of ruling out non-measured water constituents or other variables as associated factors, no causal relationships with specific water constituents can be clearly established.

# Methods for the Study of Environmental Exposures and the Risk of Birth Defects in Iowa

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(The following is a synopsis of Dr. Lynch's talk, based on his slide presentation)



in 1986.

The percent of infant deaths attributed to birth defects in the United States between 1916-1986 shows a general increase in percent from approximately 6-8% in 1916 to approximately 22%

The ten leading causes of infant mortality in the United States for 1986 were as follows: birth defects - 22%, low birth weight/prematurity/Respiratory Distress Syndrome - 20%, SIDS - 16%; maternal complications - 5%, intrauterine hypoxia, birth asphyxia, perinatal infections, accidents/adverse effects, etc. - each < 5%.

Data on birth defects in Iowa is collected by the State Health Registry of Iowa (SHRI). SHRI surveillance goals include: programming and planning, quality assurance, evaluation of intervention strategies, environmental monitoring and hypothesis testing.

Research on environmental exposures and development of birth defects in Iowa is supported by the University of Iowa Center for Health Effects of Environmental Contamination (CHEEC), which maintains a large environmental data base. Uses of the CHEEC databases include descriptive reports of environmental quality, descriptive (or aggregate) epidemiologic studies, and analytic (case-control) epidemiologic studies.

Types of adverse reproductive outcomes include infertility/ sterility, fetal wastage, stillbirth, birth defects, low birth weight/prematurity, developmental disabilities and various abnormal behaviors.

Problems for surveillance systems include finding and classifying cases, biological plausibility and significance, assessing exposure data, and linkage and tracking of cases.

Causes of birth defects include genetic factors such as chromosome abnormalities and gene abnormalities, and environmental factors including infectious agents, physical agents, drugs, chemicals and maternal factors. These factors can work in combination as well.

## Table relating type of exposure and associated birth defects

Genetic alteration	Exposure	
	Hereditary	Environmental
Spontaneous	-	-
Hereditary	+	-
Environmental	-	+
Interactive	+	+

Selected examples of gene-environment interactions

Genetic Defect	Environmental Exposure	Health effect
Phenylalanine hydroxylase deficiency	phenylalanine in diet	mental retardation
Alpha-1-antitrypsin deficiency	cigarette smoking	Pulmonary emphysema

Within the Departments of Biology and Pediatrics at the University of Iowa, the Craniofacial Anomalies Research Center is conducting a study of genetic and environmental causes of cleft lip and palate. The study design is a case-control based on statewide surveillance via the Iowa Birth Defects Registry.

Methods of the Iowa Cleft Lip and Cleft Palate Study include: statewide surveillance for 300 cases; 300 controls randomly selected from all Iowa newborns without birth defects; data on demographic background, medical and family history, diet, and environmental exposures collected via telephone interviews and mailed questionnaires; blood samples collected by local physicians and sent to Iowa City for analyses.

Genetic studies of the Iowa Cleft Lip and Cleft Palate Study include: identification and mapping of genes associated with cleft lip and palate; cloning and sequencing of candidate genes; studies of involvement of selected genes in neural crest formation and craniofacial development; study of normal expression of genes during lip and palate development in a mouse model.

Personal exposures during pregnancy possibly related to cleft lip and cleft palate include maternal smoking, anti-convulsant medication, alcohol and poor nutrition.

Nutritional factors during pregnancy possibly related to cleft lip and cleft palate include excess vitamin A intake, low intake of Vitamin A, Riboflavin (B2), Folic acid and Pyridoxine (B6).

- General environmental exposures possibly related to cleft lip and cleft palate include agricultural activity, urban vs. rural residence and low social class.

## The President's Water Quality Initiative: Protecting America's Water Resources

Harry Mussman

Office of Science and Education, U.S. Department of Agriculture

**P**ublic health and the President's Initiative on Water Quality are synonymous. President George Bush, in a message to Congress, said that "...given sound research, innovative technology, hard work, sufficient public and private funds, and — most important of all — the necessary political will, we can achieve and maintain an environment that protects the public health and enhances the quality of life for us all."

The U.S. Department of Agriculture is taking seriously the evidence that agricultural nutrients and pesticides are contaminating water supplies and has developed programs accordingly. Just as agriculture is a part of the problem, we also believe we can be an important part of the solution. One of the ingredients of that solution is to improve our management of both nitrogen fertilizer and pesticides to reduce their potential for leaching into ground water or running off into surface waters.

Through technology, the United States has developed the most efficient food, fiber, and forest system in the world. For example, the latest figures show that U.S. consumers spend only 11.8 % of their disposable income for food. To underscore this, I would point out that agriculture accounts for 17 % of the gross national product, utilizes 20 percent of the workforce, and consistently is on the positive side of our balance of payments ledger in international trade. Yet all of this productive capability comes from less than 4 % of the total U.S. population.

But we now recognize that the technology that has made this possible has had some costs which were not fully anticipated at the time of its introduction. Science continues to refine and enhance our analytical technology to where we will be able to detect some agrichemicals not at the one or two parts per billion level, but at 0.01 part per billion or less. That is a significant increase in sensitivity. With that type of capability and scientific achievement, our findings will face

continued public misunderstanding which will be exacerbated by media misconceptions regarding residues in foods and chemicals in our waters.

Today, to solve the problem, we have a choice between a broad, regulatory approach and a voluntary agrichemical/land management approach. The fear of excessive leaching and runoff of pesticides and nutrients tends to drive public policy over the short term to a regulatory solution, acre by acre, locale by locale. But the voluntary approach is the preferred long term solution because technologies are only now evolving that provide producers with management practices that are both environmentally friendly and economically sound. It also takes time to alter the production behavior of thousands of independent farmers working the 300 to 400 million acres of land devoted to the production of food and fiber.

One of the major underlying policy issues for now, therefore, is whether there is time to wait for the better solution. We believe there is. The available evidence tells us our ground water is vast and still essentially potable. Nitrate-nitrogen levels in ground water are generally very low, below 3 milligrams per liter (mg/L) in 91 % of the principal aquifers in 46 states where the U.S. Geological Survey (USGS) has summarized ground water data. The levels in the remaining aquifers range between 3 and 10 mg/L. (The maximum contaminant level (MCL) or highest acceptable level for nitrate-nitrogen is 10 mg/L.)

A 1990 nationwide study by the Environmental Protection Agency (EPA) on pesticides and their degradates in drinking water wells revealed minimally detectable residues in 10.4 % of the community wells, and 4.2 % of the private wells. Contamination at levels of health concern was less than 1 % in private wells. A study focusing on herbicides and fertilizers in agricultural areas of 26 states found that less than one-tenth of 1 % of the 1,430 drinking water wells sampled

exceeded the EPA's maximum contaminant level for herbicides. Detections of up to 2 parts per billion of the herbicides were found in 12.8 % of all wells. However, the National Alachlor Well Water Survey did find that nitrate was present in half the wells, with approximately 5 % of the wells containing nitrate-nitrogen in excess of 10 mg/L, the MCL.

There are a number of hot spots within some aquifers where the nitrate concentration is rising and is close to, or exceeds, the MCL. Most frequently, these hot spots appear in shallow aquifers under sandy or gravelly, highly permeable soils where nitrogen use is heavy and combined with irrigation agriculture. Corn usually is the main crop. Karst areas also reveal higher levels of ground water contamination. Clearly we need to focus our attention on the hot spots for early solutions as we work on technology and improved cultivating systems to manage nitrates acceptably with respect to water quality.

Data and studies relating to causes of well water contamination strongly point to farmstead sources such as barnyards, silos, feedlots, buried or stacked organic material, and septic tank system effluent as the origin of much of the contamination. Fractured well linings or casings, old wells, and poor location simply make the problems worse. Thus, such wells likely serve as pipelines feeding pesticides, nitrates, and even pathogens into aquifers. Evidence of well contamination from the aquifer is very limited.

This year's debate on reauthorization of the Clean Water Act will continue to keep the spotlight on public health; further it appears that ecological risk assessment will be expanded. Risk assessment and risk management are central to most of the programs now being carried out by the USDA water quality family: The Agricultural Research Service, the Cooperative State Research Service, the Extension Service, the Soil Conservation Service, the Economic Research Service, the Animal and Plant Health Inspection Service, the National Agricultural Library, the Forest Service, the Farmers Home Administration, and the National Agricultural Statistics Service. These agencies are meeting the challenge of providing farmers, ranchers, and foresters with the knowledge and technical means to respond independently and voluntarily in addressing environmental concerns and related State water quality requirements.

The USDA Water Quality Initiative pursues three main areas of action: (1) research and development; (2) education and technical assistance; and (3) data base development and evaluation.

USDA works in close and productive partnership with the Fish and Wildlife Service, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the Tennessee Valley Authority. Across the country today, there are 16 USDA demonstration projects, 74 hydrologic unit area studies, 35 special water quality projects, and 5 management and systems evaluation areas. They are found in every state except Nevada and Alaska.

