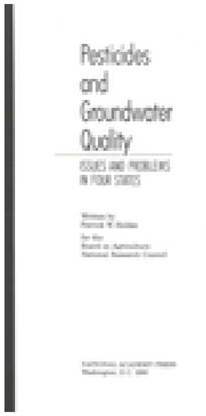
Pesticides and Groundwater Quality
ISSUES AND PROBLEMS IN FOUR STATES

Pesticides and Groundwater Quality: Issues and Problems in Four States

Written by Patrick W. Holden for the Board on Agriculture, National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This project was initiated with program initiation funds provided by the National Research Council. Drawing on information gathered during the summer of 1984, a series of technical memoranda were prepared for the Board on Agriculture. Subsequently, the Board developed a proposal for an in-depth project assessing the interactions of soil erosion control efforts and water quality. Following the preparation of the proposal, the Board decided that a publication summarizing the information in the memoranda would be timely and useful. Preparation of the publication was supported by funds from the W.K. Kellogg Foundation and the FMC Corporation.

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Preface

During the summer of 1984, the Board on Agriculture contracted with Patrick W. Holden, a graduate student in the Department of Hydrology and Water Resources at the University of Arizona, to study and analyze the nature and scope of groundwater contamination by pesticides in California, New York, Wisconsin, and Florida. Holden compiled detailed information by traveling to each state, where he conducted interviews in person and by telephone and collected literature. He also interviewed several federal officials in Washington, D.C., and a number of agrichemical company representatives.

Subsequently, Holden reviewed the status of the problem in a series of six memoranda to Charles M. Benbrook, Executive Director of the Board on Agriculture. Because the memoranda present a unique picture of pesticide/groundwater issues, which are on the agenda of agencies at all levels of government, the Board on Agriculture has concluded that the essence of Holden's findings should be made publicly available.

This report, summarizing the memoranda, provides a rich resource for scientists and policymakers interested in the relationship of agriculture to groundwater quality. Perhaps its most important contribution lies in the diversity of the information it brings together. It contains quantitative data and the personal views of experts; juxtaposes four state case studies and summarizes federal agency and industry activities; and reviews the relevant scientific, technological, managerial, and regulatory contexts. Significantly, despite the site-specific nature of groundwater contamination problems and the diverse views on needs and priorities expressed by those interviewed, similar themes and concerns emerge. These generalizations are highlighted and discussed in the Executive Summary.

At the same time, the nature of the issue and the focus on cases in four disparate states give rise to several questions concerning scope, terminology, and currentness. Terms defining primary data and analytic protocols vary among states and localities. These variations reflect the difficulty of compiling information and comparing specific problems across the country. The following caveats indicate how these factors were addressed in preparing the report:

1. *Scope*. This report represents the substance of one individual's investigation. It is not a comprehensive analysis of the issue, nor is it a comprehensive survey of nationwide contamination incidents. Rather, it presents anecdotal evidence of the problem in four states where pesticides have been detected in groundwater. Other examples could have been found. For example, recent investigations by the Iowa Geological Survey in the Karst region of northeast Iowa suggest the movement to groundwater of residues from field-applied pesticides, a problem possibly associated with conservation tillage practices but not investigated herein.
2. *Attributions*. Personal comments attributed to individuals have been recast in the report to protect confidentiality. However, a complete list of persons interviewed or consulted appears in the Appendix. Notes and documents, which are occasionally quoted from, are on file at the Board on Agriculture. A list of selected sources appears in the bibliography.
3. *Contamination*. The word "contaminate" has two common meanings: (1) reducing native purity by intrusion from outside and (2) making unfit or unwholesome by the introduction of outside elements. The second meaning is more restrictive than the first and implies that the intruding substance is at a level that is biologically significant. In the course of this study, many technical experts, policymakers, and others used the term "contaminate" in the broader (first) sense; but some believed that the term should properly be restriced to the narrower sense — specifically, only to cases in which residues of an intruding substance exceed an established health standard. These individuals argue that because modern analytic techniques can detect residues at levels well below concentrations having any known biological significance and because the word "contaminate" has for many people a highly negative connotation, its use to refer to any "detectable" residue may give rise to unjustified fears.

However, since any level of residue may justify concerns about potential hazards and no health standards have been set for many pesticides in water, and because of the widespread use of the term "contaminate" to refer to the presence of an impurity, this report does not restrict the term only to circumstances where the concentration of pesticide resi dues exceeds health standards. Under this broader use, "contaminate" denotes "detectable residues."

4. *Agricultural use*. This report focuses on the relationship between the *field application* of pesticides and potential groundwater contamination. However, it is not always possible to discriminate between possible sources of residues, and certain activities such as mixing and loading pesticides may be more-or-less inseparable from field use.
5. *Pesticide nomenclature*. A pesticide can be referred to by any of three names: (1) the chemical name; (2) the trade name(s), which may vary between companies and countries; and (3) a common name, which may be the chemical or trade name or some other appellation. In writing this report, some minimum level of consistency was sought, with common names often added for clarity. The *Farm Chemicals Handbook 1985* was used as a guide.
6. *Other agricultural chemicals*. Pesticides are just one category of agricultural chemicals that might appear as residues in groundwater. Fertilizers, fuels, and wastes, for example, may involve analogous problems, but they have been excluded from this report to sharpen its focus, without regard for their relative importance.
7. *Currentness*. Knowledge about pesticide/groundwater relationships is evolving rapidly. In a number of cases, information gathered during the research phase of the study—the summer and fall of 1984 — had been superseded by the time of the writing phase — the winter and spring of 1984-1985. In preparing this report, information has been updated when necessary to prevent misinterpretation. Nevertheless, most of the report necessarily and appropriately remains based on the original data. Important new information is identified as such in context.

WILLIAM L. BROWN, *CHAIR*

BOARD ON AGRICULTURE

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Executive Summary

When groundwater pollution emerged as a public issue in the late 1970s, major documented sources of contamination were generally associated with the disposal of manufacturing wastes. By the early 1980s, several incidents of groundwater contamination resulting from the field application of pesticides had been confirmed. The most widespread problems involved the insecticides/nematocides aldicarb (Temik) and DBCP (dibromochloropropane). Early findings led to monitoring for other pesticides, and several additional active ingredients have now been detected in groundwater in at least a dozen states.

Groundwater contamination from field-applied pesticides was almost entirely unexpected, particularly since the pesticides being found in groundwater included those generally assumed to degrade or volatilize rapidly. When the first incidents were documented, pesticide manufacturers and regulatory officials had little pertinent baseline data on groundwater quality to assess the scope of emerging problems. Responses to positive findings were necessarily ad hoc.

Those early responses and experiences, data recently generated on groundwater contamination, and the current technical and policy status of the issue are the subjects of this investigation. The report reviews diverse activities in four states related to the detection in groundwater of residues from field-applied pesticides. These activities include hydrogeologic investigations; regulatory actions, including monitoring and cleanup; recommended changes in agricultural management practices, including irrigation and pest management; and various research initiatives, including development of new analytic chemistry techniques. Information from state and local sources was supplemented and put into a national context with information based on interviews with federal regulatory officials and agrichemical company representatives.

The report presents a series of vignettes illustrating a wide range of variables associated with the contamination of groundwater by the agricultural use of pesticides. The cases reviewed are not detailed enough to characterize completely the current status of groundwater in the four states reviewed, nor are they necessarily representative of other states with significantly different agricultural activities. Nevertheless, the experiences in these four states suggest a number of generalizations concerning groundwater quality research needs, federal and state regulatory actions, and agricultural management practices associated with pesticide use.

RESPONSES TO GROUNDWATER CONTAMINATION

When pesticides were first detected in groundwater, no formal or informal regulatory mechanisms were in place to respond. As a result, programs to detect pesticides in groundwater and to remedy problems of contamination were largely ad hoc. Several patterns of response across states emerged, indicating opportunities to share knowledge and possibly coordinate activities. In other cases, inconsistent decisions between states indicate areas needing research and possible reassessment.

Detection and Monitoring

The detection of aldicarb in groundwater in Suffolk County, New York, first led to expanded local monitoring and then to programs to test for that pesticide in the groundwaters of other states where it was used. This sequence of looking for pesticides in groundwater has been repeated several times. Detection of DBCP in a limited number of wells in California led to a much more extensive statewide monitoring program. Positive findings in California convinced other states to undertake monitoring in areas where DBCP had been in use, leading to more positive findings.

Until recently, programs for monitoring pesticides in groundwater tended to develop incrementally, covering only one or a few suspect pesticides in particular areas. Hence, most early monitoring is of limited use for developing a statistically reliable data base on the presence of pesticide residues in groundwater. In the four states visited, relatively comprehensive monitoring in major agricultural production regions has been conducted for a limited set of active ingredients. These include for California—DBCP; New York (Suffolk County only)—aldicarb, 1,2-dibromoethane (EDB), carbofuran, carbaryl, oxamyl, methomyl, and 1,2-dichloropropane; Wisconsin—aldicarb; and Florida—aldicarb and EDB. The monitoring has been funded and conducted by various parties, including the U.S. Environmental Protection Agency (EPA), state or local agencies, and pesticide producers (for example, Union Carbide Corporation for aldicarb).

Responses to Contamination

Where residues have been found, actions to protect the public health and to prevent further contamination have been adopted largely on an ad hoc basis. Consequently, the levels of residues in groundwater that trigger concern and remedial actions are not always consistent from state to state. For example, Wisconsin and Florida have set health guidelines for aldicarb at 10 parts per billion (ppb), whereas New York has set its health guideline for aldicarb at 7 ppb. The EPA's Office of Pesticide Program's Acceptable Daily Intake (ADI) for aldicarb is 0.003 mg/kg/day, and its recommended drinking water Health Advisory Level is 30 ppb; the EPA's Office of Drinking Water's ADI for aldicarb is 0.001 mg/kg/day, and its proposed Health Advisory Level is 10 ppb. The National Research Council Committee on Drinking Water and Health is currently reviewing the toxicology data on aldicarb to see if a revision is warranted.

Where wells supplying drinking water contain residues in excess of applicable standards, remedial actions have included supplying bottled water, installing granulated activated carbon filters, extending community water supplies to households with contaminated wells, capping contaminated wells, and drilling new wells. Some remedial actions have been funded by pesticide manufacturers (for example, Union Carbide and FMC Corporation on Long Island) and applicators (State of Florida, for state-applied EDB).

Regulation of Pesticides

Immediate actions to prevent further groundwater contamination have included bans on certain pesticides, at least temporarily, and use restrictions designed to minimize the possibility of contamination. Restrictions on the timing, method, site, and rate of application have been adopted for aldicarb in both Florida and Wisconsin. In Suffolk County, New York, a 1-year experimental program that restricted the conditions of aldicarb use indicated that even these steps were insufficient to keep groundwater contamination levels below health guidelines. Accordingly, the use of aldicarb is no longer permitted in Suffolk and Nassau counties.

NEEDS AND PROBLEMS

Efforts to respond to the presence of field-applied pesticides in groundwater have highlighted a series of needs and problems. The first set of needs concerns the information necessary to determine the nature and scope of groundwater contamination by pesticides: How widespread is the leaching of pesticides to groundwater? What chemical and hydrogeologic factors determine the likelihood of leaching? What is the toxicological significance of residues detected in groundwater? The second set of needs concerns the institutional and policy capabilities to respond to the problem. And the third set deals with adjustments in agricultural management necessitated by the potential for pesticides to leach to groundwater.

Understanding the Nature and Scope of the Problem

Some 200 pesticides are in common use, and a wide range of hydrogeologic conditions affect the susceptibility of groundwaters to contamination. Clearly, it is impracticable to sample every aquifer and test for every pesticide. Rather, efficient monitoring of resources depends on the establishment of systematic procedures for sampling and testing and the collection of data that can be used to identify critical site/pesticide combinations.

Monitoring

Screening and analytic techniques.

If a particular pesticide is known to be present in groundwater, sampling and analysis for that single pesticide may be appropriate, despite the relatively high costs per sample tested. But for routine screening of groundwater (or drinking water), existing analytic techniques capable of detecting more than one compound tend to be expensive, time-consuming, limited to certain pesticide classes, and/or lacking in sensitivity.

> The development of improved multiresidue analytic screens for pesticides in water would enhance monitoring efficiency. According to researchers interviewed, such a development should be possible at a reasonable cost within a few years. The Food and Drug Administration (FDA), for example,. uses multiresidue analytic methods capable of detecting up to 125 active. ingredients in a single test in its food residue testing programs. Several chemists suggested that the FDA's analytic methods could be adapted for use in monitoring pesticide residues in water.
> Any detection of residues should be confirmed by appropriately sensitive tests, preferably by a separate analytic procedure, before actions based on their presence are taken.

Sampling protocols.

Some state and federal programs to sample groundwater have been conducted in the absence of formal, established protocols concerning selection of test wells, collection and handling of samples, and development of quality assurance/quality control programs.

> The establishment of scientifically based sampling protocols would not only improve data quality and comparability, but also facilitate the training of technicians taking and handling samples.

Data Needs

Four sets of data are urgently needed to identify the potential for groundwater contamination and to develop appropriate pesticide use restrictions to protect groundwater. These are (1) the characteristics of a pesticide that determine the probability of its leaching to groundwater; (2) the complementary characteristics of the soil, the unsaturated (vadose) zone, and aquifer that determine the probability of a leachate reaching the groundwater; (3) the locations where pesticides of concern are used and in what quantities; and (4) the locations of potentially vulnerable aquifers. The comparison of patterns of pesticide use with patterns of aquifer vulnerability would delimit areas of concern, and knowledge of the chemical and hydrologic mechanisms contributing to leaching would permit appropriate regulations to be formulated on how and where such pesticides should be applied.

Moreover, because cropping and pesticide use patterns shift—sometimes dramatically in just a few years—the nature of and analytic protocols for monitoring programs must be continuously modified to retain the ability to detect emerging problems.

Environmental fate data.

Several of those interviewed commented on the need for the development and dissemination of information concerning the environmental fate characteristics of pesticides. This need is broadly recognized, and basic information is being sought.

Consequently, in spring 1984, the EPA requested pesticide registrants to supply data on the potential for groundwater contamination by 84 pesticides thought to pose a hazard to groundwater. Also, EPA has requested groundwater data for more than 50 other pesticide active ingredients as part of its registration standards program. These requests for data on the environmental fate of pesticides in relation to groundwater involve essentially all currently registered pesticides believed to pose a threat to groundwater.

In addition, some states, including Florida, Wisconsin, and California, specifically authorize state-level pesticide regulatory bodies to require any additional data needed to assess particular local problems. Also, the interviews revealed that some pesticide producers are making marketing decisions based on the potential for groundwater contamination.

Defining characteristics of susceptible sites.

Despite the many differences among the four states visited, several hydrologic variables clearly influence the potential for groundwater contamination, Including the porosity, organic matter content, and pH of the soil and the depth, confinement, and recharge areas of aquifers. Particularly susceptible areas are characterized by sandy soils, shallow water tables, and special hydro-geologic conditions that expose aquifers to infiltration by surface contaminants.

> Many areas with special susceptibility are already well known, but continued and additional research on the conditions that make aquifers vulnerable to contamination by pesticides should be given a high priority.

Models to describe the potential leaching of chemicals to groundwater exist, but their applicability to field conditions remains uncertain. Controlled field studies provide tests of such modes, but much more testing is required before the general applicability of models in the field can be assessed with confidence.

Delineating vulnerable areas.

Enough is already known about critical soil and aquifer conditions, however, to permit identification of broadly vulnerable areas. Work to characterize susceptible areas is ongoing in all four states, both to specify particular problems (for example, aldicarb migration studies in New York, Wisconsin, and Florida) and to identify geographic areas where groundwater would be at high risk of pesticide contamination (for example, in heavily farmed regions of California with a rising water table). Crucial hydrogeologic conditions can be so site-specific, however, that the thorough identification and delineation of sensitive regions could be a highly resource-intensive activity. There are, for example, approximately 460 groundwater basins in California, and, within each of those, extensive variations may affect the potential for pesticides to leach to groundwater.

Pesticide use data.

A lack of historical pesticide use data has hindered identification of potential contamination problems. Furthermore, current pesticide use data are seldom adequate (they are either incomplete or too aggregated) to identify specific areas of high risk. The absence of up-to-date and accurate pesticide use data is particularly troublesome in susceptible regions where pesticides may be newly introduced to replace products restricted because of previous groundwater contamination.

Because of the need for pesticide use data for groundwater monitoring and protection programs, as well as for other environmental and public health purposes, restrictions in current regulatory law and procedures on the public dissemination of such data may need reevaluation.

In summary, a key finding that emerged from this project is the high priority that should be placed on (1) research on the environmental fate characteristics of pesticides and of hydrologic conditions favoring pesticide contamination of groundwater; (2) the development of data on the location of areas highly susceptible to groundwater contamination; and (3) the generation of data on the use of pesticides in detail sufficient to pinpoint loadings in susceptible areas. Such data would more clearly focus the scope of the problem; allow limited resources to be directed at specific, high-risk areas; and support appropriate pesticide use restrictions. Furthermore, increased effort should be applied to the development and validation of models predicting the environmental fate and transport of pesticides in the vadose zone before the use of these models in regulatory programs is accepted or rejected.

Point Source Contamination

With some local exceptions, residues in groundwater from field application of pesticides tend to be restricted to perched groundwater and the upper levels of unconfined aquifers. However, contamination may be more extensive, migrate more deeply, or reach confined aquifers, particularly when the source of the residues is more concentrated or the integrity of an aquifer's confining layer is pierced. Concentrated point sources of pesticides include manufacturing and formulating sites, applicator loading and mixing sites, and chemigation systems—each of which has on occasion been associated with contamination.

Procedures for identifying and preventing point source threats of pesticide contamination to groundwater need evaluation.

Health Assessment

Where pesticide residues are detected in groundwater, the practical problem arises of determining what residue concentrations should trigger regulatory actions. The importance of this challenge is growing rapidly and will continue to grow in step with the development of increasingly sensitive analytic techniques and with expanding coverage in monitoring programs.

Health standards.

The EPA has set few maximum contaminant levels (MCL) or health advisories. Often states have set their own MCLs, health advisory levels, action levels, and guidelines; and even though they may rely on data generated by the federal government, the lack of formally set levels can lead to inconsistent state standards.

> Local and state officials and agrichemical representatives interviewed consistently voiced strong sentiments regarding the need for the EPA to be more aggressive in setting appropriate MCLs or health advisories for pesticides (and other chemicals) in water.

In support of their calls for federal leadership, these officials and representatives cited the resources required to assess health effects; the fact that the EPA, at least in the pesticide program, already requires the submission of data regarding health effects from which advisories should be able to be calculated; the problem of inconsistent state and local actions; and the need to mitigate public distress.

Treatment technologies.

Where groundwater used as drinking water has been contaminated with pesticide residues in excess of applicable standards, various remedial actions have been adopted.

> The cost-effectiveness of different remedial actions appears to be highly site site specific and deserves more research and evaluation. Less costly, long-term solutions for domestic application are especially needed.

Institutional and Policy Capabilities to Respond to the Problem

Because groundwater protection is a relatively new environmental issue, it lacks a developed body of law, established institutions, and formal administrative policies and procedures. Laws, institutions, and policies are developing at the federal level and in many states, but at varying rates and degrees. For example, Florida and Wisconsin have new groundwater protection laws that differ in many ways, including the provisions addressing monitoring, regulatory responsibilities, relationships between groundwater and surface water, and funding mechanisms.