The hydrologic unit area sites were selected through a process that gave weight to problems identified by State Water Quality agencies under the program authorized by Section 319 of the Clean Water Act. Landowners in these hydrologic unit area projects are receiving technical, educational and financial assistance to solve water quality problems where agriculture is concerned. The 35 special water quality projects were selected because each addresses multiple problems. The demonstration sites were established to show farmers various ways to minimize the effects of agricultural nutrients, pesticides, and animal waste on both surface and ground water, but with an emphasis on ground water.

The Soil Conservation Service, Agricultural Research Service, universities, and the pesticide industry have worked together to produce guidance for farmers on the potential for pesticides to move in leaching water or surface runoff. This information provides the farmer with better pesticide application methods to prevent surface or ground water contamination.

The Extension Service has accelerated educational programs for farmers and rural residents, with emphasis on pesticides, nutrients, animal wastes and wellhead protection. Systems that reduce or eliminate agricultural nonpoint sources of contamination while maintaining the profitability of the farm enterprise are a high priority.

In the short term, one priority for the current decade will be reducing ground water contamination from farmstead sources through the water well itself. In the longer term, we will continue to recommend and extend the voluntary adoption of modified farming practices and to introduce improved technology and management systems.

In the case of nitrate contamination of water, information currently available confirms the recent EPA determination that there is reason for concern, but not alarm. The same can be said for pesticides. It is clear there are multi-faceted and



often localized problems that must be addressed and solved. Given the fact, however, that we are not faced with a crisis, research, technology transfer and implementation can move in an orderly manner rather than on a crash program.

Basic policy on pesticide and nitrate use must be founded on sound science. Today, there are more questions than answers. Yet, we must continue to advise farmers about what we do know and help them with current information, technical assistance, and cost share incentives. As research reveals further answers and we gain new knowledge, we move the information to the field as quickly as possible through vigorous educational and technical assistance efforts.

The true test of the effectiveness of the USDA's program efforts lies in how well we

provide farmers, ranchers, and foresters with the knowledge and technical skills to respond independently and voluntarily in adopting environmentally gentle agricultural practices while maintaining a profitable operation.

Measuring our effectiveness is difficult. Progress in water quality protection and improvement, especially for ground water, cannot be determined in weeks or months, or even a few years in many cases. Even though farmers are responding to new farming practices, progress may not be measurable for several years, or a decade or more, after they change their production methods.

But we need to persevere. The stakes are too high not to do so.

## **Agrichemical Formulations - Inert Ingredients**

*Earl Spurrier*

*State Affairs, National Agricultural Chemicals Association*



he crop protection chemical industry is making great strides to put the inerts concern in the past. One of these days, and I hope in the near future, the public health concern about inerts in agricultural pesticide formulations can be greatly abated. Because many things are happening.

Historically, inert ingredients which are added to formulations have not been considered as high in the toxicological data generation hierarchy as active ingredients. But since 1985 inerts have been elevated to a higher order of commercial evaluation as to their need and public health concerns. For many years, inerts were considered as GRAS - generally regarded as safe. But now industry toxicologists are evaluating the status of toxicity, relevancy of concerns and appropriateness of inerts in our commercial formulations. Inerts play a significant role in the formulation of crop protection chemicals. There is a need for solvents, dispersants, surfactants, anti-oxidizers, neutralizers, acidifiers, anti-foamers, drift retardants, spreaders, stickers, water solubilizers, scavengers, anti-precipitates, chelators and carriers. Carriers can be corn cobs, oat hulls, sand, clay, water, organic solvents or other inert materials that can make very little if any contribution to product efficacy. The sole role is to provide distribution over, to or on the target site. This broad spectrum of diverse uses of inerts within formulations becomes a matter of real competitive innovation. Protection of confidential formulas is critical. It is truly the life blood of many

formulators of non-proprietary products or for that matter many proprietary products. Formula composition is just as important to formulators and manufacturers as is process technology.

Meetings with the EPA, environmental organizations and industry have been taking place since 1985 to evaluate the status of inert ingredients in the product registration and re - registration structure. In 1985, the U.S. Environmental Protection Agency first categorized 1,200 inerts into four groups:

- List 1: inerts of toxicological concern
- List 2: potentially toxic inerts: high priority for testing
- List 3: inerts of unknown toxicity
- List 4: inerts of minimal concern

On April 22, 1987, the EPA published Lists 1 and 2 in the Federal Register along with their proposed public policy for dealing with inert ingredients.

List 1 consisted of 54 ingredients of significant toxicological concern. The criteria for this testing included carcinogenicity, adverse reproductive effects or developmental toxicity. These effects must have been demonstrated in laboratory or human studies and the data subjected to peer review. The criteria also included documented ecological effects and the potential for bioaccumulation.

EPA further listed about 75 ingredients in List 2 which it believes are potentially toxic and should be assessed for effects of concern. Some of these are structurally similar and some have data suggesting a basis for concern. Most are slated for testing through the National Toxicology Program, the EPA Office of Toxic Substances or other regulatory or government bodies.

List 4 (minimum hazard list) is generally related as innocuous. This included cookie crumbs, corn cobs, clay, sawdust, etc., and considered GRAS. List 4 contains about 300 ingredients.

List 3 has no basis for being included on the other three lists. There are about 800 inert ingredients on this list.

Regulatory actions are then directed toward the 120 or so inerts. Remember some inerts in agricultural formulations, such as emulsifiers, thickeners, gels, and the like can be the same or the same type products that are used in preparation of food and other consumer products.

Registrants are encouraged to substitute inert ingredients not included in Lists 1 or 2. If a product contains an ingredient on List 1 or 2, the name of that ingredient is required to be stated in the label.

Inert ingredients are subjected to a data call-in just like active ingredients. Data requirements may be just as extensive as that of an active ingredient. Some inerts have been reclassified as active ingredients. Also, any pesticide chemical used in food must have a tolerance or an exemption. If the EPA determines that an inert of toxicological concern is no longer used in any food use, the exemption from need of a tolerance will be revoked.

No new product containing a List 1 inert will be registered unless the product is closely similar to an existing product or unless the registrant can demonstrate that the effects to humans or the environment will be reduced by the new registration claims.

In the summer of 1985, NACA met with EPA, environmental groups and other parties interested in inerts. Right after the first meeting with EPA, NACA, using List 1 of 53 inerts of toxicological concern as the subject, surveyed 90 of their members to find out: are any of these inerts being used, can they be substituted or replaced, will they be replaced within 3 years, do they serve an unique purpose and to what extent are they being used? We had 67 respondents which represented over 90 percent of the inert ingredient use in our industry. All manufacturers and

formulators provided data and input. The question regarding substitution or replacement in three years would realistically reflect the time necessary to test for shelf-life, compatibility, efficacy and all other criteria necessary to properly evaluate a new formulation.

The survey results, when compiled, showed that:

- 1) of the 53 inert ingredients on the list, only 6 were used extensively by NACA members;
- 2) twenty-nine of the inerts were not used at all;
- 3) seventeen were used ranging from minor (less than 20,000 pounds) to a range of 500,000 - 1,000,000 pounds per year. In some cases only a few hundred pounds were used in processing, most to clean out processing lines;
- 4) xylene was the most extensively used solvent although mixtures of xylene with other solvents were used but in the survey only xylene was mentioned. Since the survey, xylene is no longer listed in List 1 toxicological concern. It is now in List 2 with high priority for testing;
- 5) methylene chloride was used at less than 500 pounds per year primarily for line clearing; and
- 6) formaldehyde was used only in minor quantities in formulated products.

According to EPA, since the 1988-89 data call-in, hundreds of products have been reformulated or cancelled. EPA states that virtually all the list inerts were reviewed and very few can now be identified with agricultural chemical formulations. Even so, efforts are now being made to reduce the use of inerts on List 2.

In a report from EPA, Mr. Rick Tinsworth of the agency stated: EPA has reviewed the available data base for each List 1 inert ingredient and has called in data from registrants of products that continue to contain these toxic inerts. From the first call-in of data to registrants of over 800 products, approximately 400 products have been reformulated or the registrant has committed to reformulate to remove list adjuvants.

Several years ago, I received a list of 26 synthetic organic compounds that had been identified as being detected in Iowa water supplies. I compared that list to what EPA had identified as inerts on List 1 and List 2. Interestingly, there were only 3 List 1 inerts and two List 2 inerts on the Iowa list of 26 compounds. Based on the 1985 industry survey of inerts used in pesticide formulations, only 3 inerts used in pesticide formulations were identified to be on the Iowa list

of 26. Xylene is on the EPA List 2 and only methylene chloride and methyl chloroform of EPA List 1 were identified. Both of these products are minor inerts used in trace amounts in agricultural chemical formulations. Xylene is now on list 2. Xylene and xylene mixtures are widely used as industrial solvents and can be found in many other products of industrial origin which includes gasoline and other petroleum fuels. From this, I concluded that most of the inerts identified on the list of 26 must have come from other sources.