This undeveloped nature of groundwater law, institutions, and policy encourages continued ad hoc responses to perceived problems. Consequently, several key issues concerning pesticide use and groundwater quality remain unresolved:

- It appears probable that in some regions little can be done to prevent agricultural chemicals from leaching to groundwater unless agricultural production practices are substantially modified or curtailed. In such cases, it is critical to determine what level of residue can be accepted without undue risk to public health and to relate this level to agricultural management practices in the region.
- Where drinking-water wells are already contaminated by pesticides, only ad hoc remedies may be available. Who should bear the responsibility and costs for mitigating contamination in cases where the source of pollution is known needs to be clarified, and the appropriate responses of users, manufacturers, and landowners in cases where the source of contamination is unknown need to be established.
- The lack of federally set MCLs or other health advisories for pesticides in water is widely perceived as a critical impediment to local and state health protection programs. Overcoming constraints to the issuance of health advisories and other quantitative standards and focusing federal scientific resources more effectively on developing such standards are high-priority needs.
- The lack of clear policies for the respective state and federal roles in funding and carrying out such research, and for coordination between research in the

public and private sectors, remains a critical institutional shortcoming that deserves continued attention.

IMPLICATIONS FOR AGRICULTURE

The unexpected presence in groundwater of residues from previously acceptable and sanctioned agricultural uses of pesticides has already had significant local impacts on agriculture in several major farm states, Aldicarb, for example, is no longer approved for use in Suffolk County, New York, and the timing and quantity approved for use in Wisconsin and Florida are restricted on a crop-by-crop and geographic basis. Many of those interviewed believed that such case-by-case, site-by-site restrictions are feasible and warranted, although there are concerns regarding the feasibility and administrative costs of such an approach in light of the generally complex and often cumbersome regulatory tools currently available at the state and federal levels. There is also considerable concern that public apprehensions about groundwater contamination will grow to the point where statewide or national bans will become politically expedient, even in cases where pesticide contamination is a controllable, localized phenomenon.

These concerns have implications for agricultural management practices as well as for pesticide availability and use. The development of regulatory restraints and the growing sensitivity of pesticide producers to the problem (and to potential liability) suggest that directions for pesticide use will increasingly be written with an eye toward avoiding groundwater problems.

> Pesticide use restrictions—along or in combination with adjustments in other agricultural management practices—have been the primary approach to addressing contamination problems. This study raises questions about how users can bests be informed, of and trained in improved practices, ranging from integrated pest management to calibration, of application equipment, and how the adoption of improved practices can be fostered, monitored, and, if necessary, enforced.
>
> Adjustments in crop management and tillage practices in some areas may be the most efficient means of

avoiding groundwater problems, especially where nematode control is required. Since soil conditions favoring nematodes tend also to allow for the ready movement of water and solutes through the vadose zone, and since nematocides by design tend to be highly water soluble and thus easily leach below the root zone, the adoption of new cultivars or adjustments in cropping patterns to minimize nematode problems may be necessary to avoid groundwater problems in some areas.

Integrated pest management (IPM) programs have significant potential to reduce pesticide Use and thus the possibility of contamination. More emphasis is needed on IPM for nematodes and other pests of the root zone and for sites and crops associated with vulnerable hydrologic areas.

Irrigation efficiency and water management affect the potential for agricultural chemicals to leach to groundwater. The influence of irrigation on pesticide leaching is closely related to the site-specific chemical and physical properties of the vadose zone. Return-flow water management and drainage discharge practices may also contribute to groundwater contamination (for example, the discharge of wastewaters into inactive wells, which is of concern in California) and need to be assessed.

Groundwater protection needs associated with the complete process of manufacturing, formulating, transporting, delivering, and applying agricultural pesticides should be assessed, and appropriate management standards developed where necessary.

CONCLUSION

Overall, the emergence of the problem of pesticide residues in groundwater adds a new dimension to the whole array of public health, environmental protection, pesticide innovation and marketing, and agricultural management. The interviews conducted and documents collected during this project indicate that new information is being integrated into ongoing programs and activities, though not always promptly and coherently. Not surprisingly, variations in *approach* have arisen from special local conditions, different interests involved, and lack of federal leadership in key areas. The most urgent actions needed to address groundwater problems arising from field-applied pesticides appear to be

- Federal determination of health-based standards for pesticides in water;
- The development of improved, multiresidue analytic tools for screening groundwater for pesticides at the parts-per-billion to parts-per-trillion range;
- The development of a systematic monitoring program;
- The development of improved models of pesticide behavior and fate in soils, the vadose zone, and aquifers, and assessment of their validity under field conditions;
- The development of data on environmental fate and pesticide use patterns, in conjunction with local hydro-geologic conditions, at a level of specificity adequate to identify areas especially vulnerable to groundwater contamination and to develop site-specific restrictions on pesticide use; and
- The integration of groundwater resource considerations into an array of agricultural management practices and choices, including cropping, tillage, irrigation, and pest management.

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California

California is a major agricultural state where nearly 25 percent of the pesticides used each year in the United States are applied. Californians groundwater is a vast natural resource of vital importance to the economic growth and development of the state. The current understanding of the extent or seriousness of agricultural chemicals in groundwater is extremely limited and disjointed because of the incomplete data base currently available.

Nearly everyone interviewed agreed that additional sampling and monitoring of water quality trends is needed to establish the extent of pesticide contamination of groundwater. An engineer with many years of experience

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On June 21, 22, 25, and 26, 1984, Holden visited with various individuals in California either directly familiar with groundwater problems caused by agricultural chemicals or working in disciplines with the potential to reduce future problems. The institutions represented by the individuals interviewed include the University of California, Davis and Riverside campuses—sources of outstanding basic agricultural research for many years; the California Department of Food and Agriculture (CDFA)—the state agency responsible for pesticide registration, use permit processing, and enforcement; the California Water Resources Control Board (WRCB)—the state agency responsible for the protection of groundwater quality; and the Water Quality Control Board (WQCB), Central Valley Region—one of nine regional boards that work directly with growers and make water quality decisions subject to appellate review by the WRCB.

said that the problem of groundwater contamination by organic chemicals that are not regulated as groundwater pollutants is "virgin territory" and that regulatory agencies are groping in the dark as to how to proceed. Complicating the picture is the fact that little or no baseline and trend water quality data exist for the approximately 460 groundwater basins in California.

THE STATUS OF EFFORTS TO MONITOR GROUNDWATER FOR RESIDUES OF AGRICULTURAL PESTICIDES

Despite the limited data base, some specific problems are well established. Agencies in California have sampled approximately 8,000 wells for the nematocide DBCP. The pesticide was found in more than 2,000 wells and is known to have contaminated groundwater in an area encompassing 7,000 square miles of the San Joaquin Valley. DBCP was used in California from the late 1950s until its registration was canceled in August 1977. It was used mainly in areas with sandy soils, including the east side of the San Joaquin Valley, but the actual acreage to which it was applied is not known because accurate records are not available for the entire period of use. However, typical annual application rates ranged from 20 to 80 lbs per acre, with total usage in California from 1960 to 1977 estimated by the CDFA to be approximately 3 million lbs per year. Unfortunately, the type of comprehensive, coordinated monitoring effort undertaken to assess the extent of DBCP contamination has been rare.

Past Monitoring Efforts

Historically, monitoring for pesticides has been a fragmented and uncoordinated series of special studies of limited duration and scope. Many of the sampling programs were conducted under time and budgetary constraints in response to a specific contamination incident and thus lacked adequate sampling protocol development.

Past monitoring efforts have been severely limited in two ways. First, in most of the California groundwater monitoring programs, samples were collected from existing wells because of the high cost of installing monitoring wells. Second, samples were typically analyzed for a limited range of pesticides that were chosen on the basis of their use in a given area, their potential for leaching, or problems caused by their use in another basin. Other agricultural chemicals may have been present in the groundwater but were not detected in the chemical-specific analysis used to quantify the pesticides of concern. Multiresidue analytic techniques to better assess water quality in areas susceptible to contamination from agricultural chemicals need to be developed.

But despite these significant gaps, more than 50 different pesticides have been found in the groundwater of 23 California counties.

The most extensive monitoring effort was the 1979-1982 DBCP sampling program, which revealed that the pesticide was present in approximately one out of four wells tested. Most of the samples with detectable DBCP levels had concentrations below 100 ppb. A high correlation between the presence of DBCP and elevated nitrate levels in groundwater suggests that DBCP was transported to the groundwater via percolating irrigation water.

Other pesticides widely monitored in groundwater include 1,2-dibromoethane (EDB), 1,2-dichloropropane/ 1,3-dichloropropene (D-D), simazine, atrazine, and carbofuran. The confirmed presence of these pesticides in California's groundwater is much less extensive than that of DBCP. A 1983 study by the WRCB found that the water in 67 wells of 266 sampled (25 percent) contained 1,2-dichloropropane, a manufacturing by-product present in the soil fumigant D-D. A 1982 monitoring program by the CDFA examined samples from 217 well sites chosen to tap shallow aquifers in four groundwater basins of agricultural areas. Four pesticides were tested for:

1. DBCP—detected in water from 27 wells (12 percent); concentration: 0.1-10.5 ppb.
2. The herbicide simazine—detected in water from five wells (2 percent); concentration: 0.5-3.5 ppb. (Originally, the herbicide sampled for was atrazine, but none was detected; instead, simazine was found.)
3. The nematocide EDB—detected in water from two wells (1 percent); concentration: 0.1-0.2 ppb.
4. The *insecticide* carbofuran—detected in water from one well (0.5 percent); concentration: 0.5 ppb.

The CDFA sampling program was not established to characterize the basin-wide groundwater quality with reference to the chosen pesticides. Additional or more extensive groundwater contamination caused by the target pesticides could exist in the four basins, since only one well in a 36- or 72-square-mile area was sampled. By the same token, a positive finding is an inadequate basis for projecting that such a large area is widely contaminated with a given pesticide.

Current Monitoring Efforts

Current monitoring efforts in California remain fragmented and lacking in scope and depth. Funding levels for monitoring programs within the various agencies have increased only slightly, remained constant, or even declined. Despite increasing concern about contamination of groundwater resources, the research budgets for development of baseline and trend water quality data and for special investigative projects have not risen significantly. In fact, the WRCB budget for development of baseline water quality data has been cut over the last 5 years from $400,000 to approximately $240,000. This level of funding has constrained the state WRCB, which is the only agency currently developing baseline and trend data on groundwater basins. Of the 461 groundwater basins in California, 160 are heavily pumped for water consumption. Of these 160 basins, 24 have been designated Priority I based on a comparison of beneficial uses, population, present water quality, and stress on water quality. Of the 24 Priority I basins, the WRCB selected 4 for its initial monitoring.

Monitoring efforts began in 1978 with a sampling site concentration of approximately one well per square mile. Twelve toxic organic chemicals (including the pesticides EDB, DBCP, aldicarb, and D-D), toxic metals, nitrates, and some minerals were selected for monitoring. Although the program was established to collect baseline and trend water quality data, routine sampling of some wells has been halted for years due to funding restrictions. In fiscal year 1984, the approximate budget for this program was $240,000, which causes obvious constraints when the estimated analytic cost alone is $250-$300 per sample. Consequently, baseline and trend data back to 1978 are currently being gathered on only eight Priority I groundwater basins in California. Nevertheless, this remains the only continuous groundwater monitoring program in California attempting to evaluate background and trend data for an entire basin. No other western state, and few states nationwide, have groundwater monitoring programs of the scope and quality of California's.

A broad special investigation initiated in 1984 involves a one-shot sampling effort of all wells serving as sources of public water supplies. The samples are tested for the presence of organic chemicals. This investigation was authorized by California Assembly Bill 1803, passed in September 1983, as one response to concerns about toxic chemicals in drinking water sparked by the rice herbicide controversy in the Sacramento area (see subsection Best Management Practices for Pesticide Use). The California Department of Health Services (CDHS) is responsible for implementing the statewide program and for establishing which industrial and agricultural chemicals will be subject to analysis relative to land use in the vicinity of a particular public supply well. If contaminants are found in the initial screening, follow-up sampling will be conducted. The sampling and analytic costs will be borne by the public water supply systems. Whatever the technical shortcomings of this ad hoc program, it is generally perceived as a constructive response to the growing level of public alarm regarding groundwater contamination.

Another current monitoring effort by the WRCB is the "hot spot" program, or 205(j) Project, funded through the federal Clean Water Act. The intent of this program is to develop sampling methods and analytic techniques that can be used by the WRCB and regional WQCBs in the event of a contamination problem. It will consist of highly focused studies that investigate specific contaminants in worst-case situations. At present the hot spot program has $400,000 to initiate a 2- to 3-year study of specific chemicals at sites to be chosen based on the greatest likelihood of preexisting groundwater contamination. These sites and chemicals have yet to be determined, although an industrial chemical, such as trichloroethylene, and an agricultural chemical will be chosen. Limited field testing of predictive models is planned.

Finally, sampling mandated by the Safe Drinking Water Act (SDWA) is carried out by public health agencies on wells serving public water supply systems. Six pesticides are tested for: the insecticides endrin, lindane, methoxychlor, and toxaphene; and the herbicides 2,4-D and 2,4,5-TP (Silvex). However, many uses of these pesticides, especially endrin, lindane, toxaphene, and 2,4,5-TP, have been curtailed by regulatory actions or limited by the availability of more efficacious, modern compounds. In addition, the chlorinated hydrocarbon insecticides are not very mobile in the soil/water environment. Although 2,4-D and 2,4,5-TP are more mobile, they are relatively nonpersistent (soil half-lives of less than 20 days) and thus are rarely observed in groundwater. Consequently, sampling conducted under the SDWA does not represent an important data base with regard to contemporary or future groundwater problems caused by pesticides.

The most recent and comprehensive review of pesticides in California groundwater is presented in Table 1-1, which shows the number of positive detections and the maximum concentrations. This table includes numerous detections associated with point sources, but the data do not distinguish sources in individual cases.

CRITICAL PROBLEMS AND NEEDS

Nematocides

One class of agricultural chemicals, nematocides, poses a particularly high risk of groundwater contamination. Nematocides are designed to be mobile in the soil/water environment in order to protect the root zone, where pest problems occur. Furthermore, most severe nematode problems occur in sandy, porous soils with low water-holding capacity, which increases the likelihood of leaching to groundwater. The nematocide DBCP has caused the most extensive groundwater contamination from an agricultural chemical documented to date in the United States. Other nematocides, such as EDB, D-D, and aldicarb, have also leached to groundwater.

The problem of nematocides reaching groundwater presents a difficult management problem with no obvious resolution. A nematologist at the University of California, Riverside, believes there is a need to rethink control of nematodes with an eye toward protecting groundwater resources. Staff at the CDFA voiced a similar concern.

Interdisciplinary Research

A number of those interviewed felt that the land grant university system needs a broader, more interdisciplinary

TABLE 1-1 Pesticides in California Groundwater

Pesticide	Number of Positive Detects (total number of wells sampled if information available[a])	Maximum Concentration (ppb)	EPA-Suggested Analytic Method[b]
Aldicarb	17 (106)	47	c
Aldrin	21	17.8	
Basagran	1	20	
Benzaldehyde	1	2	
Chlordane	4	22	608
CIPC	1	8	
Dacthal	4	35	
DBCP	2,000+ (8,000+)	1,240[d]	502
1,2-Dichloropropane	68 (266)	1,200	601
Delnav	5	25	
DDD	3	3	
DDE	15	5	
DDT	10	20	
DEF	1	1.7	
Diazinon	13	9	
Diclone	1	2.7	
Dieldrin	6	5	
Dimethoate	24	190	
Dinoseb (DNBP)	14	740	615
Diphenamid	1	6,000	
Disyston	7	6	
DNOC	5	35	
Dursban	3	90	
EDB	35	140	502
Endosulfan	17	100	
Endrin	1	40	608
Ethion	5	30	
Ethylenethiourea	1	7	
Furadan	2	5	632
HCB	2	0.05	
Heptachlor	3	0.3	608
Kelthane (Dicofol)	3	1.99	
Lindane	32	46	608
Malathion	5	23	
Methylenechloride	4	7	
Omite	2	92	
Ordram	3	6.3	
Paraoxon	1	6	
Parathion	3	4	
PCNB	2	0.3	
PCP	38	44,000,000.0[e]	604
Phorate	2	20	
Phthalates	4	10	
Simazine	9 (217)	0.53	619
Sevin	3	80	
Treflan	1	0.9	
TCP	6	980	
Toxaphene	5	123	608
Zytron	4	30	
2,4-D	11	4.0	615
2,4,5-T	3	1.4	
2,4,5-TP	3	1.0	615

NOTE: The California WRCB found some errors in the compilation of data by Ramlit Associates, Inc., used to produce this table of their report. The WRCB rechecked the data to verify the detections and concentrations listed, and this table incorporates those corrections of January 1985. The Ramlit study includes not only detections associated with field use of pesticides, but also detections associated with manufacturing facilities, mixing and loading facilities, and so on.

[a] Information on the total number of wells sampled is not available from the California WRCB for most of the pesticides listed.
[b] Numbers given refer to approved EPA analytic method for pesticides selected for national monitoring survey. The analytic technique associated with each number is as follows: 502—purge and trap gas chromatography (GC); 601—purge and trap GC; 604—solvent extraction GC; 608—solvent extraction GC; 615—derivation GC; 619—solvent extraction GC; 632—solvent extraction high-pressure liquid chromatography (HPLC).
[c] EPA is developing an HPLC-based analytic procedure for the determination of aldicarb.
[d] From well near DBCP manufacturing plant in Lathrop, California.
[e] Presumably from a point source—for example, where wood is treated.
SOURCES: Ramlit Associates, Inc., for the California WRCB, 1983, Groundwater Contamination by Pesticides: A California Assessment; California Department of Food and Agriculture, 1983, Pesticide Movement to Groundwater. Vol. 1: Survey of Ground Water Basins for DBCP, EDB, Simazine, and Carbofuran; Materials submitted to the FIFRA Scientific Advisory Panel by Union Carbide Agricultural Products Co., Inc., June 12, 1984.

research effort to address the groundwater issue. Some felt that while considerable money has been available historically for research related to efficacy of pesticides, comparatively little money was available to study their environmental fate and movement. It was the view of these persons that the potential for groundwater contamination from pesticides and the agricultural management strategies to mitigate such problems have not been given sufficient attention by schools of agriculture. Land grant universities appear to be logical centers to address this problem.

Data Base and the Need for a Multiresidue Analytic Screen

A lack of water quality data impedes efforts to determine the severity of groundwater contamination caused by agricultural chemicals. Often, samples from wells have not been analyzed for pesticides. In other cases the monitoring was limited in scope with regard to areal extent or analytic sensitivity to pesticides of concern or was done so poorly that it is meaningless. Not enough water quality data are available to assert with confidence that groundwater contamination by pesticides is a broad problem. The data base needs to be expanded, but such efforts are hindered by the high costs of establishing monitoring programs and performing analyses. A multiresidue analytic screening technique is critically needed to drive down the cost of sampling for a wide range of pesticides.

Irrigation Practices

Improved irrigation efficiency can help reduce the potential for deep percolation of irrigation water carrying dissolved pesticides, fertilizers, and salts as solutes. If minimal water percolates through the vadose zone to cause recharge of an aquifer, the direct pathway available for a pesticide to move through the unsaturated zone to the water table is also minimized. However, poorly constructed wells without annular seals in place to prevent surface water or soil water in the first few meters from migrating down the side of the well casing to the groundwater can serve as direct pathways to aquifers. Corroded, damaged, or fully screened casing could cause similar problems.

Efficient irrigation scheduling can provide the water needed to prevent water stress to a crop, while minimizing the amount of water percolating beyond the root zone. Two complicating factors in attempts to reduce pesticide leaching via irrigation water are (1) the need to apply excessive water in some regions of the country to leach soluble salts out of the root zone and (2) the need to provide enough irrigation water to meet the requirements of the least permeable areas of a field, consequently providing an excess to the remainder of the field. The excess water can carry some pesticides beyond the root zone, through the vadose zone, to the groundwater. Thus, more efficient irrigation may reduce pesticide contamination of groundwater, but is unlikely to eliminate it.