### **Changes in Technology**

The chemical industry, keeping pace with environmental concerns and rapid changes in technology, is constantly upgrading its products to make them more efficacious and compatible with societal needs. New formulations are being developed and marketed. These include dry-flowables, granulars, slow-release micropills, soybean oil and water bases instead of organic solvents, less toxic inert ingredients, and dye-based formulations that include markers to improve applicator coverage. Biological pesticides, now being researched and marketed, are specific for particular pests, cause no direct harm to beneficial insects, and pose negligible risk of environmental damage.

Although the application of biotechnology will result in new products, a decade may elapse before a major product is available for commercial utilization. Conventional chemistry will remain the standard-bearer for pest control for some time to come. Recombinant DNA research and testing will have many regulatory and patent-protection barriers to overcome before any meaningful progress can be made. Specific products for specialized crops or uses will be the first approved for field testing. After the first bio-engineered products are registered, on-the-farm field evaluation and acceptance of these products by the farm community will be essential. Pricing of bio-engineered products must be relative to benefits derived for successful market penetration. Growers, if they see performance and environmental advantages, may accept these new products readily only if the products meet a need not already being satisfied by conventional chemicals and application techniques.

The incorporation, through cell biology, of resistant genes into crop varieties to gain chemical, insect, or disease resistance is being tested. Chemical companies are buying seed companies in order to exploit the concept. Only by

marketing to growers seeds from resistant seed stock developed by this process can a company enjoy the benefits of this technology. The resistant crop variety must be adaptable to a wide area of use to provide sufficient market volume or be of such specialized use to justify the higher cost for introduction and continued production.

Pheromones, trapping, and pest monitoring are changing pest management strategies significantly. Economic threshold evaluation and trap-baiting are used to determine when and what pest management chemical, if any, is required. Placement of pheromones to reduce reproduction of certain insects has reduced the need for chemical control in some instances.

Higher biological activity and lower rates of use per unit/acre for active pest control ingredients are now feasible. Several new products, requiring only grams vs. kilograms per hectare of older products, have been introduced into the marketplace. At the same time, the newer products that have higher biological activity will require an attitude change by the grower regarding application accuracy; sloppiness during application cannot be tolerated. Further, many formulations are being researched or new versions of older products now use nothing but inert carriers. Dry flowables are coming on strong.

As new innovative formulations come to the market, they generally are more biologically active. Thus, less inert product is used per acre. In addition, some new products have none of the inerts of concern. So exposure to the applicator or the environment to inerts of toxicological significance is being even further reduced. Some new formulations have low melting point active ingredients. The need for solvent is reduced as much as 30 to 70 %. They require as little as 2 % or less of surfactant to make them emulsifiable in the water diluent. As rates per acre are reduced and as new innovative ideas come forward, the need for inerts decreases both reducing exposure to operators and to the environment.

Biodegradable packaging (to reduce waste disposal problems) and bulk or minibulk handling with closed systems transfer and dedicated containers will become standard approaches. In some cases, biodegradable cornstarch plastic packaging could be utilized. Water-soluble plastic containers or pouches and effervescent tablets that can be put into the spray tank are possible means of reducing worker exposure and eliminating container disposal problems.

Use of rinsates, container disposal, and recycling options and educational programs are being developed to reduce the chemical disposal load in landfills and to assure the possibility of rinsates being applied to the field as part of the spray application. Recycling plastic or metal containers for resource recovery has great promise.

Some 16 states now have programs.

All of these innovative ideas and practices serve to reduce or completely eliminate the potential for inerts and exposure to humans and the environment. Industry is complying to social needs. Now, we need to keep the ball rolling and inform the public that changes are taking place.

## Using Quantitative Risk Assessment to set a Drinking Water Standard for Alachlor

*Dennis Ward*

*Toxicology Department, Monsanto Agricultural Company*

**D**uring recent years there have been reports of industrial and agricultural chemicals entering North American ground and surface water supplies. The mere presence of a chemical in drinking water does not automatically constitute a state of emergency or human health concern. Since all chemicals, both natural and man-made, have toxicological properties, the risk of experiencing an adverse health effect is dependent on the extent of exposure. Therefore, judgements about drinking water safety must take into consideration the concentration of a chemical that is present. A safe level of human exposure can be established for all chemicals. Quantitative Risk Assessment (QRA) is a recently developed tool that has become widely used in the United States for the regulation of chemicals that are potentially carcinogenic. QRA can easily be used for establishing health-based drinking water standards. This presentation describes how QRA can be used to set a safe drinking water standard for a typical agricultural chemical.

QRA is a process that involves the use of toxicology or epidemiology data to derive a quantitative prediction of human health risk associated with a specific chemical exposure. Chemically-induced health risks are a function of: 1) the chemical's toxicological properties, 2) its potency, and 3) the magnitude, frequency and duration of the chemical exposure. Thus, to perform a quantitative risk assessment each of these parameters must be defined.

Occasionally, human toxicity data (i.e. epidemiology data) are available. In most cases, however, laboratory animal studies are used to define the toxicological properties of a chemical. The operating assumption behind the use of these studies is that laboratory animals and humans will respond alike to a chemical exposure. In the absence of data to the contrary, this is a prudent

assumption. The quantity and quality of toxicity data that is available varies considerably depending on the chemical's intended use. Some chemicals, such as pharmaceutical agents and pesticides, have been extensively tested; yet others (e.g. naturally occurring substances) have very little toxicity data available. Routine toxicology data requirements for pesticides include: acute toxicity (multiple species and routes of exposure), skin and eye irritation, dermal sensitization (i.e. allergy potential), subchronic and chronic toxicity (3 species), carcinogenicity (2 species), developmental toxicity (2 species), reproduction (2 generations), genetic toxicity (3 to 6 test systems), neurotoxicity, metabolism and pharmacokinetics. Chemical potency is determined from these laboratory animal studies. Potential human exposure can be estimated from crop residue and water monitoring studies.

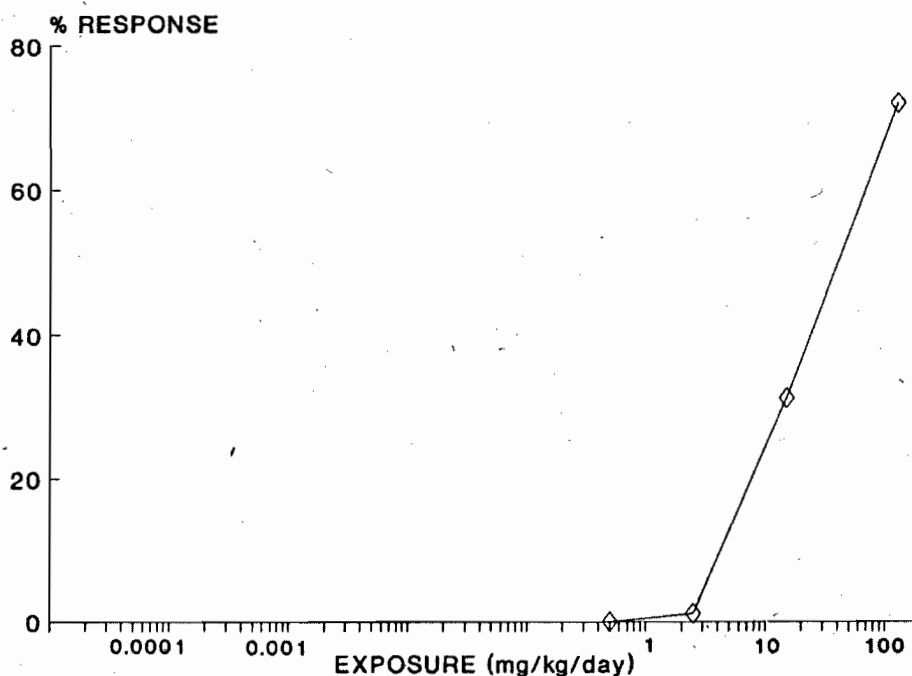
To demonstrate how the risk assessment process functions, evaluation of the herbicide, alachlor, will be used as an example. Alachlor is a preplant or pre-emergent herbicide used for the control of grasses and certain broadleaf weeds in corn, soybeans, peanuts and milo. This product has been on the market and approved for use by the U.S. Environmental Protection Agency (EPA) since 1969. The results of laboratory animal tests reveal that alachlor is no more than slightly toxic following acute exposure, does not produce birth defects or impair reproduction, and is not neurotoxic or mutagenic. Alachlor causes liver and kidney toxicity in animals following prolonged high levels of exposure. Lifetime exposure to high doses has also been shown to cause tumors in laboratory rats, but not mice. Alachlor is poorly absorbed through the skin. Significant species differences in alachlor metabolism and pharmacokinetics have been observed.

The formation of benign nasal tumors in rats is a toxicological response of concern and will constitute the basis for the alachlor QRA. An explanation of how these rodent cancer studies are conducted will aid in the understanding of the QRA process. Multiple groups of male and female rats (50 rats/sex/group) are fed a diet containing different concentrations of alachlor over the majority of their lifetime. Rats in the high level exposure group receive what is referred to as a "maximum tolerated dose" (MTD). The MTD is intentionally selected to produce significant toxicity in the test animals. The animals are examined throughout the study for evidence of toxicity. At the end of the study all animals are autopsied and examined microscopically for the presence of tumors and other toxicological effects. The number of animals found to have tumors can be plotted as a function of exposure level (see Figure 1).

encountered by humans. This part of the QRA process is commonly referred to as the "low-dose extrapolation".

At present, EPA and several state regulatory agencies are using the "linearized multistage model" (LMS) for QRA of chemical carcinogens. The LMS is a conservative model that predicts a 95% upper confidence bound (UCB95) estimate of excess lifetime cancer risk. The term "excess" refers to the fact that this estimate represents risk above and beyond that of getting cancer from other causes. By computing an upper bound on risk (i.e. UCB95), the LMS minimizes the likelihood of underestimating the true risk. True risk will be lower than this upper confidence bound ninety-five percent of the time and may be as low as zero. The LMS enables computation of risk associated with any estimate of exposure or computation of exposure associated with any level

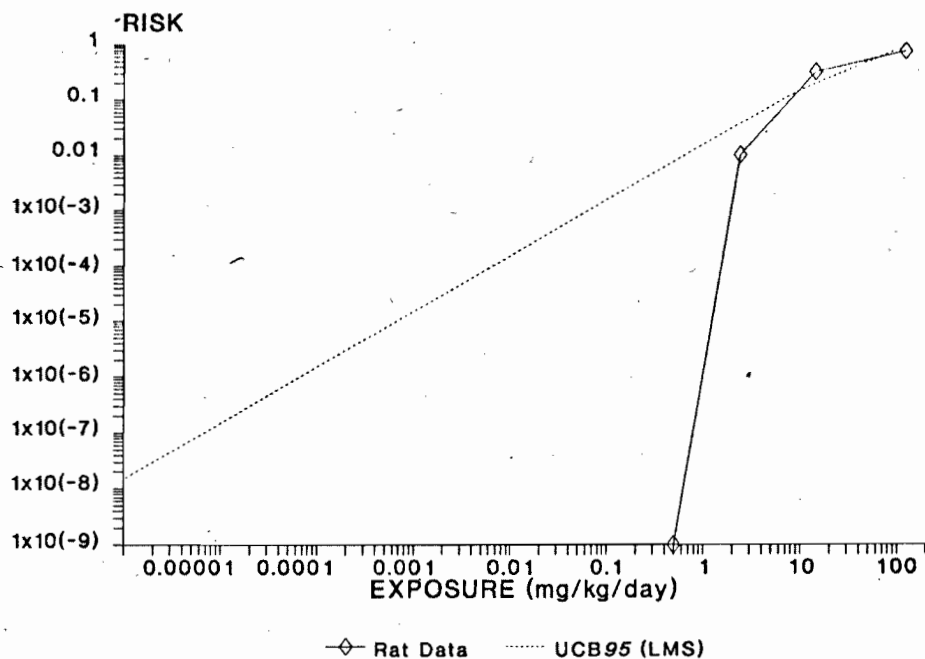
**Figure 1. Incidence of nasal tumors in rats plotted as a function alachlor exposure.**



Since the number of animals with tumors increases as the exposure level increases, a mathematical dose-response relationship for alachlor exposure and nasal tumor formation can be established. A number of mathematical "models" have been developed to describe this dose-response relationship. These models are used to predict the probability (i.e. risk) of tumor formation at a given level of exposure. They are also used to extrapolate risk associated with high exposure levels received by animals to the low levels of exposure likely to be

of risk. At low levels of exposure, the UCB95 becomes linear. The slope of the UCB95 line represents a measure of carcinogenic potency for the chemical and is commonly denoted as  $q1^*$ . At low levels of exposure, risk is computed as the product of potency and exposure: [  $UCB95 = q1^* \times \text{mg/kg/day}$  ]. Risk is typically expressed in one of the following formats (using one in one million as an example): 0.000001 or  $1 \times 10^{-6}$  or  $1E-6$ .

**Figure 2.** The 95% upper confidence bound (UCB<sub>95</sub>) estimate of excess lifetime risk predicted by the linearized multistage model (LMS) is plotted as a function of alachlor exposure. Also shown is the measured risk (as opposed to predicted risk) of tumor formation in rats.



A graphical representation of the LMS low-dose extrapolation for alachlor is shown in Figure 2. The solid line represents measured cancer risk in rats (i.e. tumor incidence) and the dotted line represents LMS predictions of risk, both plotted as a function of alachlor exposure over a lifetime. The  $q_1^*$  for alachlor is 0.015 (mg/kg/day)<sup>-1</sup>. This graph illustrates the very conservative nature of the LMS. The LMS low dose extrapolation for alachlor is strictly linear, whereas the observed rat dose-response data are not. At lower levels of exposure this results in predictions of risk that are dramatically higher than would be expected based on the rat data.

For a herbicide like alachlor, there are basically three opportunities for potential human exposure: 1) consumption of crops containing alachlor residues; 2) consumption of water containing alachlor; and 3) dermal contact or inhalation of the product during field application. Numerous crop residue studies have been conducted to measure potential dietary exposure. Water monitoring studies have been conducted to measure the prevalence of alachlor in drinking water. Field biomonitoring studies have been conducted to measure potential applicator exposure.

These studies provide a measure of potential alachlor exposure for which it is possible to compute an estimate of excess lifetime cancer risk. Estimates of theoretical risk for dietary, drinking water and applicator exposure are presented in Table 1. Risk estimates of 1x10(-5) or less are generally considered to be trivial; whereas, risks exceeding 1x10(-4) may require regulatory or remedial action. For comparative purposes, Table 1 also presents the calculated margins of safety for these sources of exposure. The margin of safety is a ratio of the nontoxic exposure level from the most sensitive animal test to the estimate of human exposure. For suspected carcinogens a margin of safety in excess of 1,000 is generally considered to be protective of public health. As shown in Table 1, potential human exposure to alachlor is low. As a result, risks are small and the margins of safety are large.

An exposure value can be computed for any given level of risk and is referred to as a "risk specific dose" (RSD). Public health officials can use the RSD to set an acceptable exposure limit, such as a safe drinking water standard. The RSD for alachlor corresponding to an excess lifetime cancer risk of 1x10(-6) is: 6.6x10(-5) mg/kg/day (milligrams of alachlor per kilogram of body weight per day). A 60 kg adult drinking 2 liters of water

**Table 1.** Calculated values of excess lifetime risk (UCB<sub>95</sub>) and margins of safety for possible sources of alachlor exposure.

Source of Exposure	Exposure (mg/kg/day)	Risk (UCB <sub>95</sub> )	Margin of Safety
Diet	9.5x10 <sup>-6</sup>	1x10 <sup>-7</sup>	105,000
Drinking Water <sup>a</sup>	2.9x10 <sup>-6</sup>	4x10 <sup>-8</sup>	345,000
Field Application	5.8x10 <sup>-6</sup>	9x10 <sup>-8</sup>	216,000

a - Average annualized mean concentration

per day, containing alachlor at a concentration of 2 micrograms/L (ppb), would receive this level of exposure. Thus, a drinking water standard of 2 micrograms/L of alachlor is associated with an excess lifetime cancer risk of no greater than 1x10(-6).

If QRA is used for setting of health-based standards, it should be with a clear understanding of what these risk numbers really mean. The LMS predicts an upper confidence bound on *excess* lifetime risk. This is risk above and beyond that of getting cancer from other causes. In the United States the actual cancer rate from all causes is approximately 0.3. This means that 3 out of every 10 persons will get cancer from one cause or another. Lifetime exposure at the alachlor 1x10(-6) RSD would theoretically increase an individual's cancer risk from 0.3 to 0.300001. A risk of 1x10(-6) does not mean that one out of every million people will get cancer from alachlor. These measures of risk should be viewed in the context of a "theoretical maximally exposed individual or population". For 1,000,000 people that each drink 2 liters of water per day containing 2 ppb of alachlor for a lifetime, the expected number of cancers could theoretically increase from 300,000 to 300,001. In the real world there is virtually no possibility that 1,000,000 persons will consume water containing this much alachlor for a lifetime.

QRA is a conservative process that is preferred over the safety factor method for regulation of suspected carcinogens in the United States. Proponents of QRA favor the process because theoretically it takes into consideration the shape of the dose- response curve. In practice,

however, this does not always happen. Inspection of the alachlor data presented in Figure 2 reveals LMS predictions of risk (i.e. UCB95) that are completely linear with dose, whereas the actual animal data are not. The LMS is consistent with some theoretical molecular mechanisms of carcinogenesis. It is rare that the cancer mechanism is known for any given chemical. The LMS assumes there is no exposure threshold (i.e. risk-free exposure level) for the cancer response even though one is often observed in the laboratory animal tests. Another assumption in the QRA process is that continuous lifetime exposure received by the test animals is relevant for predicting risk associated with intermittent human exposure. Due to these limitation, QRA has not been widely adopted outside the United States. Other developed countries of the world continue to rely on the safety factor approach for regulation of agricultural and industrial chemicals. Both approaches have merit. Continued research into the mechanisms of chemical carcinogenesis will undoubtedly lead to refinements in quantitative risk assessment.