One state water quality official interviewed believed that relatively inexpensive water available to growers in California prompted excessive irrigation and thus contributed to the groundwater problems in the San Joaquin Valley. Higher priced irrigation water most probably would result in more efficient use of the resource and could lead to the substitution of drip irrigation for flood irrigation methods.

Dry Wells

Another possible cause of groundwater contamination is the channeling of irrigation tailwater (that is, surface runoff from flood irrigation, which can contain significant levels of pesticides and fertilizers) down dry, abandoned wells. This practice can short-circuit the natural percolation mechanisms *that* degrade organic chemicals present in the water. In the Central Valley region alone, approximately 5,000 abandoned dry wells could be used for this purpose, put the actual extent to which such wells contribute to groundwater contamination is unknown.

Ground and Aerial Applicators

Work yards of ground applicators and airstrips used by aerial applicators of pesticides have on occasion been the sites of poor disposal practices of residual pesticide solutions and tank rinse waters. Approximately 500 aerial and ground applicator sites exist in the Central Valley Region alone. In some cases, severely contaminated soil and water have been severely contaminated. For example, at the Sutter County Airport, toxaphene was found in excess of 100,000 ppm in soil, and in Kern County the soil near one airstrip was found to be nearly saturated with DDT (dichlorodiphenyltrichloroethane; a relatively nonmobile, persistent chemical) from the soil surface to the water table, and thus had contaminated groundwater at low levels.

Generally, however, the problems at these sites are considered to have been caused by outmoded practices. Current practices rely on tank rinse water recycling or on spraying three tankfuls of rinse water on the fields just treated. But, largely due to funding restrictions, no comprehensive assessment of the applicator sites for potential groundwater contamination has occurred, nor are such sites closely regulated.

Delineation of Regulatory Areas

The wide range of hydrologic conditions in California results in great variations in the recharge of aquifers by rainfall or irrigation water and thus in the possibility that pesticides will contaminate groundwater.

Thus, officials and staff interviewed at the CDFA indicated that the selective restriction of pesticides in certain areas where the site-specific hydrogeology indicates that groundwater is highly vulnerable to contamination is preferable to statewide bans.

One member of the CDFA staff noted, however, that attempts to map boundaries in a complex and varied hydrologic setting like California would impose considerable technical challenges that could severely tax the expertise and resources of state agencies. Also, the implementation of such a strategy would be difficult because the delineation of areas vulnerable to groundwater contamination would certainly not coincide with existing political boundaries, nor be readily accepted by all parties at risk.

Public and Institutional Perceptions of California Groundwater Contamination

Citing the number of public inquiries and requests for agency publications, officials in California water agencies pointed out that the average California citizen is becoming increasingly aware and concerned about the threat posed to groundwater resources by toxic organic chemicals from both agricultural and industrial sources. Usually, however, the public does not differentiate between agricultural and industrial sources of toxic chemicals and perceives DBCP in the San Joaquin Valley, the industrial solvent trichloroethylene (TCE) in the Santa Clara Valley, or toxic wastes inadequately disposed of at the Stringfellow Acid Pits in Southern California as representative of a unitary threat to groundwater resources. In other words, the origin, relative toxicity, and pervasiveness of the different contaminants are not separated.

The lack of sophistication in public thinking about the general issue of groundwater quality is a considerable worry to the CDFA as agricultural chemicals continue to appear in analyses of groundwater samples. As public pressure mounts to protect groundwater, the CDFA is concerned that public responses to future agriculture-related problems could result in pressure to ban pesticides vital to the interests of California agriculture. The CDFA believes that more intelligent use of pesticides with a high potential for causing groundwater problems is needed and that selective restrictions are the best way to balance growers' needs for effective agricultural chemicals with the need to protect groundwater resources underlying agricultural areas.

The state WRCBs and regional WQCBs are charged with the protection of groundwater quality, and are concerned about potential contamination of groundwater by many toxic organic chemicals used in California by industry and agriculture. With regard to agricultural chemicals, the regional WQCBs appear willing to work with growers to develop strategies to mitigate groundwater problems. However, while best management practices can be developed and recommended to growers, the WQCBs have no policing or enforcement mechanism. Management practices that could mitigate potential problems may not be followed by growers; in fact, it is suspected that label recommendations on application rates for pesticides are ignored by some growers. Nevertheless, the actions of rice growers in the Sacramento area—described under the subsection Best Management Practice for Pesticide Use—indicate that a combination of effective techniques and perceived need can lead to the adoption of management solutions.

Researchers visited at the University of California expressed varying degrees of concern about contamination caused by agricultural chemicals. Some of the agricultural scientists felt the problem was principally restricted to nematocides (DBCP, EDB, aldicarb, D-D, and so on) applied to sandy soils with shallow water tables. They expressed the view that few, if any, additional problems existed. Others felt the problem could potentially be much broader and that an integrated research effort cutting across disciplines was critically needed to assess the dimensions of the problem and develop strategies to mitigate future problems.

AGRICULTURAL MANAGEMENT STRATEGIES AVAILABLE TO MITIGATE PESTICIDE/GROUNDWATER QUALITY PROBLEMS

Irrigation Efficiency

The potential and limitations of irrigation efficiency to reduce pesticide leaching have already been mentioned. A flow of irrigation water that is sufficient to satisfy the leaching requirement for western soils, but that minimizes deep percolation and recharge, could help mitigate pesticide contamination of groundwater. Improved efficiencies could reduce water consumption for irrigation 25-30 percent. And although field irrigation efficiencies for most surface irrigation systems (furrow, border, basin) are probably not more than 60 percent for the western states as a whole, specially designed systems using drip irrigation or laser leveled basins are thought to yield efficiencies of greater than 90 percent.

Best Management Practices for Pesticide Use

Best management practices (BMPs) to mitigate contamination of groundwater from the use of pesticides include closely following label instructions, carefully calibrating spray equipment, efficiently scheduling irrigation, optimizing timing of pesticide applications, altering cropping patterns, and properly disposing of tank rinse water or residual pesticide solutions and containers. While everyone interviewed considered these BMPs important, some were skeptical of the effectiveness of promoting them, believing that some growers would likely ignore such recommendations for a variety of reasons, including lack of economic incentive and their determination to provide a stress-free growing environment for their crops.

The potential for reducing pesticide contamination problems through combined irrigation and BMPs was recently demonstrated in the resolution of a rice herbicide controversy in the Sacramento area. In this case, which involved discharges to surface waters, irrigation water containing the herbicides Bolero (thiobencarb) and Ordram (molinate) was released from fields into the Sacramento River and caused the eventual presence of these pesticides in the drinking water of various communities that use the Sacramento River as a source of potable water. Because of the detection of Bolero in the water—up to 2.8 ppb at the City of Sacramento's water intake—and the bitter taste the chemical imparted to the water, the California rice industry found itself having to defend the use of Bolero and other herbicides from regulatory action.

Working quickly, the rice industry, with help from the University of California and the Central Valley Region WQCB, began an educational campaign to encourage growers to adopt management strategies that could reduce the pesticide load released to the Sacramento River. The management strategies included (1) holding irrigation water in the fields up to 8 days after the late spring application of Bolero and Ordram to allow the pesticides in solution more time to degrade fully and (2) irrigating more efficiently with more recycling of water. Those recommendations have been widely accepted and practiced by the rice growers. The alternative was perceived to be the potential loss of the chemicals due to pressures brought to bear by a concerned and upset public.

As a result of this program, releases of irrigation water from some drains have dropped dramatically. Daily monitoring of the river water revealed that concentrations of Bolero had been reduced 50 percent during late spring, when the concentrations peak. Concentrations are expected to continue to decline as a larger percentage of growers follow the recommendations.

This example could serve as a model for future surface and groundwater cases involving agricultural chemicals where adoption of BMPs have the potential to reduce environmental degradation while preserving the availability of a chemical for growers. By slightly altering their practices, the rice growers lessened the environmental degradation associated with their operations and most likely avoided the cancellation of use permits for agricultural chemicals believed to be important for efficient production.

Integrated Pest Management (IPM)

Integrated pest management is the coordinated application of a range of pest management techniques designed to manage pests at levels below economic damage thresholds. Careful scouting of pest populations, biological controls, and crop management techniques are the first line of defense against pests. Chemical pesticides are used only as required, and the levels are typically less than levels applied under routine spraying schedules, thus reducing the possibility of groundwater contamination. California has been a leader in the development of IPM techniques. However, experts interviewed varied considerably in their confidence in the availability of IPM for major crops.

It appears that IPM has the potential to reduce the total pesticide load and, hence, the residues introduced into the soil/water environment. But additional research is needed to develop and refine IPM strategies through field testing so that extension personnel can make their recommendations with confidence and so that the techniques can compete economically with the alternatives. Growers may not make use of such pest control measures, however, until forced by circumstances such as insect resistance to specific agricultural chemicals.

Formulation Changes

Formulation changes are a strategy to reduce groundwater contamination. The shift through formulation changes from D-D (Shell) to Telone II (Dow) eliminated a constituent that was contaminating groundwater. The active ingredient in both products is the nematocide 1,3-dichloropropene (1,3-D). The original D-D product marketed by Shell contained 30-35 percent 1,2-dichloropropane (1,2-D), which is relatively ineffective as a soil nematocide. Although the toxic constituent 1,2-D was discovered in eight counties in the water from shallow and deep wells, the less mobile, less persistent 1,3-D has never been found in groundwater in California. The logical solution was to reduce or, if possible, eliminate 1,2-D from the formulation of the original D-D product. Currently, Telone II contains 92 percent 1,3-D and 8 percent inert ingredients, of which less than 2 percent is 1,2-D. Thus, Telone II remains available but the threat to groundwater is diminished.

MODELS TO PREDICT THE TRANSPORT AND ENVIRONMENTAL FATE OF PESTICIDES

Pioneering work on simulation models to describe the movement of trace organics in soil has been done in California. (A more detailed description of some models appears in Chapter 2 on New York.) Currently, the bulk of the work on models has been in the laboratory with columns of soil of known texture and structure under controlled conditions. Experimenters are "reasonably confident" about the usefulness of these models in a controlled environment. However, current models offer no precise method of predicting the depth of movement of pesticides in soil or the concentration at depth in the field.

The use of simulation models in field' situations is in an incipient state. The EPA's Environmental Monitoring Systems Laboratory in Las Vegas is developing a report to assist researchers engaged in field verification of simulation models. Entitled Guidelines for Field Testing Soil Fate and Transport Models, it is expected to be published in 1986.

Problems with using models to simulate the fate and transport of pesticides in the soil/water environment in the field include uncertainties related to soil heterogeneity, macropores, and microbial activity.

The spatial variability of heterogeneous soils represents a considerable problem in the application of laboratory models to field situations. Generally, the models currently available compute the rates of leaching and degradation as a function of time. Average water percolation rates through the soil and vadose zone are used, but these may not conform to actual field rates. Also, factors such as permeability, organic matter content, texture, structure, hydraulic conductivity, and depth of soil horizons can vary widely in a single field. And predictions of the transport and environmental fate of a chemical, based on observed environmental conditions, could be quite different within a relatively small area.

In addition to soil heterogeneity, other features in the soil/water environment such as macropores could cause sizable errors when simulation models are used to predict pesticide movement in the field. Macropores are structural features in soil that characteristically allow the ready movement of percolating water. Because of macropores and soil heterogeneity, individual "parcels" of water in the soil do not all travel at the same rate. For most hydrologic purposes, one need only predict or measure the average rate of water transport, not the rate of movement (velocity) of an individual parcel. For assessing the movement of pollutants, however, one must know these individual parcel rates. At present, the models to predict these parcel velocities and the techniques to quantify the necessary parameters for a hydro-logic basin, or to sample individual field performance, are still in the early stages of development.

Another important process not fully amenable to current simulation models is the variable rate of degradation of pesticides by soil-dwelling bacteria and fungi Microbial activity is believed to be a major contributor to the degradation of organic chemicals in soil. Because the concentrations and types of microbes in soil vary considerably from field to field, biodegradation rates vary widely as well. Biodegradation is a complex and not fully understood process that is difficult to incorporate into mathematical models.

Perhaps for the reasons just outlined, and because of the particular needs of regulators, the state personnel at the WRCB, WQCB, and CDFA were skeptical of the use of simulation models for predicting the environmental fate of pesticides in the soil/water environment. The consensus was that the models were currently untested and unproved in field situations and, thus, could not be used with confidence outside the laboratory. It is generally believed, however, that simulation models could be of considerable value to regulators and manufacturers attempting to assess the environmental fate and impact of a specific chemical prior to registration and intensive manufacturing once they have been verified in the field.

2

New York

A vast aquifer system underlies Long Island. It represents the only source of drinking water for more than 3 million people (primarily those in Nassau and Suffolk counties) and has been designated a sole source aquifer by the EPA under the provisions of the Safe Drinking Water Act (SDWA).

Groundwater contamination problems in Suffolk County are varied and widespread. Currently, the most significant problems are contamination by synthetic organic chemicals including pesticides, solvents, and degreasers (such as trichloroethylene and related chemicals);

On July 23 and 24, 1984, Holden visited various individuals in New York who are knowledgeable of the problems caused in Suffolk County, Long Island, New York, by leaching agricultural chemicals, especially the pesticide aldicarb (Temik). The Suffolk County experience provides a significant case history because of the extensive sampling carried out to determine the presence of aldicarb and other pesticides in water from public and private water wells and because of the actions taken to address the problem of Pesticide usage in sensitive hydrologic environments. The institutions represented by those individuals visited include the Suffolk County Department of Health Services, which has been most directly involved in sampling and testing water from wells in areas suspected of being contaminated with toxic organic chemicals; the Suffolk County Cooperative Extension Office, which works on a daily basis with growers and makes management recommendations; and Cornell University.

nitrate contamination from sewage disposal and fertilizer use; and saltwater intrusion caused by groundwater overdraft or depletion.

The primary aquifer on Long Island is composed of unconsolidated geologic material that ranges in thickness from a few hundred feet to more than 1,000 feet. This geologic formation, known as the Magothy, is moderately permeable, while the glacial outwash deposits *that* overlie it are moderately to highly permeable. The glacial sediments composing the unsaturated zone above the Magothy have a high vertical permeability, and recharge to the water table occurs virtually all over the island. The depth to groundwater in most locations in Suffolk County is less than 60 feet, which is relatively shallow. These characteristics indicate a high potential for waterborne contaminants to percolate to the aquifer.

In addition, the soils of Long Island are cold, low in organic matter, and acidic. Also, Long Island groundwater is generally acidic, with pH values between 5 and 6 quite common. In this environment, aldicarb and similar compounds break down slowly, remaining available for leaching and persisting once they reach the groundwater. The U.S. Geological Survey estimates that the residence time of water in this aquifer system may be extremely long, perhaps many hundreds of years.

The western portions of Suffolk County are heavily developed, but the eastern end of the county, which includes the North and South Forks, is comparatively undeveloped. In the rural areas of eastern Suffolk County, where agricultural production primarily occurs, most homes are served by private residential drinking-water wells. Approximately 70,000 domestic wells are currently in use in Suffolk County.

Suffolk County, with agricultural products having market values exceeding $100 million a year, is the leading farm county in New York State. The main crop grown on Long Island is potatoes, but the number of acres planted has been steadily declining since 1960. In 1984, potato growers planted just 14,000 acres—a decline of 8,000 acres over the last 5 years. Efforts to control potato pests, especially the Colorado potato beetle and the golden nematode, have been the source of the most important pesticide contaminants of Suffolk County groundwater. The golden nematode, which was apparently introduced into New York State on infested seed potatoes in the late 1940s, has been the subject of quarantine and eradication programs. Fortunately, it has been contained to Long Island and an upstate area.

TABLE 2-1 Pesticides in Suffolk County Groundwater

Pesticides Detected and Confirmed	
Aldicarb (Temik)	Dinoseb
Carbofuran	Oxamyl (Vydate)
Chlorothalomil	D-D (1,2-Dichloropropane)
Dacthal	EDB (1,2-Dibromoethane)[a]
Pesticides Detected but Not Yet Confirmed	
Carbaryl (Sevin)	Paraquat
Dibrom	Picloram (Tordon)
Methomyl (Lannate)	

[a] The ethylene dibromide (EDB) detected—at very low levels in one agricultural well—may have resulted from gasoline contamination.

SOURCE: Suffolk County Department of Health Services.

Virtually all the crops, including potatoes, grown in Suffolk County are irrigated. Frequency of irrigation depends on the crop and need and ranges from 1 to 6 or 8 times per growing season. Essentially no pesticides are applied through irrigation water.

THE STATUS OF EFFORTS TO MONITOR GROUNDWATER FOR RESIDUES OF AGRICULTURAL PESTICIDES

Past Monitoring Efforts

In 1976 the Cooperative Extension Service of Suffolk County had recommended sampling groundwater for carbamate pesticides after it had examined the results of a water pollution study assessing the use and impact of pesticides in Suffolk County. Three years passed, however, before any groundwater samples were taken. Contamination of groundwater with pesticides was first detected on Long Island in August 1979, when samples taken from shallow wells located at the Long Island Horticultural Research Laboratory at Riverhead (a branch of Cornell University) indicated that aldicarb was percolating through the unsaturated zone to groundwater. To date, 13 pesticides including aldicarb have been detected in Suffolk County's groundwater. Of these, eight have been confirmed by retesting (see Table 2-1).

TABLE 2-2 Selected Chemical Characteristics of Aldicarb and Its Metabolites

Oral LD_{50}	Aldicarb and A. sulfoxide	0.9 mg/kg
	Aldicarb sulfone	20-25 mg/kg
Water Solubility	Aldicarb	6,000 ppm
	Aldicarb sulfoxide	43,000
	Aldicarb sulfone	7,800 ppm
K_d (distribution coefficient)	Aldicarb sulfoxide: clay with 1.4% organic matter Silt loam with 1.4% organic matter	3.3 0.34
K_{OC} (organic carbon coefficient)	Aldicarb	36
	Aldioarb sulfoxide	42
Vapor Pressure	Aldicarb	1×10^{-4} mm/kg at 25° C
Hydrolysis Half-life	(Hydrolysis of total residues: aldicarb + sulfoxide + sulfone) at pH 7.5 and 15°C at pH 5.5 and 5°C	5.0 years 12.5 years

NOTE: Cohen, S.Z., et al., 1984, "Potential for pesticide contamination of groundwater resulting from agricultural uses," pp. 297 in Treatment and Disposal of Pesticide Wastes, American Chemical Society Symposium Series, suggest that chemicals with the following characteristics should be considered a potential groundwater contaminant: water solubility greater than approximately 30 ppm; K_d less than 5; K_{OC} less than 300-500; and hydrolysis half-life greater than 25 weeks.

Aldicarb

Aldicarb, which triggered the issue of groundwater contamination by field-supplied pesticides, is a systemic carbamate insecticide that also has nematocidal properties. Aldicarb is the common name for the active ingredient 2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime. It is manufactured by Union Carbide Agricultural Products Co., Inc., and sold in granular form under the trade name Temik. Because of its high acute mammalian toxicity, aldicarb is available only in granular formulations (5-15 percent active ingredients) for soil incorporation. Under field conditions, the parent material is quickly transformed to aldicarb sulfoxide and aldicarb sulfone. The characteristics of aldicarb and its metabolites indicate that the pesticide is a potential groundwater contaminant (see Table 2-2). The general character of residues in groundwater is 0 percent aldicarb, 40-60 percent aldicarb sulfoxide, and 60-40 percent aldicarb sulfone. This ratio remains essentially stable as the aldicarb metabolites degrade to biologically inactive compounds. The acute mammalian toxicity of aldicarb sulfoxide is similar to that of aldicarb, whereas that of aldicarb sulfone is considerably lower. Aldicarb and its metabolites have been relatively well tested and are not known to be carcinogenic or teratogenic.