# Atrazine Water Quality Issues: An Industry Perspective

K. Balu

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(The following is a synopsis of Dr. Balu's talk, based on his slide presentation)



survey of private wells was conducted by CIBA-GEIGY which included water sample analyses for triazine herbicides. The tables shown below give general information on these wells and the herbicides tested for.

## Sources for Atrazine Detections

Description	No. of Wells			
	GA	IA	IL	WI
Location				
total wells	60	60	60	60
wells with detections >0.1 ppb	10	18	1	29
<b>Sources</b>				
back siphoning	1	0	0	0
spill at well	4	0	1	5
mixing/loading	5	1	0	3
karst area	0	1	0	0
poor casing	0	0	0	6
unknown	0	16	0	15

## Environmental fate data and lifetime health advisory levels (HAL) for triazine herbicides

Common name	lifetime HAL (ppb)	degradation		relative mobility
		solubility (ppm)	half-life (days)	
atrazine	3.0	33.0	60	1.37
simazine	4.0	3.5	75	1.04
propazine	10.0	8.6	169	0.64
ametryn	60.0	185.0	57	0.71
prometon	100.0	750.0	>365	NA

Sources for atrazine detections include point source routes: bulk storage sites, mixing/loading spills and back siphoning; direct conduits include sink holes, faults/fractures, abandoned wells, drainage wells, dry wells and poor casing in wells; surface water infiltration comes from streams in recharge area and lakes and ponds; and field leaching occurs from normal infiltration and sandy soils.

A large scale study was conducted in which retrospective monitoring for atrazine was done. Sites selected for this study were in high product use areas with high ground water vulnerability (based on DRASTIC scores). Sixty wells were selected in each of 4 regions (total of 240 wells).

Atrazine monitoring sites were located in McLean county, Illinois (corn), Floyd and Mitchell counties, Iowa (corn), the Central sands area in Wisconsin (potatoes) and Dougherty Plains, Georgia (peanuts). Wells targeted for atrazine monitoring were located within 500 feet of the field and tapped shallow aquifers (<100 feet). A site inspection was conducted to avoid defective wells and possible point source contamination, and the well owner's permission was obtained. Domestic, observation and monitoring wells were included in the study and well construction data were available for all sites.

Hydrogeological vulnerability scores for atrazine monitoring locations are presented below. A Varscore greater than 143 indicates high vulnerability.



State	Counties	Varscore	State	Counties	Varscore
Georgia	Calhoun	165	Iowa	Floyd	134
	Decatur	179		Mitchell	132
	Dougherty	159	Wisconsin	Adams	179
	Baker	195		Juneau	162
	Miller	195		Portage	168
	Mitchell	183		Waushara	129
	Seminole	192		Wood	158
Illinois	McLean	125			

A summary of the monitoring data for atrazine is presented below:

St.	# wells	# analyses	Distribution				
			<0.1	0.1-0.5	0.5-1.0	1-10	>10ppb
GA	60	237	210	13	5	9	0
IA	60	230	165	46	9	10	0
IL	60	232	228	0	0	0	4
WI	62	220	143	50	10	12	5
Total	242	919	746	109	24	31	9
% Distribution			81.1	11.8	2.6	3.4	0.98

The frequency distribution for atrazine monitoring data follows:

	— Groundwater —			
	sensitive areas	general monitoring	all areas	surface water
# observations (N)	2604	7251	9855	4729
median (ppb)	<0.25	<0.25	<0.25	<0.25
90% below (ppb)	<0.25	<0.25	<0.25	2.25
95% below (ppb)	0.75	<0.25	<0.25	3.75
99% below (ppb)	6.25	1.25	2.25	13.75

The distribution of wells with atrazine detections follows:

State	# wells	# wells with N detections				total wells with detections
		N=4	N=3	N=2	N=1	
GA	60	4	1	3	2	10
IA	60	12	2	4	0	18
IL	60	1	0	0	0	1
WI	62	9	6	3	11	29
Total	242	26	9	10	13	58

The level of atrazine in affected wells is outlined below:

Description	# wells			
	GA	IA	IL	WI
location				
total wells	60	60	60	62
wells with detections >0.1 ppb	10	18	1	29
wells with detections >1 ppb	3	5	1	8
wells with detections >0.1 ppb from unknown sources	0	16	0	15
wells with detections >1 ppb from unknown sources	0	3	0	2

*The atrazine monitoring project is summarized below:*

Two hundred and forty two wells were monitored in four sensitive regions in Georgia, Illinois, Iowa and Wisconsin. The wells were selected in the uppermost aquifer, were relatively shallow and were close to fields with high atrazine use. Sixty-five wells (27%) showed detections for atrazine. Site investigations were conducted to determine contaminant sources. Only 5 wells (3 in Iowa and 2 in Wisconsin) showed detections >1 ppb attributed to unknown sources. All other detections were attributed to known or suspected point sources. Leaching appeared to be a minor pathway for atrazine detection in ground water and source investigation was essential for interpretation of the monitoring data.

*Iowa-based study of atrazine in ground water*

A computer generated map of Iowa (using MAPINFO) showed the locations of 235 ground water wells that have been sampled for atrazine. Of the 235 wells sampled, 68 had average atrazine concentrations exceeding 0.1 ppb and 27 were impacted by point sources. Conclusions drawn from this computer survey were: 1) the MAPINFO system is very useful for the interpretation of monitoring data; 2) the data base is flexible enough to address any queries in an interactive mode; 3) atrazine findings in ground water showed poor correlation with nitrate levels, well depths or DRASTIC scores; 4) follow-up investigations showed that point sources were the major causes for atrazine detection (these investigations are essential for understanding atrazine findings); and 5) the MAPINFO system has limited applications for the interpretation of the surface water monitoring data.

CIBA-GEIGY has developed a response to public concerns about ground water quality and atrazine exposures and how they can be reduced. A Best Management Program for atrazine was instituted on September 1, 1990, which contains the following points:

- all atrazine-containing products become RUPs
- application through irrigation system prohibited
- maximum rate for corn and sorghum 3 lbs. ai/A
- lists need for contaminant and mix/load pads
- adds a protective clothing requirement
- applications must be made before crops reach 12 inches in height
- no mixing/loading/application within 50 feet of wells-sinkholes
- noncrop-land application rates reduced to 10 lbs. ai/A.

Based on its investigations of atrazine and ground water quality, CIBA-GEIGY has come to the following conclusions:

- point sources are the major causes for atrazine detections
- site investigations are essential to determine the sources
- atrazine findings show poor correlation with nitrate levels, well depth or DRASTIC scores
- data base and mapping system are very useful for interpretation of monitoring data

CIBA-GEIGY has implemented a Best Management Program to address ground water issues.

CIBA-GEIGY has also conducted a long term study in which surface water monitoring was done in the Mississippi River and a number of its tributaries. Monitoring data for atrazine over a ten-year period showed seasonal peaks during the growing season and ambient levels during other periods of the year. No increase in the ambient levels or seasonal peaks were found during the ten-year period. Levels found in small tributaries reflected the impact of runoff from use areas, whereas the levels in the major rivers were significantly lower because of the dilution factor. Typical monitoring data for atrazine showed in the range 0.1 ppb - 5.9 ppb.

CIBA-GEIGY also conducted surface water monitoring of fourteen rivers in seven states in major atrazine use areas over a two year period. Samples were collected once in two weeks during growing season and monthly at other periods. Sampling sites for this study included the following:

Site No.	River	County, State
A-3	West Palm Beach Canal	Palm Beach, Florida
A-9	Wapsipinicon River	Buchanan, Iowa
A-11	Coon Creek	McHenry, Illinois
A-18	LaMoine River	Hancock, Illinois
A-20	Little Crooked Creek	Washington, Illinois
A-23	Pigeon River	LaGrange, Indiana
A-27	Wabash River	Knox, Indiana
A-28	Ninnescah River	Reno, Kansas
A-34	Deer Creek	Ingham, Michigan
A-37	Pigeon River	Huron, Michigan
A-38	Hog Creek	Hillsdale, Michigan
A-47	Platte River	Hall, Nebraska
A-53	Clifty Creek	Bartholomew, Indiana
A-54	Little Indian Creek	Floyd, Indiana

Conclusions drawn from this study showed that atrazine detections ranged from <0.1 ppb to 30 ppb with a mean of 1.48 ppb. Ninety-one percent of the detections were less than 3 ppb. Stream-flow measurements and precipitation records indicated good correlation between atrazine detection and runoff events, with the highest concentrations found after atrazine applications followed by heavy rainfall.

CIBA-GEIGY has proposed atrazine exposure reduction measures for surface water including reducing soil erosion and runoff through terracing, contour planting, conservation tillage, utilizing filter strips and buffer strips, incorporating pesticides, and introducing changes in the formulation and use of additives.

Other factors which could affect atrazine exposures to surface water are pesticide mixing, loading and disposal methods, the

interaction of surface water with ground water, changes in pesticide application timing and selection, integrated pest management approaches and compliance with conservation measures.

Based on its investigations of atrazine and surface water quality, CIBA-GEIGY concluded that:

- atrazine levels in rivers show seasonal peaks during growing season and ambient levels at other periods
- atrazine levels correlate with rainfall and runoff events
- atrazine levels in large rivers are significantly lower because of dilution effects of stream flow.

CIBA-GEIGY has proposed a Best Management Program for addressing surface water quality issues with respect to atrazine.

## Speaker Biographies

*K. Balu* is Senior Group Leader, Contract Studies, in the Residue Chemistry Department, Agricultural Division of CIBA-GEIGY Corporation, Greensboro, North Carolina. His responsibilities include research in ground and surface water and residue chemistry studies related to registration of pesticides developed by CIBA-GEIGY, and all residue chemistry and environmental studies conducted in outside contract facilities. He has a Ph.D. degree in analytical chemistry from Columbia University and a M.B.A. degree in management from the University of North Carolina.

*Michael Burkart* is a geophysicist with the U.S. Geological Survey, Water Resources Division, Iowa District. His recent work has involved coordination of interagency research on the impacts of agricultural chemicals on water resources in twelve midwestern states. Prior to working with the U.S.G.S., he taught physics and mathematics in a West African college and worked as a geophysicist for the oil industry. He has a B.S. degree in mathematics and physics from the University of Wisconsin and a Ph.D. degree in geology from the University of Iowa.

*Keith Cherryholmes* is Assistant Director of External Programs and Research at the University Hygienic Laboratory, the University of Iowa. He has responsibility for coordinating and managing all extramural programs and research the Laboratory has ongoing with federal, state and private funding

sources. He has conducted extensive research on the impact of agricultural runoff on water quality and has worked on several international projects through the World Bank and the Islamic Development Bank. He has a Ph.D. degree in environmental engineering from the University of Iowa.

*Anna M. Fan* is Chief of the Pesticide and Environmental Toxicology Section, California Department of Health Services. She is in charge of toxicology and risk assessment activities as related to pesticide toxicology, agricultural worker health and safety, drinking water contamination, chemical contaminants in food and consumer products, and chemical standards development. Her research interests include pesticide immunotoxicity and metal carcinogenesis. Dr. Fan is a member of the Society of Toxicology and the Association of State and Territorial Risk Assessors, and is a Diplomate of the American Board of Toxicology. She has a Ph.D. degree in toxicology from Utah State University.

*Peter Isacson* is Emeritus Professor of Preventive Medicine and Environmental Health at the University of Iowa, and was acting Director of CHEEC during 1987-88. He was an EIS officer with the Communicable Disease Center, USPHS, and a faculty member at Yale University and SUNY, Buffalo, prior to his appointment as Chair of Preventive Medicine and Environmental Health at

Iowa. He served as Principal Investigator of the Iowa SEER Program, was a member of the EPA Task Force on Planning Epidemiology Research and sat on the Safe Drinking Water Committee of the National Research Council. His research involves water quality as a risk factor for cancer and birth defects and risk assessments at toxic waste dump sites. He received his M.D. degree from the University of Nebraska.

**Burton Kross** is Assistant Professor of Preventive Medicine and Environmental Health at the University of Iowa. He is a consultant to the National Governor's Association on water quality issues, and is currently conducting research on exposures to contaminants in rural water supplies and exposures to pesticide applicators. Prior to this, he held several management positions with ERT, Inc., a subsidiary of COMSAT, during which he did extensive international consulting work. He serves on state advisory committees for the DNR, the Department of Public Health, and the Governor's Steering Committee on Radon. He has a Ph.D. degree in environmental engineering from the University of Iowa.

**Robert Libra** has been a hydrogeologist with the Iowa Department of Natural Resources-Geological Survey Bureau since 1982. His responsibilities involve many aspects of water quality problems, and have mainly been directed towards understanding the movement and fate of agricultural contaminants in surface and ground water. Prior to this, he worked for the University of Wyoming. He received his B.S. and M.S. degrees in geology from the University of Wisconsin-Superior and Indiana University.

**Michael Liszewski** is a hydrologist with the Hydrologic Studies Section of the U.S. Geological Survey, Iowa District. He is conducting research on the effects of agricultural chemicals on water quality in Iowa. Prior to this, he worked as a pesticide residue chemist with the U.S. Food and Drug Administration in Atlanta and with the U.S.G.S. at the National Water Quality Lab in Arvada, Colorado. He has a B.S. degree in chemistry from Southern Utah State College and an M.S. degree in geology from Washington State University.

**Charles Lynch** is Assistant Professor with a joint appointment in the Department of Preventive Medicine and Environmental Health and the Department of Pathology at the University of Iowa. He is co-Principal Investigator of the Iowa SEER Program and Director of the CHEEC Environmental Data Management Core. His research interests

include the pathology of cancer, environmental epidemiology, and cancer and adverse reproductive outcome epidemiology. He has a special interest in cancer and drinking water contaminants. In 1987, Dr. Lynch received a Preventive Oncology Academic Award from the National Cancer Institute. He received his M.D. degree and Ph.D. degree in epidemiology from the University of Iowa.

**Harry Mussman** is Deputy Assistant Secretary for Science and Education, U.S. Department of Agriculture. Prior to his appointment in 1989, he was an Assistant Professor at Kansas State University and Associate Professor of veterinary science at the University of Nebraska. He served with the USDA in Consumer and Marketing Services and the Animal and Plant Health Inspection Service, held a position with the Food and Agriculture Organization of the U.N. in Rome, and has been Director of the Animal Health and Plant Protection Program for the Inter-American Institute for Cooperation in Agriculture. He has a Ph.D. degree in microbiology and a D.V.M. degree from Kansas State University.

**Gene Parkin** is Professor and Chair of Civil and Environmental Engineering and Director of CHEEC at the University of Iowa. His research involves biodegradation of organic materials and the fate and effects of toxic materials in the environment. He has served as consultant to du Pont Corporation on in-situ biodegradation for remediation of various hazardous waste sites. He received the James R. Croes Medal from the American Society of Civil Engineers for research on modeling the effects of toxic substances in anaerobic biological processes. Dr. Parkin is a member of EPA's Environmental Engineering Review Panel and reviews proposals for the National Science Foundation. He has a Ph.D. degree in civil engineering from Stanford University.

**Earl Spurrier** is Vice President for State Affairs, National Agricultural Chemicals Association, Washington, D.C. He has been a dairy farmer and county agent and worked as an Extension Agronomist for the University of Illinois. He was employed for 25 years with Monsanto Company of St. Louis as Technical and Product Supervisor in Herbicide Marketing, Manager of the Agronomic Systems Department and Director of Government Relations and Environmental Operations. Dr. Spurrier has been with NACA since 1982, serving as Vice President for Regulatory Affairs prior to his current position. He has a Ph.D. degree in agriculture from the University of Illinois.

*Dennis Ward* is a Toxicology Manager with Monsanto Agricultural Company, St. Louis. He is responsible for product safety testing, risk evaluation and environmental compatibility assessment on numerous agricultural products, including the alachlor product line. Cancer risk

assessment is his area of special interest. He is certified by the American Board of Toxicology. He received his Ph.D. degree in pharmacology and toxicology from the University of California at San Francisco.

## Poster Abstracts

**Title** *Modeling dissolved oxygen, nitrate and pesticide concentrations in the subsurface environment*

**Investigators** D.R. Nair, J.L. Schnoor, Department of Civil & Environmental Engineering, the University of Iowa

**Abstract** A numerical model is developed to simulate the fate and transport of pesticides in the subsurface environment and uses microbial degradation kinetics dependent on varying soil environments including soil moisture, temperature, organic carbon content, oxygen content and pesticide concentration. The model is a modification of the Pesticide Root Zone Model (PRZM) with improved soil moisture and pesticide fate and transport computation subroutines. Laboratory batch studies were also conducted to study the mineralization rates of <sup>14</sup>C ring labelled atrazine in soils incubated under different environmental conditions, to determine kinetic parameters that could be included in the model. Environmental parameters varied include soil moisture, soil type, surrogate organic plant exudates, electron acceptor conditions and atrazine soil concentration. The model was calibrated and tested with experimental data from a small plot study conducted in Amana, Iowa and an independent field study done in Georgia. Simulations were performed and the results show that aerobic degradation in the unsaturated zone is the dominant fate process for atrazine. Organic carbon content and temperature were important for atrazine degradation by microbes. Plant uptake within the root zone, rainfall intensity and timing were also found to be important in affecting the amount of pesticide that leached into groundwater.