Aldicarb is a highly soluble and relatively nonvolatile pesticide, the effectiveness of which is a function of its ability to go into solution with available soil moisture. Once in solution, the insecticide enters the plant by way of root action and eventually is retained in the succulent parts of the plant. Sucking and chewing insects, such as aphids or the Colorado potato beetle, are then effectively controlled when they feed.

Typical applications of aldicarb on Long Island were 5 lbs active ingredients (ai) per acre (A) at spring planting followed with an additional 1-2 lbs ai/A as a side-dressing at mid-season. Such applications were made on virtually all the approximately 22,000 acres of potato fields in Suffolk County between 1975 and 1979. Rates were initially 3 lbs ai/A at planting (nationally labeled use rate), but the rates in New York were raised at the request of state scientists to 5 lbs for positive golden nematode control, then to 5 lbs at planting and 2 lbs side-dressed for seasonal Colorado potato beetle control. The pesticide was applied in the form of Temik 15G (15 percent active ingredient granules).

Groundwater contamination by aldicarb

Aldicarb has been the focus of groundwater investigations in Wisconsin and Florida (discussed in Chapters 3 and 4, respectively) as well as in New York. However, nowhere has the groundwater contamination caused by aldicarb been more extensive and better documented than on Long Island. Between August 1979 and mid-March 1980, approximately 270 wells were sampled on eastern Long Island; of those sampled 45 were public, 214 were domestic, and 11 were irrigation wells. Aldicarb concentrations in water samples from 61 wells (29 percent) exceeded the acceptable guideline of 7 ppb established by New York. Thirty-five wells (16 percent) had detectable traces below the guideline. The analyses were carried out by Union Carbide analytic laboratories. Most of these samples were taken in areas with the greatest potential for contamination—that is, locations with shallow water tables, sandy soils, and intensive potato production coupled with heavy use of aldicarb.

As a result of the initial investigation, an extensive well sampling program was begun to investigate the water quality of all wells near potato farming operations. An intensive monitoring program conducted from April to June 1980 included the collection of water samples from nearly 8,000 wells, the majority privately owned. The Suffolk County Department of Health Services (SCDHS) provided staff for the sample collection. Union Carbide paid the costs of shipping samples and also conducted the analyses. Of the 7,809 wells sampled during this survey, 5,745 (73.6 percent) had nondetectable concentrations of aldicarb; 1,025 (13.1 percent) had concentrations over the recommended standard of 7 ppb; and 1,032 (13.3 percent) contained traces of the pesticide (see Table 2-3). The mean concentration of aldicarb in all samples in which it was detected was 23.5 ppb.

On the basis of the rate of groundwater flow (approximately 150-200 feet/ year) and the number of years the pesticide had been used, the SCDHS concluded that only wells within 2,500 feet of potato farms were subject to possible contamination. Given this sampling constraint, more than 100 square miles remained to be surveyed and sampled. The area was divided into grids approximately 1,500 feet square resulting in 1,235 coordinate grids. The SCDHS field staff, assigned to specific areas, conducted block-by-block searches to assess the water quality of domestic wells. All accessible wells within 2,500 feet of potato farms were sampled. The percentage of wells with positive aldicarb detections in individual Suffolk County communities within the five townships sampled varied from 0 to 48.2 percent. On a township basis (Table 2-4), the percentages ranged from 9.0 to 32.2 percent.

Data collected from this survey confirmed that the highest concentrations of aldicarb were found closest to the potato fields. The relationship between the number of contaminated wells and the distance to the potato fields is represented in Figure 2-1.

Treatment of water contaminated by aldicarb.

Individual homeowners were informed of the quality of their drinking water. Those homeowners whose well water contained concentrations of aldicarb in excess of the recommended guideline of 7 ppb were cautioned not to use their water supply for cooking or drinking purposes. In response to the sampling program findings, an offer was made by Union Carbide to provide a granular activated

TABLE 2-3 Aldicarb Results by Suffolk County Township

		Wells with Aldicarb Concentrations in Excess of 7 ppb		Wells with Aldicarb Concentrations Between 1 ppb and 7 ppb		Wells with Aldicarb Concentrations Below Detection Limits	
Town	Total Number of Wells Sampled	Number	Percent	Number	Percent	Number	Percent
Brookhaven	222	2	0.9	18	8.1	202	91.0
Easthampton	434	43	9.9	46	10.6	345	79.5
Riverhead	2,161	351	16.2	345	16.0	1,465	67.8
Southampton	1,832	270	14.7	256	14.0	1,306	71.3
Southold	3,160	359	11.4	374	11.8	2,427	66.8
Totals	7,809	1,025	13.1	1,039	13.3	5,745	73.6

SOURCE: Baler, Joseph, and Dennis Moran, 1981, p. 16 in Status Report on Aldicarb Contamination of Groundwater as of September 1981, Suffolk County Department of Health Services, Long Island, New York.

TABLE 2-4 Half-Life Values of Aldicarb Sulfoxide and Aldicarb Sulfone at Environmental Hydroxide Ion Concentrations

	Half-life (days) at Indicated $[OH^-]$		
Compound and Temperature	10^{-8} (pH = 6.0)	10^{-7} (pH = 7.0)	10^{-6} (pH = 8.0)
Aldicarb Sulfoxide, 15°C (distilled water)	4,221	422	42.2
Aldicarb Sulfoxide, 15°C (well water)	8,212	821	82
Aldicarb Sulfone, 15°C (distilled water)	1,458	146	14.6
Aldicarbe Sulfone, 25°C (well water)	597	59.7	5.97
Aldicarb Sulfone, 15°C (well water)	2,431	243	24.3
Aldicarb Sulfone, 25°C	420	77	9.8

SOURCE: Lemley, Ann T., and Wei Z. zhong, 1984, "Hydrolysis of aldicarb, aldicarb sulfoxide, and aldicarb sulfone at ppb levels in aqueous media," J. Agric. Food Chem 34 (4):714-719.

carbon (GAC) treatment unit to those homeowners. To date, approximately 2,000 GAC units, each typically containing 29 lbs of granulated carbon, have been installed in Suffolk County at a cost to Union Carbide of approximately $450 each. Additionally, Union Carbide recharges the GAC unit with fresh activated carbon every 9 to 15 months, at a cost of approximately $60-$70 per unit.

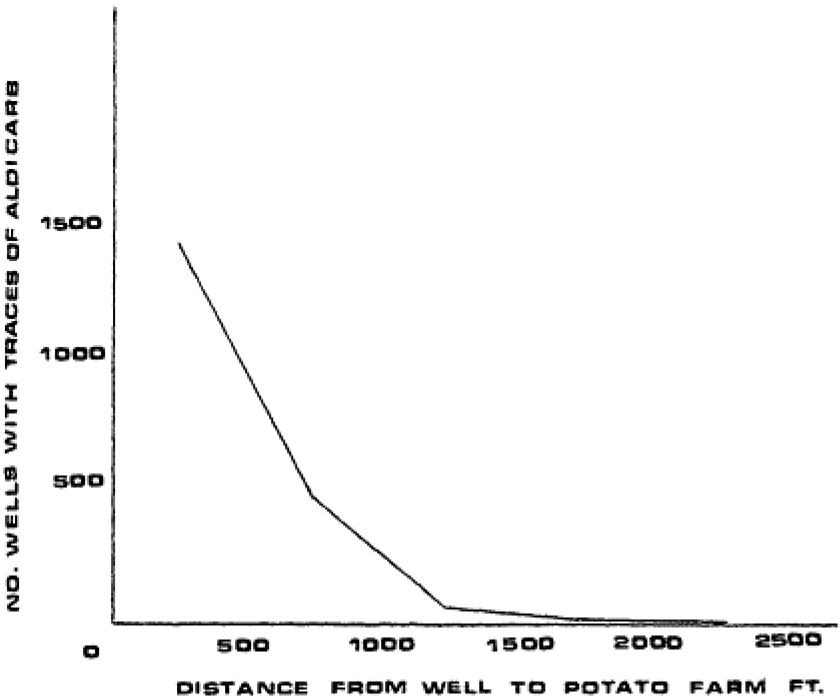

Figure 2-1
Number of wells with traces of aldicarb as a function of distance from well to potato farm. Note: The graph represents a point in time during the 1980 sampling program. Therefore, with passage of time and movement of groundwaters, wells farther from the fields have been contaminated. Source: Baler, Joseph, and Dennis Moran, 1981, p. 24 in Status Report on Aldicarb Contamination of Groundwater as of September, 1981, Suffolk County Department of Health Services, Long Island, New York.

In addition to domestic wells, a few municipal public supply wells exceeded the aldicarb guideline of 7 ppb.

These wells required the installation of large GAC treatment units. For example, Union Carbide installed a permanent GAC unit at Greenport well 6-1 (Greenport is on the North Fork east of Southhold) that contains 20,000 lbs of activated carbon and is able to treat 450 gallons of water per minute. It treated 168 million gallons of water prior to recharging after 1 year of operation. Recharging of this large unit is required on an annual basis, with Union Carbide paying all associated expenses. Additionally, large mobile GAC units have been used in Suffolk County to treat municipal wells that temporarily exceed the state aldicarb guideline.

From the viewpoint of Suffolk County, the GAC units were an immediate response to an emergency situation, but never a long-term solution. Many of these units have been in place for more than 4 years, however, and no obvious alternative exists to their continued use, which is considered to be highly effective.

Factors contributing to. groundwater contamination by aldicarb in Suffolk County

The primary factors that contributed to the presence of aldicarb in Suffolk County's groundwater include the pervasive and high rates of use of aldicarb, its high water solubility, heavy spring rainfalls following application, very permeable soils typical of glacial outwash deposits, cold soil temperature, *acid* soil conditions, low organic matter content, shallow water table conditions, and the presence of many shallow wells immediately downgradient of treated fields.

Once aldicarb reaches the groundwater, it may behave as a "conservative" substance—one that is absent or nearly absent from natural waters, does not react chemically with the natural water, and is not absorbed by the porous media of an aquifer. Those working on the problem have been frustrated by the longer than expected half-life of aldicarb in Suffolk County's groundwater. Initial estimates that the half-life of aldicarb in the Magothy aquifer would be 3 year. s have been revised, and currently the SCDHS assumes that total aldicarb (that is, aldicarb plus its metabolites) will remain above the 7 ppb levels in the groundwater for decades.

Studies have shown that the half-life of aldicarb sulfoxide in well water at 15°C and pH 6.0 is approximately 22.5 years, whereas at the same temperature but with base conditions (pH 8.0), the half-life value is only 82 days (see Table 2-4). Given the acidic nature of groundwater in Suffolk County (commonly pH 5.0-6.0), the implication for the persistence of aldicarb and other carbamate pesticides in the groundwater is clear.

Experimental use permit.

As a result of the sampling and detection of aldicarb in the groundwater, Union Carbide voluntarily removed Temik 15G from sale on Long Island before the 1980 growing season. The abrupt withdrawal of the pesticide from the market created problems for potato farmers who were hard-pressed to find an effective substitute to control the Colorado potato beetle. In response to this situation, an interagency steering committee, working with farm representatives and Union Carbide, agreed to the urgent need for an Experimental Use Permit (EUP) for aldicarb. An EUP, authorized by section 5 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), permits the field testing of an unregistered use.

It was believed that the EUP was needed to determine whether variations in the quantity or timing of applications might diminish or eliminate the possibility of aldicarb or its metabolites leaching to groundwater. An EUP permit was granted by EPA to Union Carbide on March 28, 1980, to evaluate this hypothesis. The company then made arrangements to fund the Cornell Cooperative Extension and the SCDHS for the planned investigation, which occurred from March 28, 1980, to March 25, 1981. The EUP allowed controlled use of aldicarb on several test areas; approximately 50 acres from three farms were planted with potatoes and treated with aldicarb by several methods of application.

In a cover letter accompanying the June 1982 Aldicarb EUP Report, Dr. Theodore L. Hullar, Director of the Cornell University Agricultural Experiment Station, outlined the prominent overall findings of the EUP investigation:

- The withdrawal of the pesticide from the Long Island Market seriously reduced the ability of farmers to control the Colorado potato beetle.
- It would be virtually impossible to use aldicarb on Long Island in a way that was consistent with the 7 ppb guideline.
- Most of the aldicarb appears to disappear from the soil fairly soon after planting. The data are insufficient to determine whether this is primarily due to biological causes or leaching.

The EUP investigation concluded that sufficient quantities of aldicarb leached below the root zone in each experimental treatment to cause the concentration of aldicarb in the groundwater recharge to exceed the New York State guideline of 7 ppb, assuming 50 cm of recharge per year. Little more than 1 percent of the applied aldicarb could be allowed to leach if the guideline were not to be exceeded. It was concluded that achieving such efficiency in pesticide removal was impossible for chemicals with properties similar to those of aldicarb.

Additional groundwater monitoring for aldicarb.

Groundwater monitoring for aldicarb has continued since 1980, with the total number of samples analyzed approaching 18,000. Of those wells sampled, a consistent 10-11 percent exceed the recommended guidelines for aldicarb. A 1982 report published by the SCDHS entitled Report on the Occurrence and Movement of Agricultural Chemicals in Groundwater: North Fork of Suffolk County concluded that

- Aldicarb contamination is currently limited to the upper 30-40 feet of the Magothy aquifer except in the central recharge portion of the North Fork, where it has been detected 100 feet below the water table.
- If aldicarb proves to be conservative in groundwater, it will eventually contaminate most of the North Fork aquifer, even though it has not been used in 1979; concentrations will probably approach or exceed the 7 ppb drinking-water guideline.
- If aldicarb does not break down in groundwater, it will take approximately 100 years for the East End's (North and South Forks) groundwater system to purge itself of the pesticide.

According to testimony provided by Union Carbide to EPA's FIFRA Scientific Advisory Panel on June 13, 1984, trends in the concentration of aldicarb vary by well depth. In some shallow wells in Suffolk County, aldicarb levels have been declining since 1980, whereas concentrations in some intermediate-depth wells have remained about constant and some deep wells have shown increases.

Monitoring for Additional Pesticides

Aldicarb is not the only pesticide that has been detected in Suffolk County's groundwater; rather, it is one of approximately 50 pesticides for which groundwater has been tested (Table 2-5). However, as indicated in Table 2-5, sampling and analysis for most pesticides have been infrequent, with the exception of the carbamate pesticides, 1,2-dibromoethane (EDB), and 1,2-dichloropropane. Complicating the picture is the lack of historical pesticide use data for Suffolk County or any other county in New York. In some cases, use data has been estimated based on the historical use of fields and the recommended pesticide application rates at the time. This approach has many shortcomings and at best can be relied on only to generate "ballpark" indications of pesticide usage.

Carbofuran (Furadan), another acutely toxic carbamate insecticide/ nematocide, has been detected in 30 percent of the approximately 5,100 samples analyzed by the SCDHS. A much smaller percentage of the samples, about 5-6 percent, actually equaled or surpassed the New York State guideline of 15 ppb for carbofuran. Manufactured by the FMC Corporation, carbofuran is highly soluble in water (700 ppm) with a distribution coefficient (K_d) value generally reported as less than 2, and a mean organic carbon coefficient (K_{OC}) value for five soil types reported as 29 ± 9. Its hydrolytic half-life at pH 6.0 is approximately 1 year. All these characteristics indicate a chemical with the potential to contaminate groundwater.

FMC voluntarily removed carbofuran from sale on Long Island in 1980. Later, FMC also agreed to pay for the installation of GAC treatment units for domestic wells with water containing carbofuran in excess of the New York State guideline of 15 ppb. Since only about 250 wells exceeded the water quality guideline for carbofuran, the financial liability to FMC for installing the GAC units was not as severe as that experienced by Union Carbide.

The Commissioner of Health for Suffolk County has recently been orchestrating a meeting among representatives of various agricultural chemical companies such as Union Carbide, FMC, Dow, and Shell to discuss sharing responsibility for groundwater contamination caused by their respective products. Union Carbide has long felt that, where feasible, the costs of installing and recharging GAC units should be shared among all those responsible for the presence of organic contaminants in Suffolk County's groundwater.

TABLE 2-5 Suffolk County Department of Health Services Pesticide Testing Program

Compound	Number of Samples Analyzed	Detected?	Total Number of Detects	Remarks
Aldicarb (Temik)	~18,000	Yes	~4,000	Highest concentration 515 ppb; approximately 11% exceed New York State guideline of 7 ppb
Aldrin	67	No		
Alachlor (Lasso)	24	No		
Arsenic	700	No		
Atrazine	14	No		
Benomyl (Benlate)	6	No		
Captirol (Difolatan)	24	No		
Carbaryl (Sevin)	3,945	—*		Traces up to 48 ppb found in seven wells; resamples negative
Carbofuran (Furadan)	5,083	Yes*	1,535	Highest concentration 65 ppb
Chlordane	67	No		
Chlorathalonil	24	Yes*	8	Highest concentration 16.3 ppb
Dacthal	166	Yes*	25	Highest concentration 1,039 ppb
Diazinon	17	No		
Dibrom	17	—*		Traces detected; confirmation samples negative
Dicapthon	3	No		
Dichlorvos	6	No		
Dieldrin	67	No		

Compound	Number of Samples Analyzed	Detected?	Total Number of Detects	Remarks
Dinoseb	66	Yes*	6	Traces up to 4.5 ppb found in wells
Disulfoton (Disyston)	3	No		
DDT (p, p)	67	No		
DDT (p, p)	67	No		
Endtin	88	No		
Eptam	12	No		
EDB	4,000	No*		Trace found at minimum detection level of 3 ppb
Ethyl Parathion	24	No		
ETU	49	No		
Guthion	54	No		
Heptachlor	67	No		
Heptachlor Expoxide	67	No		
Kelthane (Dicofol)	28	No		
Lannate (Methomyl)	3,945	—*	29	Traces found up to 9 ppb
Lead	>700	—*		Traces detected
Lindane	88	No		
Linuron (Lorox)	28	No		
Malathion	3	No		
Mancozeb	34	No		
Maneb	49	No		
Manzate (EBDC)	28	No		
Methyl Parathion	24	No		
Monitor (Methamidophos)	17	No		
Metasystox-R	3	No		
Methoychlor	88	No		
Organochlorine Screen	15	No		
Organophosphate Screen	15	No		
Oxamyl (Vydate)	3,945	Yes*	40	Highest concentration 18 ppb
Paraquat	14	_*		Traces found in one well; resample negative

Compound	Number of Samples Analyzed	Detected?	of Detects	Total Number Remarks
Parathion	3	No		
Permethrin (Pounce, Ambush)	29	No		
Penncap-M (encapsulated methyl parathion)	3	No		
Picloram	11	—*	1	Trace found at minimum detectionlevel
Simazine (Princep)	14	No		
Thiodan I and II (Endosulfan)	29	No		
Toxaphene	88	No		
Telone (D-D)	32	—*		1,2-Dichloropropane detected
Yapam (Metam-Sodium)	31	No		
Vorlex (methyl isothiocyantate)	34	—		1,2-Dichloropropane detected
Zineb	28	No		
1,2-Dichloropropane	~1,000	Yes*	~500	Highest concentration 300 ppb
2,4-D	88	No		
2,4,5-TP	88	No		

* See remarks.

SOURCE: Dennis Moran, Drinking Water Section, Suffolk County Department of Health Services. Values given are for December 1984.

Golden nematode quarantine program.

Another pesticide compound that has been regularly detected in groundwater samples is 1,2-dichloropropane (1,2-D). Pesticides containing 1,2-D were used in Suffolk County from the early 1950s until 1983 on fields that were quarantined by the U.S. Department of Agriculture (USDA) because of golden nematode infestation. The pesticides used that contained 1,2-D included D-D, Vorlex, Vidden D, and Telone II. (Telone II contains less than 2 percent 1,2-D.)

The USDA initiated the quarantine in an attempt to eradicate the golden nematode on Long Island. It applied D-D (which contained approximately 30-35 percent 1,2-D) at levels up to 100 gallons per acre in a single application. If the initial application were thought to be unsuccessful, additional treatments were made a few weeks later. Thus, the total application of D-D for a field in a single season may have been as high as 200-300 gallons per acre. Several thousand acres were treated with D-D and Telone II, or both, over the years the program was carried out. D-D was used from the early 1950s until the late 1970s, when it was replaced by Telone II. Telone II was then used through the 1983 growing season. (Aldicarb was used by farmers to control the golden nematode but was never used by the USDA for this purpose.)

Following the 1983 season, the USDA decided to stop all chemical treatment for the golden nematode because it concluded that no chemicals on the market could provide control without threatening the groundwater. During the 1984 growing season, the USDA recommended the use of resistant varieties of potatoes if golden nematode cysts were found in fields.

Some 1,000 domestic and irrigation wells have been sampled for 1,2-D with concentrations of 30-300 ppb detected in approximately 50 percent of the samples. (The water quality guideline established by New York for 1,2-D is 50 ppb.) This high percentage of detects is most likely caused by biased sampling methodology; the areas sampled were chosen based on estimates of heavy 1,2-D applications. The USDA has been involved in the sampling of wells in Suffolk County for 1,2-D and sends samples, on a regular basis, to its analytic laboratory in Gulfport, Mississippi, for analysis.

Suffolk County well testing program.

The SCDHS has established one of the most extensive groundwater sampling programs in the nation in an attempt to characterize the water quality of the more than 70,000 domestic and municipal wells serving Suffolk County residents. The water quality testing is free of charge, but, because of the great number of requests received, there is a long waiting list for this service. Under this program approximately 7,000 samples are analyzed each year for organic compounds including industrial solvents, petroleum derivatives, and pesticides. The SCDHS analytic laboratory, with the help of Union Carbide, has developed the capability for performing a carbamate scan that uses a liquid chromatography process. The carbamate scan allows the laboratory to analyze for aldicarb, aldicarb sulfoxide, aldicarb sulfone, oxamyl, methomyl, 3-hydroxycarbofuran, carbofuran, carbaryl, and 1-naphthol. The minimum detection level for aldicarb, its metabolites, and the six other compounds is 1 ppb. Using this method, the average recoveries of the nine pesticide and pesticide-related materials, when added to water at concentrations of 8 and 40 ppb, exceeds 95 percent. The process is automated and requires virtually no sample preparation.

Groundwater sampling for pesticides in upstate New York.

Little groundwater sampling for pesticides has occurred in New York outside of Long Island. A modest program carried out in 1983 at Cornell University's Center for Environmental Research sampled groundwater for the presence of aldicarb at 60 locations in potato growing areas in six upstate counties. Wells were selected that seemed most vulnerable to aldicarb contamination based on heavy usage of the pesticide, shallow depth to groundwater, and assumed position downgradient with regard to groundwater flow from the potato fields. (Owing to budget constraints, a precise determination of the groundwater flow direction in the proximity of the sampled wells was not possible in this study and, consequently, flow direction was estimated.) The analytic work was performed by a Union Carbide laboratory.

Aldicarb concentrations in three wells (5 percent) exceeded the New York State health guideline of 7 ppb. The soils near these wells were sandy, and aldicarb had been applied in the areas either every year or every other year for 8 years preceding the sampling. At 15 locations (25 percent), the groundwater was found to have concentrations between 1 and 7 ppb; the remaining 42 locations (70 percent) had no detectable amounts of aldicarb. Some of the areas tested had muck soils with higher organic matter content and microbial populations than the sandy soils of Suffolk County. Aldicarb concentrations in groundwater in these muck-soil areas never exceeded 2 ppb. Cornell University scientists postulated that the elevated presence of organic matter resulted in the aldicarb being strongly sorbed by the muck soils, which facilitated the pesticide's accelerated breakdown by high bacterial populations. Of the 19 samples analyzed for nitrates, 16 contained measurable levels between 0.05 and 18.0 ppm. No well showed positive detections for both nitrate and aldicarb, so no comparison could be made between nitrate and aldicarb concentrations.

Also in 1983 the New York State Department of Health sampled 10 wells in upstate New York for aldicarb. This effort found one well with an aldicarb concentration of 30 ppb. This well was only 25 feet deep and located adjacent to a potato field. Other wells had no detectable amounts of aldicarb in the groundwater. Porter and Pacenka (1983) in a Cornell University report entitled Results of 1983 Upstate New York Sampling of Groundwater for Aldicarb, recommended that the state initiate a "carefully specified sampling program for rural drinking water wells in upstate New York." They suggested that the state identify the chemicals that are likely to be introduced and persist in groundwater, determine groundwater flow direction from the point of use of these chemicals, and calculate the travel time required for the chemicals to move from the point of application to a well. However, no systematic survey of this type has been initiated to determine possible threats to drinking-water quality in rural areas of New York.

Current Monitoring Efforts

Virtually all current monitoring of groundwater for pesticides in New York is being conducted in Suffolk County, where 35-45 percent of approximately 20,000 samples collected annually are analyzed for organic constituents including pesticides. The carbamate pesticide scan mentioned earlier is used to analyze approximately 5,000 samples per year. The well testing and subsequent analyses are done on a request basis. Frequently, months elapse between the time a request is made and the time the sampling and analyses actually occur.

Cooperative sampling by Union Carbide and the SCDHS of wells where aldicarb was detected is continuing to provide environmental fate data on aldicarb in the Magothy aquifer. Also, the USDA is carrying out limited sampling for 1,2-D to assess the extent of groundwater contamination caused by pesticides containing 1,2-D used in the golden nematode quarantine program.

CRITICAL PROBLEMS AND NEEDS

Nematocides

Nematocides such as aldicarb, D-D, and carbofuran have caused extensive groundwater contamination in Suffolk County. None of the nematocides just mentioned is used any longer in Suffolk County. As in California, nematocides reaching groundwater present a difficult management problem with no obvious resolution. The golden nematode (Heterodera rostochiensis) and root lesion nematode (Pratylenchus penetrane) are significant pests in potato production. But because of the highly vulnerable hydrologic environment in Suffolk County and the high water solubility of most nematocides, few nematocides can be used there without threatening groundwater.

In recognition of this problem, the USDA decided in 1984 against chemical treatment for the golden nematode and recommended the use of resistant varieties of potatoes in areas where golden nematode cysts are discovered. The root lesion nematode (RLN) was identified in 1984 as an important pest in potato fields, especially on the South Fork, where a rotation of potatoes with rye is common. Rye is an excellent host for RLN. Factors such as soil moisture, temperature, organic matter, and pH also may be more favorable for the RLN on the South Fork. Potato varieties resistant to nematodes are being advocated as an alternative to the use of nematocides. However, existing resistant varieties may not possess the quality or other necessary traits that would lead to their widespread adoption by potato growers. Short-term options to control nematodes are thus considered very limited.

Interdisciplinary Research

The need for interdisciplinary research to address the impacts of agriculture on groundwater was generally recognized among those visited in New York. For example, researchers at Cornell University, Pennsylvania State University, the University of Maryland, and the University of Delaware have submitted to the Northeast Regional Cooperative States Research Service of the USDA a proposal for research to evaluate pesticide and nutrient losses by leaching and runoff in tilled and untilled soils. The research program would also establish a data base for the development and testing of water quality models. The research would draw on the talents of agronomists, soil physicists, hydrologists, chemists, entomologists, and agricultural engineers at the universities mentioned. Justifying the need for this research, the researchers assert that most environmental fate research is retrospective, after the chemical is released to the system. But with properly constructed and validated models it may ultimately be possible to consider pesticide usage on a prospective basis, thus managing chemical applications to prevent unacceptable groundwater contamination. Additionally, studies are needed to determine what, if any, additional risk no-till agriculture poses to groundwater given the increased use of herbicides required by that management strategy.

A scientist associated with the Chemicals-Pesticide Program at Cornell University said that the occurrence in Suffolk County of groundwater contamination from pesticides was just the "tip of the iceberg" in terms of the overall problem and that the issue was not going to disappear and deserved the immediate attention of an interdisciplinary research team. His main concern was that additional detections of pesticides in groundwater could lead to public pressures to ban pesticides known to be contaminants. He voiced a commonly heard observation that the ability to detect trace amounts of pesticides in water was much more advanced than the understanding of the toxicology associated with such discoveries.

Evaluation of Leaching Potential of Pesticides

The aldicarb experience on Long Island illustrates the insufficiency of environmental fate data that the EPA historically required from agricultural chemical companies for a pesticide's registration. Based on the environmental fate studies reported at the time of registration, aldicarb was expected to break down to nontoxic by-products long before it could leach to the groundwater in a toxic form. Unfortunately, events and increased analytic capabilities proved this was not the case. EPA is increasing its environmental fate data requirements (see Chapter 5), but the methodology for easily evaluating the potential movement of pesticides beyond the root zone and predicting more accurately the environmental fate of pesticides remains elusive. This problem is discussed more fully in the section MODELS TO PREDICT THE TRANSPORT AND ENVIRONMENTAL FATE OF PESTICIDES.

Groundwater Quality Data Base

The groundwater quality data base dating back to 1979 for a handful of pesticides in Suffolk County is extensive and useful; however, the data base for New York as a whole is practically nonexistent. More than 18,000 samples from Suffolk County have been analyzed for aldicarb versus less than 100 from remainder of the state. The New York State Department of Environmental Conservation has not initiated significant programs to characterize the groundwater quality in agricultural areas. Reasons for the relative scarcity of samplings outside of Suffolk County include less susceptible environmental conditions; less concentrated agriculture; and a lack of historical pesticide use data.

Residue Analysis

The carbamate pesticide scan permits analytic values to be generated from a single groundwater sample for aldicarb and its metabolites, as well as for carbofuran, carbaryl, oxamyl, and methomyl. The cost savings associated with such a multiresidue technique are significant, and the data base can be expanded more rapidly for a given sampling program budget. A multiresidue analytic screening technique that could handle an even wider range of pesticides would obviously yield even greater benefits for each dollar spent on a sampling program.

Pesticide Applicators

Unlike California, where aerial applicators often work from a single landing strip, aerial application of pesticides on Long Island is primarily accomplished by helicopters that fill their spray tanks in the area they are spraying and do not continually return to the same location for refueling and refilling. This method of applying pesticides allegedly reduces the potential for concentrated point-source pollution of groundwater caused by spills during the filling of spray tanks. Apparently, on Long Island the threat to groundwater quality from point sources of pesticides is minimal when contrasted with nonpoint sources.

Public Sentiment Against Pesticide Usage

A researcher at Cornell University mentioned his concern that the public on Long Island had become prejudiced against the use of pesticides because of the problems associated with aldicarb, carbofuran, 1,2-D, and others. He was especially concerned about the availability of pesticides for minor or specialty crops because the range of alternative pesticides for these crops is narrow. Consequently, the loss of an effective chemical for minor crops can more severely impact that agricultural sector than the loss of a pesticide for more prominent crops such as corn, soybeans, or cotton. This concern is especially relevant to Suffolk County, where minor and specialty crops are increasing in acreage as potato production declines.

AGRICULTURAL MANAGEMENT STRATEGIES AVAILABLE TO MITIGATE PESTICIDE/GROUNDWATER QUALITY PROBLEMS

Irrigation Efficiency

Improved irrigation efficiency in New York has limited potential for reducing the movement of pesticides to groundwater. In Suffolk County's sensitive hydrologic environment—that is, highly permeable soils combined with low soil organic matter content, a shallow water table, and substantial precipitation—improved irrigation efficiency would only modestly reduce pesticide leaching.

Potato Integrated Pest Management Program

Potato production has been a major agricultural activity on Long Island for about 100 years. Unfortunately, the monoculture nature of potato farming has led to problems with pest control. Pest populations have increased over the years, and heavy applications of pesticides are required to manage their numbers. Continued use of the same pesticides has reduced their effectiveness because of the development of pest resistance. Aldicarb was quickly accepted by growers when it was first introduced in 1975 for potato production because it proved highly effective against nematodes as well as the Colorado potato beetle. Since aldicarb was banned in 1979, Long Island growers have relied primarily on the pesticides fenvalerate, endosulfan, and oxamyl. They have increased both the number of pesticide applications and the total amounts applied, resulting in higher costs but not necessarily comparable crop protection.

Recognizing the double constraint of the need to control pests and to protect groundwater quality, Cornell University and its Long Island Horticultural Research Laboratory (LIHRL) have instituted a research program to study new methods of pest control for Long Island potato growers. The Cornell University Pest Management Steering Committee began a pilot potato integrated pest management (IPM) program in June 1981. The priory emphasis of this program was to obtain information on monitoring and management of the Colorado potato beetle, which is the major limiting factor in potato production in Suffolk County. The staff at the LIHRL has been collecting data to determine levels of infestation by the Colorado potato beetle and the amount of subsequent damage that can be economically tolerated. Knowing the threshold of economic damage, pest management personnel can time spraying more efficiently. Initial work with growers by LIHRL staff has been encouraging and suggests that a reduction in the use of pesticides is possible in some circumstances.

In 1982 a crop rotation study included the IPM program to assess its control of Colorado potato beetle populations. Based on the observed data and a knowledge of Colorado potato beetle population dynamics, the LIHRL staff estimated that approximately two to four insecticide sprays could be eliminated using a crop rotation that included planting a crop other than potatoes in 1 year.

Other methods for reducing the Colorado potato beetle populations being studied by the LIHRL include biological controls and certain cultural practices. Biological controls will probably not become available in the near future. An example of a cultural practice being evaluated is an earlier application of herbicides used to kill potato vines prior to harvest. This practice could beneficially reduce the food available to the beetles and diminish the numbers that survive to the next growing season.

At the same time, some agricultural management techniques to control pests create other problems. TO control potato scab, most growers maintain their soils at an acidic pH. This form of control severely limits the rotation options available, however, because many crops of economic interest cannot flourish in highly acidic soils. Thus, agricultural practices developed to control the potato scab on Long Island have fostered the monocultural practices that contribute to the problems caused by the Colorado potato beetle and the golden and root lesion nematodes. Scab-resistant potato varieties exist, but again they are not considered to be as commercially attractive as the nonresistant varieties now grown.

Best Management Practices for Pesticide Use

Using BMPs to prevent groundwater contamination from pesticide usage is especially critical in a highly sensitive hydrologic environment like Long Island. The range of practices and management options previously discussed in Chapter 1 for California are equally relevant and important for groundwater protection in Suffolk County. However, it must be recognized that in some environments a combination of soil and hydrologic characteristics will make it practically impossible to prevent the movement of highly soluble organic chemicals through the vadose zone to groundwater. In those environments, nonchemical alternatives for pest control and the use of resistant crop varieties are critically important if groundwater quality and crops are to be protected.

MODELS TO PREDICT THE TRANSPORT AND ENVIRONMENTAL FATE OF PESTICIDES

Considerable work is being done at Cornell University on models to predict the transport and environmental fate of pesticides, but few data exist to validate solute transport models under field conditions. Several models have been developed, however, to predict the downward movement of pesticides through the unsaturated zone. Examples of models currently available to predict pesticide persistence and movement in the soil/water environment include the Pesticide Analytical Solution (PESTANS) I, PESTANS II, and the Pesticide Root Zone Model (PRZM), developed by EPA; and Transport of Pesticides in Soil (TOPS), developed at Cornell University. These models generally compute the rates of leaching and degradation as a function of time.

The PESTANS I model is a one-dimensional steady-state model that is limited to projecting vertical movement through the unsaturated zone. It is computationally simple to run and is used to evaluate the relative groundwater contamination potential of various pesticides.

PESTANS II is a two-dimensional transient numerical model that will predict both horizontal and vertical movement of water and solutes. This model allows the user to vary degradation rates and soil absorption with depth. Additional input data on water flux and soil characteristics throughout the system allow separate predictions of the rate of leaching through the root zone and the vadose zone, as well as calculated concentrations in the saturated zone. PESTANS II requires much more hydrogeologic input data, is more complex to run, and requires considerably more computational time than PESTANS I.

The PRZM is a one-dimensional, transient hydraulic model for evaluating the movement of pesticides within the root zone and the lower unsaturated zones. PRZM is linked with precipitation and soil data bases to estimate leaching of pesticides.

The TOPS model was developed to simulate the vertical transport of aldicarb to groundwater on Long Island. It generally requires the same input as the PESTANS models, and the output is in a similar format.

In some models—for example, PESTANS I—the transport processes are greatly simplified so that the model can be run with minimal data. This simplification can result in misleading projections, however. In other models— for instance, PESTANS II —the attempt to take all parameters into account requires such large amounts of specific information that data may not be available nor practical to obtain. Thus, more comprehensive modules may also lead to unsatisfactory results.

Soil heterogeneity, concentration of macropores, and the level of microbial activity are problems that have proved difficult to incorporate into models. Pesticide uptake by plants has been largely ignored in most models because it was considered insignificant relative to other pathways. Some scientists, however, believe that estimates of plant uptake should be included in models to better simulate the environmental fate of pesticides.

Because of these shortcomings, many professionals are skeptical of the usefulness of current models in field situations. Continued model development and field verification are required before simulation models will be fit to replace soil and groundwater monitoring as the primary tool for assessing the environmental fate of a pesticide. Nevertheless, researchers believe simulation models will become important regulatory and management tools in the future. Because of the extreme complexity of agroecosystems, it seems inevitable that simulation models will be required to integrate the various processes that determine a pesticide's ultimate environmental fate.

3

Wisconsin

Wisconsin is a major agricultural state that ranks near or at the top as a producer of several commodities including dairy products, green peas and sweet corn for processing, cranberries, and potatoes. Cash receipts for all agricultural commodities totaled nearly $5 billion in 1983, which ranked the state eighth in the nation in that category.

Prior to 1980, no incidents of groundwater contamination caused by agricultural pesticides had been reported in the state. In 1980, after the discovery of aldicarb in groundwater in Suffolk County, New York, Union Carbide, working jointly with the EPA and several states including Wisconsin, collected samples to assess whether aldicarb residues were present in groundwater. By the

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On August 2 and 3, 1984, Holden visited with various individuals in Madison, Wisconsin, who are knowledgeable of groundwater problems in that state and of the recently enacted groundwater protection bill (1983 Wisconsin Act 410). The institutions represented by the individuals visited include the University of Wisconsin—Madison; the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP), which licenses pesticide manufacturers who do business in the state and regulates pesticides to protect public health; the Wisconsin Department of Natural Resources (DNR), which is responsible for protecting and managing the waters of the state, including groundwater; the Wisconsin Water Resources Center (WIS WRC; jointly funded by the U.S. Department of the Interior and the state), which carries out or directs research related to water resources in Wisconsin; and the Wisconsin Public Intervenor's Office.

summer of 1981, analysis of samples taken jointly by Wisconsin and Union Carbide detected aldicarb in approximately 18 percent of the wells sampled. That discovery, in conjunction with a growing national concern about groundwater contamination, resulted in additional sampling for a range of pesticides and ultimately contributed to the passage of the groundwater protection law, 1983 Wisconsin Act 410.

Since 1957, irrigation in Wisconsin has burgeoned, and the demand on groundwater for irrigation is expected to rise dramatically in the next few decades. Several factors make large portions of the state ideal for irrigated agriculture. Relatively flat land can easily accommodate center pivot irrigation equipment. Sandy, permeable soils allow water to quickly infiltrate and drain, providing good soil aeration and root penetration. The sandy soils are easy to prepare for planting, need less plowing, and allow easier harvesting in wet weather. These conditions have allowed Wisconsin, once considered predominantly a dairy state, to become nationally prominent in the production of potatoes, peppers, snap beans, peas, corn, soybeans, and cranberries.