**Title** *Pesticide oxidation by ozone for point-of-use/point-of- entry treatment systems*

**Investigators** B.C. Kross, L. Odell, J. Hwang, L. Raue, Department of Preventive Medicine & Environmental Health, the University of Iowa

**Abstract** The main purpose of this project was to examine the feasibility of ozone oxidation of six common pesticides (alachlor, atrazine, cyanazine, metolachlor, metribuzin and propachlor) for point-of-use/point-of-entry drinking water treatment. The challenge concentration for each pesticide was 10ppb, which is in the range of ambient levels of these pesticides in contaminated groundwater and surface water in agricultural regions in the nation. Ozone feed rate was 1 gram per hour. Tests were conducted in a closed system (batch mode) with varied contact times. One test was conducted in an open system (continuous mode) as a simulation of residential treatment. Pesticide oxidation by ozone at these low concentrations is feasible and is dependent on concentration times contact time (CT values). Under the batch mode test conditions, oxidation of the pesticides is complete within 8 hours. Under the continuous mode test conditions, mean reductions of pesticides were highly variable, ranging from 20% for cyanazine to 70% for metribuzin.

**Title** *Ultraviolet phototoxicity of some non-steroidal anti-inflammatory agents (NSAIDs) on the retina of the eye*

**Investigators** M. Scott, J.S. Pulido, Department of Ophthalmology; T.K. Shires, Department of Pharmacology, the University of Iowa

**Abstract** The goal of this project is to develop an in vitro technique for measuring the retinal toxicity of drugs. Retinotoxicity is measured in retinal cell cultures as the dose-dependent decline in amount of evoked neurotransmitter released per cell. Attention has been focused on the amino acid transmitters glutamine (Glu), taurine (Taur) and glycine (Gly), the former representing the major neurotransmitter substance in the retina. Most amino acids were found to be released from retinal cells into serum-free balanced salt solutions in a manner independent of depolarization. Exceptions included Glu and Taur. The reliability of decline in potassium-evoked release of Glu and Taur as a measure of toxicity was tested with the retinotoxin

gentamicin. This aminoglycoside antibiotic is used intravitreally to treat severe intraocular infections. Plots were constructed of the percent decline in neurotransmitter release as a function of the log-dose (dose-effect curves) for each of 3 neurotransmitters: Glu, Taur and Gly. Regression analysis of these curves yielded slope values of -46.5 for Glu, - 81.8 for Taur, and -77.8 for Gly with r values of .998, .70 and .36, respectively. These data show that gentamicin has significantly inhibited Glu release but not the release of Taur or apparently Gly. Further, gentamicin may be selectively toxic to Glu-releasing neurons and not to those releasing Taur or possibly Gly. From the regression slope for Glu, the half maximal toxicity of gentamicin in vitro was 410 microgram/ml. These results demonstrate that this system can sensitively measure retinal toxicity of administered agents and this warrants extension of this technique to other agents. We are presently developing a phototoxicity assay using this technique.

**Title** *Investigation of the feasibility of adapting immunoassay tests for the detection of minute amounts of pesticides in water*

**Investigators** J.M. Cowan, S.L. Berberich, University Hygienic Laboratory, the University of Iowa

**Abstract** At present there is no routine, effective and rapid way to detect modern pesticides reliably at concentrations below 0.1 micrograms/L. The University of Iowa Hygienic Laboratory (UHL), using routine gas chromatographic techniques, detects several pesticides down to approximately 0.1 micrograms/L by extracting 1L water samples with organic solvents, concentrating the sample extract to a final volume of 2 mL, and using about 0.5 mL of this concentrated sample extract to detect and identify pesticides by gas chromatography (GC) using a nitrogen/phosphorous detector. Detection of pesticide concentrations below this limit may be useful in identifying trends of increased pesticide contamination before there is a real health risk, allowing more options in addressing and correcting the possible cause of the pesticide contamination. In this study we demonstrate a procedure, using immunochemistry, for improving the detection limit approximately 300-fold for the pesticides atrazine and alachlor.

**Title** *Development of an immunoassay for the detection of glyphosate in water*

**Investigators** G.M. Breuer, S.L. Berberich, University Hygienic Laboratory, the University of Iowa

**Abstract** Glyphosate, a fairly recent broad-spectrum herbicide sold by Monsanto under the trade name Roundup, is a water-soluble liquid product of increasing use. The compound was included on the "list of 83" compounds for which Congress required the U.S. EPA to consider (and adopt on a regular schedule) regulations under the SDWA amendments of 1986. Chemically, glyphosate is N-(phosphonomethyl)glycine, and this combination of highly polar phosphono, carboxylic, and amino functions in a compound with a molecular weight of only 169.07 leads to its high solubility in water (12g/L) and its insolubility in most organic solvents. Thus, routine solvent extraction and analysis techniques do not work. A simple test to detect the presence of glyphosate in drinking water or ground and surface water in a restricted area would be very valuable and more cost effective. Recently, commercial kits have been available for the detection of several pesticides; glyphosate is not one of them. These kits are specific and can detect pesticides in raw water without clean-up or concentration steps in some cases with a sensitivity as low as 1 microgram/L. The simplicity and the relatively low cost of these tests for analysis is very attractive. In this project we propose to study the feasibility of developing such a test for glyphosate. Present at the University of Iowa are all the facilities and personnel required for the generation of a monoclonal antibody to glyphosate. If a monoclonal antibody is identified, both sensitive and specific for the glyphosate molecule, an assay configuration similar to commercially available kits will be developed.

**Title** *Analysis of aflatoxins in grain dust*

**Investigator** M.I. Selim, M. Tseui, Department of Preventive Medicine & Environmental Health, the University of Iowa

**Abstract** The primary objective of this research is to develop and validate a fast and sensitive method for the detection of aflatoxins in grain dust. The analytical approach involves the application of supercritical fluid extraction (SFE) followed by high pressure liquid chromatography (HPLC) analysis. The ultimate goal of the method development is to combine SFE and HPLC on-line for a one-step extraction and analysis of very small samples. Personal air sampling pumps are used to collect airborne dust samples on fiber glass filters during field harvesting, grain unloading, and animal feeding operations. Bulk grain and settled dust samples are also collected for comparison of their aflatoxin content with the airborne concentrations.

Field samples are collected from inside and outside harvesting tractor cabs. The concentrations of aflatoxin B1 found in the airborne dust samples collected from animal feeding buildings ranged between 5 and 8 ng/m<sup>3</sup> of air. The average concentration of aflatoxin B1 in bulk grain samples is found to be 28 ng/g. Much higher concentrations of aflatoxin B1 are found in airborne dust samples collected outside tractor cabs during the harvesting (67 ng/m<sup>3</sup>) and grain unloading (93 ng/m<sup>3</sup>) operations. Even higher concentrations of aflatoxin B1 are found in settled dust samples collected inside the animal confinement buildings (200 - 240 ng/g). Aflatoxin B1 concentrations up to 729 ng/g are found in settled dust samples collected inside industrial grain handling and storage facilities. The data demonstrate that farmers and grain handling workers may be exposed to potentially hazardous concentrations of aflatoxins. Further work is currently underway to assess the health risk to farmers and grain workers based on long term exposure measurements.

**Title** *Toxicology and purification of components of a common corn contaminant, Fusarium moniliforme: effects on early stages of carcinogenesis and fetal development.*

**Investigators** S. Lebepe-Mazur, E. Hopsmans, P. Murphy, S. Hendrich, Department of Food Science and Human Nutrition, Iowa State University

**Abstract** *Fusarium moniliforme* is a common contaminant of corn throughout the world. The carcinogenic (initiating and promoting) potential of an alcohol:water (1:1) extract of *F. moniliforme* (FUMX), containing 20 ppm fumonisin B1 was assayed. Groups of six 5-week-old female F344/N rats were fed a semipurified diet, with or without FUMX. A dose of initiating agent, diethylnitrosamine (DEN, 30 mg/kg body weight), was given orally. Placental glutathione S-transferase positive (PGST[+]) hepatocytes were detected by immunohistochemistry and counted on 5 frozen hepatic sections/rat, as an endpoint to assess early stages of carcinogenesis. Treatments and results were as follows:

Group Treatment	PGST[+] hepatocytes/cm <sup>2</sup>
1. diet, 13 wks	0.00 a
2. diet, 1 wk, DEN, diet 12 wks	0.44 a
3. FUMX diet, 13 wks	0.10 a
4. FUMX diet, 1 wk, DEN, diet 12 wks	1.98 b
5. FUMX diet, 1 wk, DEN, FUMX diet 12 wks	2.02 b

Groups not sharing a letter differed significantly,  $p < 0.05$ . FUMX had significant co-initiating activity. *Fusarium moniliforme* infection of feed has been shown to promote hepatocarcinogenesis, and may pose a cocarcinogenic risk even during short-term, low-level exposure.

**Title** *Urban/rural differences in cancer incidence and mortality among Iowa residents*

**Investigators** R.A. Oppliger, C.F. Lynch, L.F. Burmeister, D.B. Olson, C.J. Van Hoesen, W.K. Elgin, State Health Registry of Iowa, Department of Preventive Medicine & Environmental Health, the University of Iowa

**Abstract** Previous epidemiologic studies have suggested an association between rural residence and certain types of cancer including prostate and brain cancer, leukemia, and non-Hodgkin's lymphoma. While most of these studies have involved analysis of death certificate data, a few have included analysis of cancer incidence data, and none have involved simultaneous analysis of death certificates and cancer incidence data. The present research consists of a descriptive epidemiologic study to evaluate the differences in cancer incidence and mortality between rural and urban Iowa residents from 1973 through 1988.