Most of Wisconsin's 3,000+ high-capacity irrigation wells are located in the 10-county Central Sands area. The irrigation wells clustered in this region supply approximately 50-60 percent of the state's irrigated acreage. Although many of the soil and vadose zone characteristics of Wisconsin's Central Sands area are similar to those of Suffolk County, there is one important difference. Wisconsin's soils and groundwater are generally not as acidic as those of Long Island and on the average tend to be neutral or slightly acidic.

The sand and gravel aquifer underlying the Central Sands region covers approximately 75 percent of the state. It is an unconfined aquifer that has no impermeable layer overlying it. Consequently, it is highly susceptible to contaminants introduced at the soil surface.

THE STATUS OF EFFORTS TO MONITOR GROUNDWATER FOR RESIDUES OF AGRICULTURAL PESTICIDES

Past Monitoring Efforts

Limited monitoring of groundwater for agricultural chemicals has occurred in Wisconsin. Historically, the number of samples collected and the range of pesticides subject to analysis have been small. One obvious reason for this is the relatively recent discovery of aldicarb in groundwater; time has been insufficient to develop a sampling protocol or to secure funding for a broad sampling program. Additionally, the DATCP laboratory and State Hygiene Laboratory have lacked the capacity to handle a large volume of samples. Consequently, until recently the state has had to rely on laboratory support from the EPA and Union Carbide. The data base on pesticides in groundwater in Wisconsin is therefore limited in time and space, although substantial (see Tables 3-1 and 3-3). More resampling has been done of wells in Wisconsin than elsewhere.

Aldicarb

As a result of sampling conducted after the discovery of aldicarb in the groundwater of Suffolk County, New York, Union Carbide detected aldicarb in Wisconsin's groundwater in 1980. Extensive well sampling for aldicarb began in the spring of 1981 and has continued quarterly in a cooperative program between the Wisconsin DNR and Union Carbide.

In 1981, Union Carbide, the University of Wisconsin, the DNR, and the Portage County Community Human Services Department cooperated in an extensive well water sampling program for aldicarb. The sampling concentrated on potable water wells in potato-growing areas thought to be most susceptible to groundwater contamination. Sites selected for sampling were those where nitrate contamination was known;* aldicarb had been used during the preceding 2 years; sandy, acidic soils with little organic matter predominated; a shallow water table existed; and irrigated agriculture was practiced. Based on these criteria, 363 well water samples were collected and analyzed from 10 counties. Of the samples, 51 (14 percent) contained aldicarb residues at or below the 10-ppb state health guideline, 13 (4 percent) contained levels ranging from 11 to 30 ppb, and 4 (1 percent) contained levels greater than 30 ppb. The highest concentration found was 111 ppb.

* However, no correlation between nitrate contamination and pesticide residues in groundwater has been established.

The discovery of aldicarb in groundwater was a blow to Wisconsin potato growers, who consider aldicarb an extremely valuable pesticide. It is claimed to increase potato yields 15-25 percent over yields obtained by using alternative chemical controls for nematodes, Colorado potato beetles, aphids, and leafhoppers. Because various viral diseases of plants are associated with the occurrence of certain insects or nematodes, control of these pests by aldicarb often results in disease suppression with corresponding yield increases and improvement in crop quality. Since the late 1970s, aldicarb has been the pesticide of choice for control of potato pests, particularly by the larger scale potato farmers. In 1981, prior to the label changes that restricted its use, Union Carbide distributed 866,000 lbs of Temik 15G in Wisconsin.

The zones of aldicarb contamination apparently occur primarily at locations where the soil and groundwater pH are slightly acidic. The pH in the Central Sands area differs widely due to the variable nature of geologic material deposited by glaciers. For example, areas where glacially deposited limestone or other alkaline geologic material is concentrated have soils and aquifer materials with a higher level of alkalinity than areas where more acidic material has accumulated. Consequently, the pH of the groundwater in the Central Sands region varies from 5.0 to 8.5. As mentioned before, pH is a critical variable in determining the persistence of aldicarb in groundwater, and studies by the WIS WRC show that aldicarb residues tend to be encountered more often where the soil and groundwater pH are low.

Repeated sampling by the University of Wisconsin—Madison staff in the Central Sands region has shown that groundwater contamination by aldicarb does not generally extend beyond 10 or 15 feet below the water table. Accordingly, the highest concentrations detected have been in shallow wells near the potato fields where aldicarb was used. The problem of contaminated domestic water supplies has been exacerbated by the common use of well points that penetrate just the top few feet of the aquifer. As a consequence, if aldicarb has leached to the water table, these shallow wells are especially likely to tap contaminated water.

After aldicarb was detected in approximately 18 percent of the samples from the 1981 sampling program, severe restrictions were placed on its use for the 1982 growing season. The restrictions were agreed on by Union

Carbide, the DATCP, and the Pesticide Review Board (comprising the Secretaries of DATCP, DNR, and the Department of Health and Social Services). The restrictions were incorporated into an emergency rule by the DATCP and were submitted by Union Carbide, in the form of label changes, to the EPA. In March 1982 the EPA approved these changes, which are summarized below:

- Aldicarb is designated as a restricted use pesticide that may not be applied except by state-certified private or commercial pesticide applicators, or by other persons under the direct supervision of a certified applicator.
- Aldicarb applications on potatoes can only be made 4 to 6 weeks after planting, rather than at the time of planting.
- Aldicarb cannot be applied to the same field more than once every 2 years.
- Application rates for potatoes are reduced to a maximum of 2 lbs active ingredient per acre (ai/A) from 3 lbs ai/A. As a result of the reduction in the amount of aldicarb active ingredient that could be applied to Wisconsin potatoes, Union Carbide removed nematode control claims from Temik labeling.
- The revised label must include a statement of the potential for groundwater contamination associated with aldicarb use.

Union Carbide estimated that these changes would reduce the potential for aldicarb leaching to groundwater in Wisconsin. The projected influence of those changes on reducing the probability of groundwater contamination is discussed in the comments on irrigation in the section CRITICAL PROBLEMS AND NEEDS.

The restrictions on aldicarb use were included in a rulemaking change, first as an emergency rule for the 1982 growing season and then as a permanent rule prior to the 1983 growing season, under the authority vested in the Wisconsin DATCP. The purpose of the aldicarb rule is to minimize the quantity of total aldicarb reaching groundwater and to prevent aldicarb levels in groundwater from exceeding 10 ppb, the level the state has set as its advisory. In addition to the label restrictions, the rule requires prospective aldicarb users to file a report of intended use with the DATCP at least 30 days before the date of use.

Significantly, the rule further restricts the use of aldicarb An areas where aldicarb concentrations in groundwater have exceeded 10 ppb. The rule states that aldicarb applications are prohibited if the intended application site is "located within a township quarter-quarter section of land lying wholly or in part within one mile of a sample point at which aldicarb residues have been detected An groundwater at a level exceeding 10 parts per billion" (Figure 3-1). The areas where aldicarb use has been restricted are referred to as moratorium areas. In 1984, 45 wells located in 22 different quarter-quarter sections were found to exceed the 10-ppb level for aldicarb. In 1985, 30 wells located in 25 different quarter-quarter sections were found to exceed the limit for aldicarb. These detections created 11 moratorium areas for the 1985 growing season encompassing approximately 36,500 acres. Most of the moratorium areas are located in Portage County. Delineation of a moratorium area is based on a completed groundwater analysis received by the DATCP no earlier than March 1 of the year immediately preceding the year of intended application. In certain cases, sites within the moratorium areas can be exempted from the prohibition—for example, if the DATCP determines that the intended application site is not in the same recharge areas as the sample point with aldicarb concentrations exceeding the health standard.

Samples used as the basis for establishing a moratorium area must be collected by or under the supervision of the DNR, the Department of Health and Social Services (DHSS), or the DATCP. Samples must come from a potable water supply well or any other well, provided the well construction and sampling methodology do not interfere with the integrity of the groundwater sample. Samples cannot be taken from high-capacity irrigation wells or any well located within 300 feet of such a well, which can bias water quality samples by influencing the hydraulic gradient of the aquifer in its vicinity.

Under this rule, pesticide distributors and retail dealers are required to keep records of aldicarb sales and to file weekly sales reports with the DATCP. Greenhouse applications of aldicarb are exempt from the rule's provisions.

The aldicarb rule can be amended at any time if evidence indicates that the restrictions imposed on aldicarb do not satisfactorily protect groundwater. In fact, the DATCP is currently considering changes in the rule as a result of agency field research.

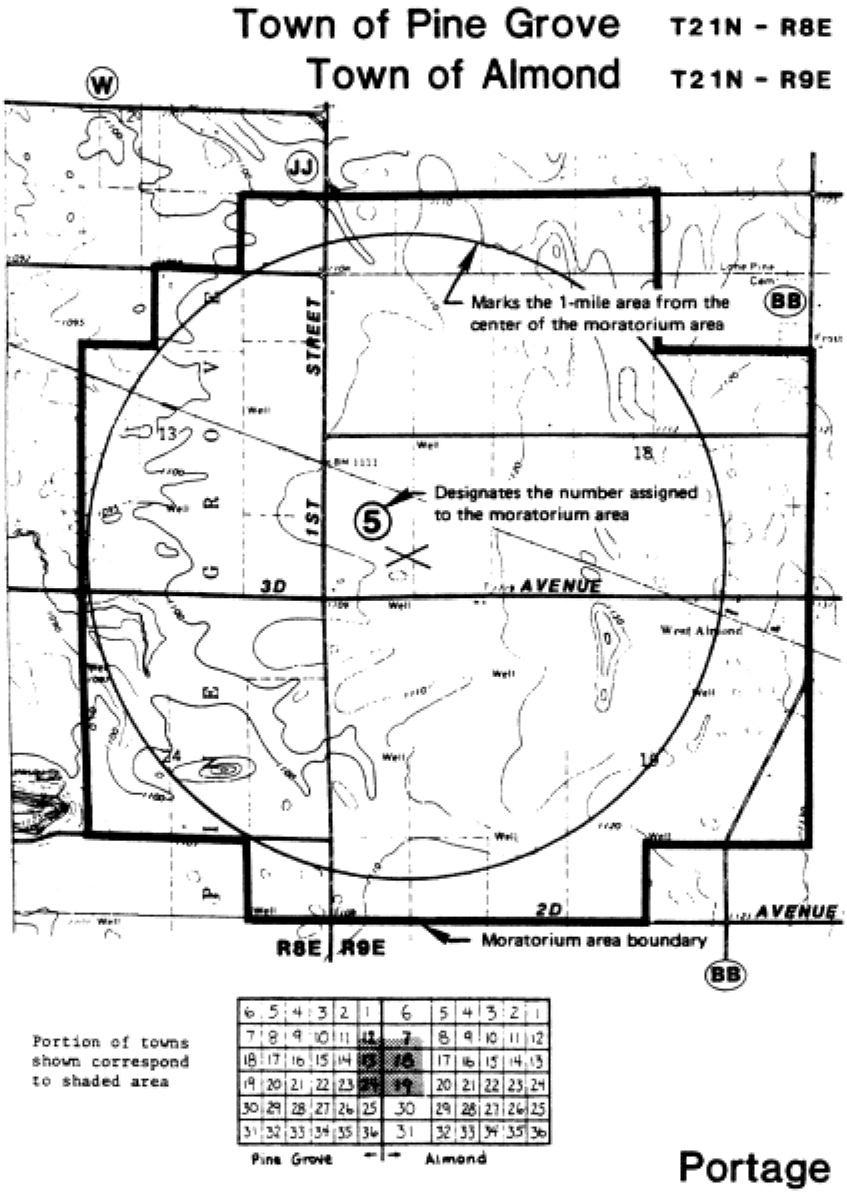

Figure 3-1
Example of moratorium area in Portage County. Source: Wisconsin Department of Agriculture, Trade, and Consumer Protection. Reproduced from a topographical map, courtesy of U.S. Geological Survey.

The most recent Union Carbide summary of groundwater analyses for aldicarb in Wisconsin is shown in Table 3-1. These data indicate that as of January 1985, 963 wells in 22 Wisconsin counties have been sampled collectively 2,293 times. Aldicarb has been detected at 116 sites (12 percent). Currently, 36 sites (4 percent) have aldicarb concentrations greater than 10 ppb. According to a Union Carbide summary accompanying the data, of the 190 wells that have been resampled 2 or more times, 123 wells (65 percent) show a downward residue trend, with 87 of those having no remaining detectable residues. By comparison, 17 wells (9 percent) have shown increased aldicarb concentrations, and the remaining 50 wells (26 percent) have had no change.

Union Carbide believes these data indicate that the overall trend in Wisconsin is toward lower residues, presumably because of declining use caused by the new label restrictions. In 1984 the highest concentration of aldicarb found in the water from a domestic well was 54 ppb—down from a high of 111 ppb in 1981.

Sampling for Additional Pesticides

The Wisconsin DNR has been actively sampling drinking-water wells and analyzing the samples for some of the 45 pesticides determined by the DATCP as having the greatest potential for reaching groundwater (Table 3-2). This list of priority pesticides was identified by the DATCP staff in collaboration with other Wisconsin agencies and with EPA staff in Washington, D.C., and Georgia. The first 22 chemicals on the list are those the DATCP identified as posing the greatest potential threat to groundwater. These should receive the highest priority in the DNR sampling program, which began in July 1983 and is continuing on a regular basis. Field sampling is carried out by DNR personnel from all six DNR district offices throughout the state, although the bulk of the sampling has occurred in the Central Sands region. Analytic support is provided by Union Carbide, which runs approximately 600 water samples (plus quality assurance samples) per year for DNR without charge, and the State Hygiene Laboratory. Annual state funding for the program has been approximately $100,000 with a total of 1,500 analyses allotted for pesticides each of the past 2 years.

TABLE 3-1 Summary of Wisconsin Wells Analyzed for Residues of Aldicarb

	Total Wells Sampled					Resampled Wells Data									
	Total	Latest Reading, ppb				County	Latest Reading, ppb				Where Resampled Residue Is:				Total
County	Sites	0	1-10	11-30	>30	Totals	0	1-10	11-30	>30	Up	Down	Even	Zero	Analyses
Adams	69	69	0	0	0	23	23	0	0	0	0	3	0	20	137
Barron	56	51	5	0	0	19	14	5	0	0	2	0	1	0	128
Columbia	4	4	0	0	0	0	0	0	0	0	0	0	0	0	4
Florence	4	4	0	0	0	2	2	0	0	0	0	0	0	2	7
Iowa	4	4	0	0	0	1	1	0	0	0	0	0	0	1	7
Jefferson	6	6	0	0	0	1	1	0	0	0	0	0	0	1	7
Juneau	22	18	0	3	1	8	5	0	2	1	3	0	0	5	37
Langlade	71	63	7	1	0	16	11	4	1	0	0	2	4	10	139
Lincoln	4	4	0	0	0	8	0	0	0	0	0	0	0	0	4
Marathon	115	71	25	12	7	66	26	21	12	7	15	17	17	17	506
Marinette	1	1	0	0	0	0	O	0	0	0	0	0	0	0	1
Portage	395	355	30	6	4	130	103	24	7	4	12	40	11	75	956
Richland	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Rusk	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Sauk	3	3	0	0	0	2	2	0	0	0	0	0	0	2	7
Sawyer	4	4	0	0	0	0	0	0	0	0	0	0	0	0	4
Vilas	15	15	0	0	0	0	0	0	0	0	0	0	0	0	15
Walworth	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Waukesha	2	2	0	0	0	1	1	0	0	0	0	0	0	1	4
Waupaca	57	50	7	0	0	10	6	4	0	0	1	2	0	7	105
Waushara	94	91	3	0	0	21	18	3	0	0	1	1	3	16	158
Wood	25	20	3	2	0	15	10	3	2	0	0	5	1	9	63
Totals	963	847	80	24	12	323	223	64	24	12	34	70	37	174	2,293
Percents	100	88	8	3	1	100	69	20	7	4	11	24	11	54	100

SOURCE: Union Carbide Agricultural Products Co. 1985. Temik—Wisconsin well monitoring; sample collection by portage County or Wisconsin Department of Natural Resources. January 22. Memorandum.

TABLE 3-2 Priority Pesticides Identified by the Department of Agriculture, Trade, and Consumer Protection (DATCP)

Pesticide	Remarks
1. Alachlor (Lasso)	High use, high leach, and detection
2. Metolachlor (Dual)	High use, unknown acceptable daily intake (ADI)
3. Amitrole (Amizole)	Animal carcinogen
4. Chloramben (Amiben)	Suspected animal carcinogen and leach
5. Aldicarb (Temik)	High toxicity, leach, and high detection
6. Carbaryl (Sevin)	Suspected animal carcinogen and high use
7. Carbofuran (Furadan)	High detection, toxicity, use, and leach
8. Metam-sodium (Vapam)	Unknown ADI, high leach, potential increased use
9. Methomyl (Lannate, Nudrin)	Low detection, variety of use
10. Oxamyl (Vydate)	High toxicity, low use
11. Ethylenethiourea (ETU) (breakdown of dithiocarbamates)	Animal carcinogen, leach, use
12. MBC (breakdown of benomyl and thiophanate)	High use, leach, unknown toxicity
13. Dinoseb (Dinitro)	High toxicity, detection, and use
14. Dibromochloropropane (DBCP)	Animal carcinogen, high leach, detection in other states
15. PCNB (Terrachlor)	Animal carcinogen and leach
16. Dimethoate	Medium toxicity, variety of uses, breakdown of concern
17. Disulfoton (Disyston)	High toxicity and leach
18. Fonofos (Dyfonate)	High toxicity, leach, and use
19. Phorate (Thimet, Rampart)	High toxicity, leach, and use
20. Terbufos (Counter)	High toxicity, leach, and use
21. Picloram (Tordon, Amdon)	Suspected animal carcinogen
22. Linuron (Lorox)	High use, low ADI
23. Dicamba (Banvel)	Medium toxicity and use, high leach
24. Paraquat	LOW use but potential for increase
25. EPTC (Eradicane, Eptam)	Low toxicity
26. D-D (Vidden D)	Low use (sample selectively where use known)
27. Diazinon (Spectracide)	Variety of uses and high toxicity
28. Isofenphos (Amaze)	High toxicity, increasing use (because of efficacy problems, withdrawn from Wisconsin market)
29. Methamidophos (Monitor)	High toxicity, low leach
30. Methyl Parathion	Variety of use, high toxicity, low leach
31. 2,4-D	Significant use, large public concern
32. Maleic hydrazide	Lack of information on ADI, low use
33. DCPA (Dacthal, chlorothal)	Low detection and toxicity
34. Endothall	Medium toxicity, low use
35. Atrazine (Aatrex)	High use, low detection and toxicity

Pesticide	Remarks
36. Cyanazine (Bladex)	No ADI for teratogenicity reasons, lack of information
37. Metribuzin (Sencor)	Low detection, high use
38. Simazine (Bitemal, Princep)	Medium use, low detection and toxicity
39. Bromacil (Hyvar)	Detection, leach, low toxicity and use
40. Chlorothalonil (Bravo),	Low toxicity and leach
41. Dichlobenil (Casoron)	Low use and toxicity
42. Butylate (Sutan^{+})	High use, low leach and toxicity
43. Acephate (Orthene)	Significant use on some crops
44. Chlorpyrifos (Lorsban)	Low leach, medium toxicity
45. MCPA (Agroxone)	Low toxicity

NOTE: Category 1 high priority chemicals are the first 22.
SOURCE: "A Framework for Assessing Pesticide Impacts on Wisconsin Ground Water," 1983, Final Report of the Ground Water/Pesticide Surveillance Committee, prepared by the Wisconsin Ground Water/Pesticide Surveillance Subcommittee: Charles Goethel, DNR; O. R. Ehart, DATCP; and Hank Weiss, DHSS.

Results of this DNR sampling program are given in Table 3-3. Pesticides have been detected in 9-10 percent of the samples, which are taken from wells in worst-case areas (that is, heavy pesticide use, shallow water table, highly permeable soils, and so on). Aldicarb has been the only frequently detected pesticide whose presence in groundwater can be attributed to normal field application. The relatively high detection numbers for alachlor, metolachlor, and atrazine are associated with a point source problem discussed in the subsection Current Sampling Efforts.

A number of individuals interviewed during this trip criticized various aspects of DNR's sampling program. For example, it was generally suggested that sound quality control and quality assurance procedures were not always followed during some stages of the sampling and analysis program, perhaps partly because of pressure to conduct the sampling and a lack of staff training. For example, Harkin et al. (1984) noted in their WIS WRC report "Pesticides in Groundwater Beneath the Central Sand Plain of Wisconsin" that some detections of pesticides in initial screenings were false positives and were not supported by resampling and reanalysis by more sensitive analytic methods.

TABLE 3-3 Summary of Groundwater Pesticide Monitoring for 7/1/83 through 12/31/84

Chemical Name	Trade Name	Number of Samples	Number of Detects	Action Level/μg/liter	Number Exceeding Action Level	Highest Reported Concentration (ppb)[a]
Alachlor	(Lasso)	377	47	10.000	21	88[a]
Metolachlor	(Dual)	126	34	25.000	17	55[a]
Aldicarb, Total[b]	(Temik)	2,293	340	10.000	70	111
Dinoseb	(Dinitro)	125	3	12.500	2	5.5
Atrazine	(Aatrex)	349	50	215.000	0	140[a]
Butylate	(Sutan)	38	14	None	0	2.9
Eptam	(Eptam)	100	9	None	0	--
Cyanazine	(Bladex)	117	8	60.000	0	--
Carbofuran	(Furadan)	78	2	5.000	0	7
Chloramben	(Amiben)	29	2	10.000	0	50
DCPA	(Dacthal)	10	1	300.000	0	--
Metribuzin	(Sencor)	104	1	25.000	0	1.8
Carbaryl	(Sevin)	121	0	10.000	0	--
Chlorpyrifos	(Lorsban)	25	0	10.000	0	--
Terbufos	(Counter)	78	0	None	0	--
2,4-D	(2,4-D)	34	0	100.000	0	--
Diazinon	(Diazinon)	5	0	20.000	0	--
Dicamba	(Banvel)	22	0	12.500	0	--
Dimethoate	(Dimethdate)	10	0	10.000	0	--
Disulfoton	(Disyston)	100	0	1.000	0	--
Linuron	(Lorox)	82	0	62.500	0	--
Methomyl	(Lannate)	13	0	10.000	0	--
Pentachloronitrobenzene	(PCNB)	4	0	10.000	0	--
Picloram	(Tordon)	2	0	10.000	0	--
Phorate	(Thimet)	84	0	1.000	0	--
Dichlorvos (DDVP)	(Vapona)	1	0	None	0	--
Total		4,379	511			

NOTE: The total number of samples and detections do not directly correspond to the numbers of wells where pesticides were detected in the groundwater. Resampling of some wells has occurred, especially those with previous detections (e.g., aldicarb), consequently a number of the detections may come from samples taken at the same well.

[a] Includes point and nonpoint sources; important distinction for alachlor, metolachlor, and atrazine, which have been detected primarily at trace levels except for the point source in Rusk, Wisconsin.

[b] Aldicarb data from Union Carbide Summary of Wisconsin sampling activity dated January 23, 1985.

Current Sampling Efforts

The DNR's pesticide sampling program continues to assess Wisconsin's groundwater for the 45 pesticides determined by the DATCP to be most susceptible to leaching. Funding for the sampling program is expected to remain at a level of approximately $100,000 per year, with a similar amount used to expand and improve the capabilities of the State Hygiene Laboratory. The DNR groundwater staff indicated that the emphasis of its sampling program for pesticides may be shifting away from nonpoint to point sources because of recent contamination discoveries at handling and storage facilities. To illustrate its concern, the staff cited a recent incident in Rusk, Wisconsin. Pesticides have been detected in 23 out of 27 (85 percent) domestic water wells in that small community. Apparently, the contamination results from spillage at a mixing and loading site of a commercial applicator's place of business and at a dealer warehouse. The highest concentrations of pesticides detected in samples from those wells included alachlor (Lasso) at 88 ppb, atrazine at 140 ppb, and metolachlor (Dual) at 55 ppb. Approximately 40 percent of the wells had detection levels greater than the health standard established for at least one of the pesticides found. The citizens of Rusk are being advised not to use their well water, and alternative supplies are being provided by the warehouse owners.

During an interview, an official of DATCP agreed with the DNR decision to begin investigating point sources (specifically handling and storage facilities) but at the same time believed that the sampling effort to characterize nonpoint sources had not yet generated enough reliable and useful data to ascertain the full scope of the problem. The official believes DNR may be over-relying on the low percentage of detections found to date from a less than rigorous sampling program and therefore too quickly concluding that groundwater contamination caused by normal field uses of pesticides is not a serious problem. He stressed that only high-quality, reliable analytic data from samples collected in a rigorous sampling program can conclusively determine the extent and significance of pesticide/groundwater problems.

The DNR staff continues to monitor aldicarb concentrations in groundwater and is collecting approximately 600 samples per year, which are being analyzed by Union

Carbide. The sampling is done on a quarterly basis and is limited to water supply wells.

Groundwater Protection Bill

On May 4, 1984, Wisconsin Governor Anthony Earl signed into law a groundwater protection bill (1983 Wisconsin Act 410) designed to protect the quality of the state's groundwater. The bill requires each regulatory agency to identify substances that either have already been detected in groundwater or are likely to reach groundwater as a result of activities the agency regulates. Groundwater protection standards for those substances ale then to be established on a two-tiered basis: "enforcement standards" and "preventive action limits."

The enforcement standards are based on the most recent federal standard established by the EPA for the specific compound in question. When an enforcement standard is attained or exceeded, the appropriate regulatory agency must prohibit the activity from which the substance originated, unless it can be demonstrated that an alternative action will achieve compliance with the standard. Prohibitions can be limited to specific sites.

The preventive action limits (PAL) are established at 10 percent, 20 percent, or 50 percent of the enforcement standard depending on health-related characteristics of the particular substance. A PAL of 10 percent will be established for any substance having carcinogenic or teratogenic properties; a PAL of 20 percent will be established for substances having other public health concerns, such as acute toxicity; and a PAL of 50 percent will be established for public welfare concerns, such as taste or odor. The PALs serve two purposes related to pesticides. First, a PAL would be used in considering management practices so that the potential for groundwater contamination is evaluated prior to a pesticide's use. Second, the PAL triggers remedial actions designed to prevent the level of that compound from reaching the enforcement standard, which would require a ban. Thus, if a pesticide is detected above a PAL, the DATCP would be empowered to impose regulations short of a ban.

The act also stipulates that a statewide groundwater monitoring and sampling system be established to implement the overall groundwater management program. The DNR, in cooperation with other state agencies and a newly established Ground Water Coordinating Council, is to develop and manage the groundwater monitoring program. This coordinating council is an eight-member body established by 1983 Act 410 to advise state agencies in the coordination of nonregulatory programs relating to groundwater. Five classifications of monitoring activities are outlined under 1983 Act 410:

1. Problem assessment monitoring—"To determine and assess the extent to which substances are in the groundwater." This statewide sampling program would evaluate problems caused by a wide range of pollutants including volatile organic compounds (VOCs), aldicarb, or other pesticides.
2. Regulatory monitoring—"To determine the extent to which the groundwater is contaminated and meets or exceeds numeric water standards, and to obtain information necessary for the implementation of site specific response." This activity is equivalent to "hot spot" monitoring.
3. At-risk monitoring—"Monitoring areas where substances identified by regulatory agencies are in groundwater or where preventive action limits or enforcement standards have been attained or exceeded." This activity focuses on the sampling of individual wells in general problem areas.
4. Management practice monitoring—"Applied research monitoring to determine the appropriate management practices necessary to meet design and management criteria and the adoption of regulatory responses for groundwater contamination." This activity pertains to sampling in research projects on management practices and to sampling conducted by the DATCP to check effectiveness of label changes and other actions taken to minimize groundwater contamination.
5. Monitoring plan—"Planning to coordinate and carry out the above monitoring components." This activity includes the sharing and coordination of data.

The bill has other provisions relating to agriculture and groundwater. It creates a new program within the DATCP to regulate the storage of bulk quantities of fertilizer and pesticides. Rules have recently been promulgated for this program. In addition, the bill provides for laboratory certification and registration procedures to be established by the DNR (a proposed rule has been issued). Furthermore, it creates a well compensation fund that will pay up to 80 per percent of the cost of repair or replacement of a contaminated residential well that serves less than five dwelling units; certain types of livestock wells also qualify for this fund. Also as a result of the groundwater law, the DATCP has written a rule outlining its regulatory program and the DNR has written a rule both outlining its regulatory program and establishing enforcement standards and PALs for several substances.

The programs established by Act 410 will be financed by a combination of general-purpose revenues and a special fund created to support the groundwater-related activities of the DATCP, DNR, DHSS, and the Wisconsin Department of Industry, Labor, and Human Relations. This special fund will be supported by fees on activities with the potential to impact groundwater. Revenue sources include annual license surcharges of $2,000 for primary pesticide manufacturers plus an annual $2,000 research fee paid to the DATCP, and an increase in annual license fees for formulators from $100 to $200 for those formulators with a single pesticide and to $400 for those manufacturing or labeling more than one compound. The revenues generated by these license increases and earmarked for the groundwater activities of the state were approximately $300,000 in 1984. Additional revenue for groundwater activities are generated by a tax of $0.10 per ton on fertilizer spread by applicators. This tax is in addition to a prior $0.10 levy for an industry-sponsored research fund, which the legislature authorized to be expended on groundwater research. Thus, half of the $0.20 tax on fertilizers will go directly to the special groundwater fund and half will support research focused on the influence of fertilizers on groundwater quality. The revenues generated by this tax were approximately $130,000 in 1985. The well compensation fund was established with $500,000 authorized from general revenue funds.

An obvious difficulty in implementing 1983 Act 410 is the lack of federal guidance for setting enforcement standards and PALs. In particular, the EPA has established few federal maximum contaminant levels (MCLs) for drinking water. On July 29, 1983, Tom Dawson, Wisconsin Public Intervenor, speaking before the U.S. Senate Subcommittee on Toxic Substances and Environmental Oversight of the Committee on Environment and Public Works, noted,

> First and foremost, there is a tremendous need among the States, especially Wisconsin, for the adoption of reliable drinking water standards establishing "maximum contaminant levels" against which to measure groundwater pollution. Although EPA is charged with setting these standards, including those for toxic substances, not nearly enough standards have been set. There is a need for Congress to ask why this is so, and to spur EPA into action.

For chemicals without federally established MCLs, Wisconsin will have to consider suggested no adverse response levels (SNARLs), health advisory levels (HALs), health guidelines (HGs), or acceptable daily intake levels (ADIs) established at the federal level. Where no federal standards have been established, states like Wisconsin may have to create standards. Not only is this a resource-intensive problem, but it opens the Possibility of inconsistent standards between states. Thus, many state officials like Dawson believe it is critical that the EPA establish many additional MCLs and health advisories for pesticides and other toxic chemicals.

CRITICAL PROBLEMS AND NEEDS

Educational Efforts by the Extension Service

The University of Wisconsin Extension Service (UWEX) is developing extension programs and materials on groundwater in conjunction with the Wisconsin Geological and Natural History Survey, the DATCP, and the DNR. The extension materials are designed to educate farmers and the general public about the nature and occurrence of groundwater, groundwater flow, relationships between land use and well water quality, irrigation scheduling and its relationship to the movement of pesticides and fertilizers, and livestock waste management. A future UWEX goal is to develop extension recommendations for agricultural management strategies to reduce the potential for groundwater or surface water contamination from pesticides. However, before recommendations can be made, more applied research on this issue must be carried out. Field testing of various management strategies is especially needed.

In June 1984 UWEX and the New York Extension Service (NYEX) jointly submitted a proposal to the USDA Extension Service (ES) to develop a pilot groundwater education program and information transfer network. The primary purpose of the program will be "to develop, test and refine materials that can effectively be used by community resource development, family living, agriculture, 4-H, and State, area, and county Cooperative Extension Service faculty to assist individuals and communities in identifying and dealing with problems and concerns related to groundwater contamination." A secondary purpose of the proposed program will be to "develop an information-sharing network to facilitate the exchange of educational material and programs developed through the pilot program, and by other states, so that Cooperative Extension Service nationally can effectively use research-based educational materials and programs to respond to individual and public groundwater educational needs in a timely and effective manner."

A significant thrust of this program will be the development of and documentation for computer models that can be used to illustrate the physical nature of groundwater movement and the Potential for contamination of groundwater. The program will include a series of computer programs developed by Cornell University that relate land use and a range of environmental variables to groundwater quality.

UWEX and NYEX have separately developed a number of groundwater-related educational materials, but major needs still exist. A proposed joint effort to develop extension publications on groundwater contamination risks and related topics is on hold because funding is not available.

Irrigation

University of Wisconsin researchers have been studying the influence of irrigation on pesticide movement. Field tests conducted in 1982 investigated the effectiveness of the label changes made in 1981 for aldicarb in Wisconsin. The findings suggest that aldicarb application at emergence (rather than at planting) is effective in reducing the leaching of aldicarb without significantly diminishing insecticidal efficacy, crop residues, and yield. Leaching is reduced because an increase in soil temperature of approximately 6°C between the time of planting and the time of emergence favors a more rapid rate of degradation of aldicarb and because the aldicarb is not available during the time between planting and emergence when the plants are not transpiring and cool spring rains occur. In addition, later applications of aldicarb can result in better crop protection because the developed root system can more effectively capture the soil water containing the pesticide.

A UWEX computer program has been developed to assist growers in irrigating more efficiently. This water budget program is called the Wisconsin Irrigation Scheduling Program (WISP), and it uses estimates of crop water use to monitor soil moisture conditions. WISP considers the available water in the root zone to be a reservoir that the plant utilizes in transpiration. The amount of water that can be removed from this reservoir without stressing the crop is called the "allowable depletion," and it varies with soil type and crop. WISP is designed to maintain soil moisture within 25-75 percent of the allowable depletion by balancing evapotranspiration (ET) losses with gains from rainfall or irrigation.

Input data required to run WISP include rainfall, irrigation, ET, and allowable depletion. For the past few years, growers in the Central Sands region have been able to calculate allowable depletion using a hand-held calculator version of WISP. Growers were required to maintain daily logs of precipitation that had fallen on crops and of the irrigation they had applied; they also had to calculate ET losses. In 1984, WISP was put on the UWEX main computer along with daily ET data and 24-hour and 48-hour rain probabilities. Using a grower's irrigation and rainfall data, WISP can calculate the amount and percentage of allowable depletion and can project depletion over the next 24 or 48 hours if the crops receive no additional irrigation or rainfall. The computer version of WISP is available through the county extension offices; some individual growers have access to the UWEX computer system and can use the program directly. WISP has three important benefits: water conservation, energy conservation, and reduced leaching of pesticides and fertilizers out of the root zone.

Groundwater Resource Evaluation

The Wisconsin Geological and Natural History Survey (GNHS), in conjunction with UWEX, the USGS, and the DNR, is conducting groundwater resource evaluations at the county level. This program, which focuses on groundwater as a resource, has important implications for the assessment of possible contamination by pesticides. Maps with a 1:100,000 scale identify areas of highest contamination potential, direction of groundwater movement, potential aquifer yields, and depth to the water table and bedrock.

The GNHS groundwater resource evaluation program is patterned after similar surveys that have been carried out for years by the Illinois Water Survey, a branch of that state's geologic survey. The evaluations are usually done in cooperation with the county under cost-sharing agreements that rely on the county paying from 10 to 50 percent of the cost depending on the specific funding sources available when the evaluation is initiated. The cost to the county may range from $2,500 to $25,000 depending on the availability of information and the level of detail requested or needed. Some water quality information is generated from sampling conducted during the evaluation and includes such parameters as nitrates, chlorides, alkalinity, hardness, and bacteria. Analyses for organic chemicals have not been performed, however.

Prevention of Groundwater Contamination

Wisconsin has identified the prevention of groundwater contamination as a critical issue. However, the expense associated with aquifer restoration is prohibitive in many cases, and much more work is needed to identify potential contaminants, sensitive hydrologic areas, and the various physical and chemical properties of soils that contribute to groundwater contamination.

The Director of the WIS WRC pointed out that a better understanding of the physical and chemical processes occurring in the vadose zone is crucial to the prevention of groundwater contamination. To detect pollutants before they enter the groundwater, more emphasis is being placed on research to characterize transport through this zone. Protocols need to be developed for the monitoring activities, an effort that will require multidisciplinary research to integrate the various components of this complicated system.

Vadose zone monitoring can afford an early warning of potential groundwater contamination. If a problem is detected, remedial measures can be implemented sooner, thereby reducing or eliminating associated aquifer restoration costs. The depth of the vadose zone in a specific area will directly influence the "lead time" granted by such monitoring. For example, areas in the Southwest may have a vadose zone hundreds of feet thick compared to that of the Central Sands region of Wisconsin, where the unsaturated material is only 5 to 50 feet thick.

AGRICULTURAL MANAGEMENT STRATEGIES AVAILABLE TO MITIGATE PESTICIDE/GROUNDWATER QUALITY PROBLEMS

Potato Integrated Pest Management Program

The potato is a major vegetable crop in Wisconsin, where 60,000 to 70,000 acres are planted annually. Total value of the crop exceeds $100 million. Unlike Suffolk County, New York, Wisconsin potato production is not plagued by the golden nematode. Nematodes generally do not pose serious problems except for early plant die-off, which is associated with them and with soil pathogens (fungi). However, the Colorado potato beetle, potato leafhopper, green peach aphid, tarnished plant bug, and variegated cutworm are economically important insect pests that require insecticides for control. In addition, fungi can cause severe early and late blight and require numerous applications of fungicide. The potato leafhopper is the single most important yield-reducing insect pest of potatoes in Wisconsin, but the Colorado potato beetle is increasingly significant. Populations of the latter were significantly reduced in the 1940s due to the widespread use of DDT, but during the last decade the numbers and range of distribution of the beetle have steadily increased, and its management is now a major concern of growers.

The importance of pest problems and pesticide use in the Wisconsin potato industry led to the initiation in 1979 of an integrated pest management (IPM) program in two major production areas—three Central Sands counties (Portage, Adams, and Waushara) and Langlade County (a certified seed production area). The program was established to demonstrate the concepts of IPM to the potato industry and to illustrate how IPM could alter approaches to pest management practices so as to reduce environmental impacts associated with pesticide usage on potatoes.

The UWEX staff assessed the effectiveness of the Wisconsin potato IPM program on the basis of grower acceptance of the program and adoption of IPM philosophy and techniques, alteration of pesticide use patterns, and economic feasibility. Overall, the acceptance by growers was considered good and increased each year, despite the addition in 1981 of a program charge on acreage scouted for pests to help defray costs. The total acreage scouted in the program increased from approximately 5,000 acres in 1981 to 8,000 acres in 1982.

This program demonstrated that during two seasons of high disease pressure and moderate insect pressure, IPM was economically favorable. Growers using the IPM program saved $7.50 to $9.00 per acre for the season. Additional, but nonquantifiable, benefits to growers from participation in the program included the peace of mind generated by regular crop inspection and by a trained, unbiased second opinion on pest problems.

The Wisconsin potato IPM program was turned over to the private sector for the 1983 growing season. Several private consultants offered scouting services patterned after the UWEX program. In the first year, the growers who used IPM applied fungicides more frequently and insecticides less frequently than growers who did not use IPM. In succeeding years, with improved IPM techniques, applications of both fungicides and insecticides decreased. In part because of IPM, aldicarb use on Wisconsin potatoes declined some 50 percent through 1985. Thus, IPM has helped to diminish the threat of groundwater contamination.