**Title** *An assessment of infant exposure to nitrate/nitrite in breast milk and rural well-water*

**Investigators** C.I. Dungy, L.B. Dusdieker, Department of Pediatrics; B.C. Kross, Department of Preventive Medicine & Environmental Health, the University of Iowa

**Abstract** The purpose of this study is to determine the relationship between maternal infant feeding practices and infant exposure to nitrate/nitrite contamination in rural well-water. The Iowa Statewide Rural Well Water Survey (SWRL) reported that about 18.3 % of all private rural well-water samples tested in Iowa exceeded the U.S. EPA maximum contaminant level for nitrate (10mg/L NO<sub>3</sub>-N). Infants are particularly vulnerable to high concentrations of nitrate/nitrite in drinking water. Although in recent years few cases of infant methemoglobinemia (a nitrate/nitrite induced condition) have been reported in Iowa, the condition may be misdiagnosed and its effect on state and national infant morbidity and/or mortality data underestimated. The study identified 384 women residing in northwest Iowa who had infants under 6 months of age. These mothers were invited to participate; of the 155 who responded, 55 were willing to participate and 70 were unwilling or unable to take part. Recruitment for 2 groups,

which includes breastfeeding mothers consuming community water supplies (less than 45 mg/L of NO<sub>3</sub>) and formula feeding mothers using community water supplies to mix the infant formulas, is complete. Breast milk, urine and water samples are currently being analyzed. In response to an extensive statewide media campaign conducted by the Iowa Department of Public Health warning about nitrate in drinking water, few mothers of infants under 6 months of age are using private well water for either their own use or to prepare their infants' formula. Recruitment to the remaining two groups (breastfeeding mothers consuming private well water; formula feeding mothers using private well water to mix formula) has been far less than anticipated. Therefore, 30 breastfeeding infant- mother pairs will be recruited from the Pediatric Outpatient Clinic, University of Iowa Hospitals and Clinics. To be eligible for the study, the mothers must be breastfeeding their infants at least twice daily, must be free of chronic illness, and be non- smokers. The infants must be older than 6 months of age and consuming breast milk alone or in combination with baby foods. In a 3 day study, these women will consume water provided by the study investigators. Breast milk and urine samples will be taken each day and analyzed for nitrate/nitrite content.

*Title Biotransformations and transport on monoaromatic hydrocarbons under stimulated denitrifying conditions in soil columns*

*Investigators* G.F. Parkin, M.E. Vermace, Department of Civil & Environmental Engineering, the University of Iowa

*Abstract* Perhaps the largest contributors of point-source contamination of ground water are leaking underground storage tanks and pipelines. It is estimated that in the United States there are over 400,000 leaking underground storage tanks. These tanks and pipelines are used to store and transport petroleum products such as gasoline, diesel fuel, and waste oils. These products are composed primarily of the monoaromatic hydrocarbons benzene, toluene, and xylene, and are collectively referred to as BTXs, or BETXs, denoting the additional presence of ethylbenzene. Nitrate, undoubtedly the largest nonpoint-source contaminant found in Iowa, is also of much concern. In this research we are examining the role of nitrate as an alternate electron acceptor. Nitrate offers an attractive alternative to oxygen due to increased solubility and lower costs. BETXs act as a sole carbon source and electron donors. The

primary objective of this research is to ascertain the parameters controlling natural and stimulated biotransformations of BETXs under denitrifying conditions. Soils, some contaminated with BETXs, have been obtained. Experiments utilizing organisms isolated from these soils are being conducted to examine sorption processes, acclimation, and nutrient requirements. Columns containing undisturbed soils are being developed and will be operated under saturated conditions. Once the control of transport and biotransformation is understood, additional experiments will be conducted to determine the effects of wetting and drying (unsaturated) conditions. Fate and net mineralization of nitrate and BETXs under these varying conditions will be quantified.

*Title A preliminary survey of Radon-222, Radium-226 and Radium- 228 in private well-water supplies in Iowa*

*Investigators* R.W. Field, Department of Preventive Medicine & Environmental Health; K.L. Cherryholmes, University Hygienic Laboratory, the University of Iowa

*Abstract* According to the Environmental Protection Agency, three radioactive components of drinking water (222Rn, 226Ra and 228Ra) may be responsible for more deaths than all the other contaminants in drinking water combined. Radon can induce lung cancer after it becomes airborne from water, entering the home from sources like showers, humidifiers, clothes washers, dishwashers and boiled water from cooking. Recent studies also indicate that ingested radon may represent a major pathway of exposure. In addition, radium ingestion has been shown to induce bone sarcomas and carcinomas of the head. In order to collect information on 222Rn, 226Ra and 228Ra in Iowa groundwater we will measure these radionuclides in the 10 percent repeat well sites (69 sites) which were previously randomly selected from the sampling framework of the Iowa Statewide Rural Well Water Survey. The information obtained from this survey will help to: develop a limited data base for 222Rn, 226Ra and 228Ra in private well- water supplies in Iowa; demonstrate the feasibility of such a study in Iowa; determine the need for an expanded state study of 222Rn, 226Ra and 228Ra in private well- water supplies; estimate the number of private rural wells in Iowa that have levels above the proposed or existing MCL for 222Rn, 226Ra and 228Ra; note any regional trends in the occurrences of 222Rn, 226Ra and 228Ra in private well-water supplies; and provide insight in how to predict



elevated levels of <sup>222</sup>Rn, <sup>226</sup>Ra and <sup>228</sup>Ra in private well-water supplies based on analyses of parameters like age of aquifer water and aquifer type.

*Title* *Assessment of exposures to bioaerosols in "sick" and "healthy" buildings*

*Investigators* P.S. Thorne, J. LeVasseur, M. Kiekhafer, Department of Preventive Medicine & Environmental Health, the University of Iowa

*Abstract* In recent years the air quality of indoor environments has received increased attention. This stems from greater awareness of building-related illness and new construction practices that make buildings more dependent on the heating, ventilating, and air conditioning (HVAC) systems for controlling the air quality. Hazards from buildup of chemical vapors have been well characterized and typical baseline levels have been determined for about 30 compounds. However, for microbial air pollutants the proper baseline levels have not been developed due, in part, to the difficulty of sampling and analysis of microbial bioaerosols. This study was undertaken to compare levels of bioaerosols in sick and healthy homes with concurrent sampling of outdoor air. A sick home is defined as one in which there is sufficient building-related symptomatology as revealed from a detailed health questionnaire. The study consists of an investigation of 15 sick homes and 25 healthy homes matched by age, type, size, and HVAC parameters. Relationships are sought between various microbial and gaseous indoor pollutants, ventilation parameters, sampling season, building types, occupant complaints, and other relevant parameters. A portion of the microbial, chemical and health data collected to date illustrate the nature and interpretation of these data.

*Title* *Regional radon exposure index model and epidemiological test of the model*

*Investigators* L. Fuortes, L. Weih, Department of Preventive Medicine & Environmental Health, the University of Iowa

*Abstract* Nationwide, concern has been expressed regarding the health effects of radon exposure in residential settings. This has been in part a response to several recent surveys which have monitored the levels of radon in homes. Nationally, Iowa is among the states with the highest average radon concentrations in air of homes tested. In Iowa, two statewide surveys have been conducted. A Department of Public Health study (part of a national survey) found that 71% of buildings studied exceeded concentrations of 4 pCi/l (EPA's

recommended action level); The Iowa Rural Radon Survey reported 70% of their sample exceeded concentrations of 4 pCi/l. Understanding the statewide geographic distribution of radon concentrations will help evaluate the public health significance of residential radon exposure, and will also aid in focusing control efforts. Consideration of this radiation exposure also becomes important in epidemiological studies of health effects of environmental contaminants. This project has two major goals:

1. to develop a regional radon exposure index based on a geological model of radon distribution in the state, and
2. to test the use of this model in an epidemiological context.

Goal 1 methods: Data collected during the Rural Radon Survey will be used to estimate likely regional concentrations. Preliminary data analysis suggests there is a statistically discernible difference in the proportion of homes within geological landform regions which exceed 4 pCi/l radon in air. However, within these regions there is a great deal of variability in the levels of concentrations of radon found in individual homes. Hence, the use of radon data aggregated by region to assess the public health significance of and health outcomes associated with radon exposure is questionable without control for intra-region variability. Goal 2 methods: To test the model, a re-evaluation of the relationship between lung cancer and radium content of Iowa public water supplies will be conducted while controlling for radon exposure. Lung cancer has been linked to radon exposure while radium exposure is more clearly related to osteogenic cancer. Thus the question arises whether the Iowa lung cancer findings are confounded by radon exposure.

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