Best Management Practices

IPM focuses on managing pests by scouting; the development of additional best management practices specifically designed to mitigate groundwater contamination by agricultural chemicals is a critical need felt within the Wisconsin Extension Service.

A member of the extension staff identified the calibration of spray equipment as an important best management practice. Growers need to be better informed that nonuniform application of pesticides (or fertilizers) can occur if spray equipment is faulty or poorly calibrated. Before sending spray rigs into the field, growers should conscientiously determine the proper size of nozzle tip, spray width per nozzle, flow rate from the nozzle, and consistency of flow rate from the nozzle.

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Florida

Groundwater is particularly important to Florida. The state depends almost totally on groundwater for more than 90 percent of its drinking water and uses aquifers for more than 50 percent of all other water uses. Furthermore, the state's groundwater and surface water supplies are closely linked, with groundwater discharges contributing significantly to Florida's stream flows. The demand for water will grow rapidly, since Florida is experiencing rapid increases in population and development.

Four major aquifers supply the groundwater used for drinking water. The largest in areal extent, underlying most of the state, is the Floridan aquifer; it provides drinking water in the north and central areas of the state and supplies 43 percent of the groundwater used for public supply. In general, it is protected from surface pollution by clay beds, by shallow overlying aquifers, and by its considerable depth. In some areas in central Florida, however, this aquifer comes close to the surface and is highly susceptible to pollution. Along

On August 16 and 20, 1984, Holden visited various individuals in Florida familiar with groundwater problems associated with agricultural chemicals. The institutions represented by the persons interviewed included the Florida Department of Environmental Regulation (DER), Ground Water Section; the Florida Department of Health and Rehabilitative Services (DHRS); the Florida Department of Agriculture and Consumer Services (DACS); and the Pesticide Research Laboratory, Institute of Food and Agricultural Sciences (IFAS), and the Department of Soil Science, University of Florida.

the east and southeast coast and in southern Florida, the Floridan aquifer is not potable.

In heavily populated southeast Florida, the Biscayne aquifer is the sole source of drinking water for Dade, Broward, and part of Palm Beach counties, and thus receives special protection under the Federal Safe Drinking Water Act. This aquifer, which supplies 44 percent of the groundwater used for public supply An the state, is highly permeable and productive of good-quality water, except where saltwater has intruded. It has no confining layer to protect it from surface pollution.

Shallow aquifers supply 10 percent of the state's groundwater used for public supply. Areas along the east and southeast coasts and in southern Florida rely on these aquifers for groundwater. They overlie nonpotable portions of the Florida aquifer and are under either water table or artesian conditions. Their water quality is variable, and they may be susceptible to saltwater intrusion.

The remaining 3 percent of the groundwater used for Florida's public supply comes from a sand-and-gravel aquifer located in the extreme western portion of the Florida panhandle. Consisting of sand, gravel, and interbedded clay layers, the aquifer varies between unconfined and artesian conditions. The unconfined and coastal areas are vulnerable to contamination.

Florida's unique hydrogeology allows fast movement of surface contaminants into aquifers. Pollution sources in the state include 6,000 mostly unlined surface impoundments; 9,000 drainage wells that inject wastewater or low-quality water into receiving aquifers; 40,000 underground storage tanks, many of which are periodically submerged in groundwater; saltwater intrusion; several hundred hazardous waste sites; and Florida's active agricultural industry, with its associated fertilizers, pesticides, and other agricultural chemicals.

Agriculture is important to Florida's economy, contributing $4.4 billion in cash receipts for 1982. Citrus accounted for more than $1 billion in sales, and vegetable, melon, and strawberry crops accounted for just under S1 billion. Pesticides are important to the production of these commodities, and possible contamination of groundwater by two of them—aldicarb and EDB—has led to monitoring and regulatory responses. Programs to detect other pesticides in groundwater are just getting under way.

Although Florida receives an average of 53 inches of rainfall per year, irrigation is practiced during early spring. Irrigation—at nearly 9,200 acre-feet/day in 1980—is the single largest use of water in Florida, accounting for more than 40 percent of total use. Slightly more than half of the water used for irrigation is drawn from groundwater sources. The acreage irrigated tripled from 414,000 to 1,217,000 acres in the first half of the 1960s, and rose to nearly 2,000,000 acres in 1978. In the north-Florida Suwannee River Water Management District, agricultural irrigation grew at a rate of 15 to 20 percent per year from 1975 to 1982, and growth is expected to continue. In the central St. John's River Water Management District, however, irrigation is not expected to increase beyond present use levels, which already cause some problems due to large withdrawals. As one way of addressing their problems, the districts are cooperating with the University of Florida on an experimental program to improve irrigation efficiencies.

The unique hydrogeology of Florida, the recognition of groundwater contamination problems, and the increasing demands for quality water have prompted several state initiatives. In 1982 the speakers of the Florida House of Representatives appointed a task force to examine water issues in the state. The resultant "Report of the Speaker's Task Force on Water Issues" was published in March 1983. Pesticide contamination was one of the issues explicitly addressed. Later in 1983 the Florida legislature passed the Water Quality Assurance Act. A number of its provisions concern pesticide contamination of water and are discussed in context.

THE STATUS OF EFFORTS TO MONITOR GROUNDWATER FOR RESIDUES OF AGRICULTURAL PESTICIDES

Past Monitoring Efforts

Historically, there has been no systematic monitoring for pesticide residues in Florida's groundwater. However, the aldicarb incident in Long Island, New York, aroused concern about contamination that led to the discovery in Florida of two significant problems and the establishment of a future monitoring program.

Aldicarb

Aldicarb—trade name Temik—is most commonly used in Florida to control citrus nematodes and mister. Approximately 10 percent of the 848,000 acres in citrus production acreage in 1982 were treated regularly with aldicarb. Before 1983 typical annual rates of aldicarb application totaled about 10 lbs ai/acre, often split into two applications. Approximately two-thirds of the aldicarb has been applied in Polk and Lake counties in the so-called sandy ridge or central ridge area of central Florida. Aldicarb is also used on potatoes in the Hastings area of northeastern Florida.

In mid-1982 the Florida Department of Environmental Regulation (DER) initiated a water sampling program to assess possible aldicarb contamination of Florida's groundwaters. Aldicarb was first discovered in groundwater at an experimental agricultural area in August 1982. Subsequent monitoring detected aldicarb in groundwater near application sites at levels approaching 600 ppb. The finding of aldicarb residues in groundwater led the state to adopt a 10-ppb health advisory quality level, a 1-year ban on many uses of the pesticide, and two monitoring programs. These programs include a continuing study of residues at seven sites in the state and a survey of drinking-water wells. Union Carbide Corporation participated in both monitoring efforts.

While the 1983 ban on aldicarb was in effect, monitoring continued and new use restrictions were developed. These restrictions state that

- No more than 5 lbs ai/acre of Temik 15G can be applied per year;
- Only one application of Temik 15G is allowed per year, which for citrus growers (the major users) must occur between January 1 and April 30;
- No use of Temik 15G is permitted within 300 feet lateral distance of any drinking-water well;
- Use is to be suspended in areas where aldicarb is found in drinking water at concentrations greater than 10 ppb;
- A notice of intended use must be posted prominently on property where aldicarb is being applied, and wells in treatment areas shall be posted with warnings, "not for human consumption."

The DER also proposed that ridge citrus users conduct annual monitoring of shallow groundwater downgradient of all application sites and that aldicarb not be applied 600 feet (instead of 300 feet) upgradient from any drinking-water well. These additional restrictions were not adopted by DACS.

An observation program at seven Florida sites is collecting field data on the behavior and fate of aldicarb. The data provide a check for Union Carbide mathematical models that describe degradation and movement of aldicarb residues and for pesticide use restrictions intended to protect groundwater. The seven sites include two citrus ridge groves, two bedded orange groves, a west coast orange grove, a fernery, and a potato field. Sampling conducted at cluster wells permits temporal and spacial assessment of residues.

Results indicate that aldicarb residues from applications in potato fields and bedded citrus groves in coastal areas may reach surficial aquifers, but generally degrade relatively rapidly. Factors reducing the impacts on groundwater in these areas (compared to sandy ridge areas) are lower groundwater hydraulic gradients, finer sands with high shell matter and more organic content, and waters with higher pH values. In fact, most believe the data base is adequate to conclude that aldicarb applied to potato and bedded citrus sites is not contaminating groundwater and that no further sampling of these areas is required. But in the sandy ridge area of central Florida, residues may be found in the surficial groundwater several hundred lateral feet from the site of application. Shallow water tables, high recharge rates, and sandy acid soils with low organic matter all contribute to the persistence of aldicarb and its contamination of groundwater. This finding has called into question the usefulness of mathematical models in describing environmental fate and transport behavior and the adequacy of the current restriction prohibiting aldicarb applications only within 300 feet of drinking-water wells. As a result, in 1984 Union Carbide agreed to drill additional test wells to clarify the movement of aldicarb in the groundwater at two sites.

The wide variations in Florida of hydrogeologic and soil conditions cause the differences in the environmental fate of aldicarb. In the northeast Florida potato growing area, despite shallow groundwater and a long history of aldicarb use, no aldicarb residues have been detected in drinking-water wells and only trace levels have been detected in monitoring wells. As noted, the specific conditions of that area appear to cause rapid degradation of aldicarb. In the sandy, acid soil of the central ridge area, however, aldicarb residues are regularly detected in monitoring wells. Clearly, the half-life of aldicarb in soil and groundwater is site-specific in Florida.

In another major aldicarb monitoring program, the DER contracted the Department of Engineering Sciences, University of Florida, to study aldicarb residues in drinking-water supplies. The study is being conducted in three phases. In the first phase, completed in the first half of 1984, the 10 largest water supplies were sampled in each of 34 counties where aldicarb was used in 1982 or 1984. No residues were found above the 2-5-ppb concentration that represents the lowest quantifiable detection limit for the method of analysis used. In the second phase, a large portion of all public community drinking-water systems in Polk, Lake, Orange, Jackson, St. Lucie, Dade, Hendry, and Highlands counties were sampled. The counties were selected on the bases of their potential for groundwater contamination and their known use of aldicarb. No residues over the guideline were detected. In the third phase, samples will be collected from cluster wells in sensitive locations, and aldicarb migration through the soil and groundwater will be monitored. Three sets of samples will be taken during the study.

In June 1984 Union Carbide Corporation presented information on groundwater contamination by aldicarb to the EPA's Science Advisory Panel. At that time, according to Union Carbide, more than 1,100 samples from 900 drinking-water wells in 27 Florida counties had been analyzed, and no aldicarb residues were found above the 10-ppb level. Detectable levels of less than 10 ppb were found in three wells, but in each instance the well casing was either damaged or poorly constructed.

Ethylene Dibromide

The nematocide ethylene dibromide (EDB), or 1,2-Dibromoethane, is the second pesticide to cause known groundwater problems in Florida. EDB was primarily used as a soil fumigant to control burrowing nematodes on citrus. It was applied for more than 15 years by private individuals and by the state to establish barrier zones to control the nematodes' spread and was also used extensively on golf courses and to some extent on such crops as peanuts and soybeans. Its use had increased in recent years as a replacement for the pesticide DBCP.

Because EDB is highly volatile, its potential to contaminate groundwater was originally unsuspected. Studies of its environmental behavior are under way, and preliminary data indicate that EDB in groundwater has a half-life measured in years.

After the discovery of EDB in the groundwater of other states, a testing program for EDB in Florida wells was begun in August 1983. When EDB was indeed detected, the state banned its use (September 1983); set a 0.1-ppb tolerance in drinking water; and formed an EDB Task Force consisting of representatives of five state agencies. The state installed a toll-free hotline and established an EDB newsletter. Information on EDB application sites was mapped, and the task force proposed sampling all wells located within 300 feet of such sites, with priority given to public drinking-water wells located within 1,000 feet of EDB applications. The volume and sophistication of tests to detect EDB required contracts with major state university laboratories.

The sampling program that began in August 1983 had, by February 13, 1985, tested 7,609 wells; 828 (11 percent) showed the presence of EDB. The three counties with the largest number of contaminated wells—Polk, Highlands, and Lake—form the heart of the central ridge citrus area. Analysis of the data from wells in which EDB was detected statewide shows that while the average contamination is about 6.5 ppb, high averages and extreme values are found in Polk and Highlands counties. This is attributed to the high application rates in these counties, the large number of application sites, the lack of organic matter in the soil, and the high susceptibility of the surface aquifers to contamination.

Most of the EDB contamination appears to be confined to surficial aquifers. In Highlands County, most of the 103 contaminated wells (643 tested) are less than 200 feet deep. In Polk County (331 contaminated wells of 2,796 tested), however, a 700-foot-deep well at Lake Wales is contaminated, which could indicate contamination of the Floridan aquifer. Golf course applications have been related to contamination at a number of specific sites; all the contaminated wells in Duvall County (14 of 203 tested), for example, are accounted for by this use.

In 1984 the Florida legislature authorized $3.1 million to remedy well water contamination problems resulting from the state application or use of EDB. The EDB task force stipulated that activated carbon filters be installed on contaminated wells, except where connections to nearby uncontaminated public water supplies are feasible. As of May 3, 1984, 36 municipal and 601 private wells in the state had been found to be contaminated; 492 of these were contaminated by EDB applied by the state, and the remainder were contaminated by privately applied EDB. Another 200 private wells are expected to be found contaminated. The total cost to clean up wells contaminated by state actions is estimated to be $4.7 million plus $331,000 for annual operation and maintenance. The total cost to clean up wells contaminated by other applicators is estimated to be $2.25 million.

As of January 30, 1985, 247 well owners signed releases, and their wells were slated for corrective action. Remedial actions were also authorized for two community drinking-water wells—Lake Alfred and Lake Wales, both in the central ridge area of the state.

Other Pesticides

As the first step in establishing an ambient groundwater quality monitoring program, the Florida DER contracted the U.S. Geological Survey (USGS) to sample 96 public water supply systems. All 96 systems tapped the Floridan aquifer and together supplied water for some 3 million people. The samples were tested for 16 major chemical constituents and physical properties, 10 selected trace metals, 4 herbicides,[a] 17 insecticides,[b] and 28 volatile organics,[c] In March 1984 the USGS reported to the DER that of the 96 systems sampled, only 8 had detectable levels of organics. These were

[a] Silvex; 2,4-DP; 2,4-D total*; 2,4,5-T total.

[b] Aldrin; methoxychlor; per thane; toxaphene; DDE total; dieldrin total; endrin; gross polychlorinated naphthalenes (PCN) total; heptachlor total; lindane total; mirex total; chlordane total; DDD total; DDT total; endosulfan I; gross PCBs total; heptachlor epoxide total.

[c] Includes EDB.

* "Total" refers to the substance and all its metabolites.

resampled and analyzed, and 4 systems were confirmed to be contaminated, of which 2 involved pesticides: Orlando, 0.02-ppb silvex; and Clearwater, 0.01-ppb lindane.

Subsequently, the DER contracted with the USGS to collect and analyze water samples from systems tapping the Biscayne aquifer plus several southwest Florida systems withdrawing from the Floridan aquifer. Seventeen systems were sampled in this phase. Preliminary results indicated that two systems were contaminated with an organic chemical that was not a pesticide.

During 1983-1984, the EPA, in cooperation with the Florida DER, sampled and analyzed 218 public water supplies in Broward, Dade, and Palm Beach counties. The samples were analyzed for volatile organic compounds (VOCs) and trihalomethanes (THMs). Four water supplies were found to exceed Florida's pending maximum contaminant levels for VOCs (discussed in the next section), and 18 others had detectable levels. THMs in excess of the 0.1-ppb maximum contaminant level (MCL) were found in 40 water supplies. In addition, 83 noncommunity water supplies were sampled; 23 had detectable levels, of which 5 exceeded applicable MCLs. Testing of groundwater itself indicated hot spots of elevated VOCs: an extensive area of the Biscayne aquifer in the Miami Springs-Hialiah-Miami International Airport-Medley vicinity is contaminated with VOCs up to 100 times drinking-water MCLs. As a result, millions of dollars for new wellfields, system modifications, and increased water treatment have been required. Another area of the Biscayne aquifer near the Fort Lauderdale Executive Airport and extending to the Fort Lauderdale Executive wellfield is contaminated by VOCs up to 2,000 times MCLs.

This testing did not include screening for pesticides. Although the DER suggested that other organic compounds be looked for during the THM analytic work, this apparently was not done.

Current Monitoring Efforts

The contamination of groundwater by EDB has focused attention on the need for close monitoring of groundwater in areas where pesticides and other chemicals are used. The problem is extremely difficult because of the large areas involved, the dispersion of pollutants, and the scarcity of accurate records of application areas and rates. Furthermore, the dispersed responsibilities concerning this problem make it essential that the departments of Environmental Regulation, Health and Rehabilitative Services, Agriculture and Consumer Services, and Community Affairs cooperate in order to locate pesticide application areas and to design monitoring wells to identify potential groundwater contamination problems.

Under the 1983 Florida Water Quality Assurance Act, the state is establishing an extensive groundwater monitoring network. The act requires the DER, in cooperation with other state and federal agencies, water management districts, and local governments, to establish "a groundwater quality monitoring network designed to detect or predict contamination of the state's groundwater resources." To do this, a three-phase program has been established. The DER has entered into agreements with the state's five water management districts to carry out the program tasks.

In Phase 1, a wide range of basic data pertinent to groundwater contamination will be collected. These data will encompass the location of point and nonpoint sources of pollution, including specifically the location of agricultural and other areas where pesticides and fertilizers are heavily used; the characteristics of aquifers, including the location of impermeable zones, well drawdown, outcrop areas of the Floridan aquifer, and recharge areas; saltwater intrusion boundaries; and the location and plugging of artesian wells.

In Phase 2, the number and location of existing wells suitable for monitoring will be determined. A DER search has located 1,800 wells that may be suitable for the monitoring network. New wells will be drilled as necessary where none exist or where existing ones are not suitably located. The existing wells and new monitoring wells will be located in relation to pollution sources so that ambient groundwater quality can be evaluated.

In Phase 3, water samples will be collected and analyzed. The sampling will be designed to provide baseline water quality data for subsequent monitoring of water quality trends.

The Water Quality Assurance Act also provides for groundwater data storage and retrieval so that information will be readily available for decision making regarding land and water use. The DER is establishing a central repository of data and will issue an annual bibliography of published data. When complete, the data system will be publicly accessible.

TABLE 4-1 Florida MCLs for Volatile Organic Compounds

Volatile Organic Compounds	Maximum Containment Level (ug/liter)	Estimated Risk Level
Trichloroethylene	3	1/1,000,000
Tetrachloroethylene	3	1/500,000
Carbon Tetrachloride	3	1/400,000
Vinyl Chloride	1	1/1,000,000
1,1,1-Trichloroethane	200	not applicable
1,2-Dichloroethane	3	1/600,000
Benzene	1	1/900,000
1,2-Dibromoethane	0.02	1/100,000

In December 1983 the DER asked owners of public water supply systems serving more than 1,000 people to voluntarily test their drinking water for a wide range of contaminants, including some 25 pesticides. In April 1984 the DER adopted a rule requiring all community water systems to be tested for 8 VOCs for which Florida had set MCLs (Table 4-1) and 118 other synthetic organic compounds.

Monitoring for the VOCs only is required at 3-year intervals, with the first sampling and analyses due June 1, 1985, for systems serving more than 1,000 persons and January 1, 1987, for smaller systems. Total estimated triennial cost for statewide monitoring of drinking water for VOCs is $6.58 per average affected consumer.

The list of 118 synthetic organic chemicals for which monitoring is required includes a category labeled "Pesticides," as shown in Table 4-2. (Certain other chemicals with pesticide uses, such as pentachlorophenol, are included in other categories.)

Analyses for the 118 synthetic organic chemicals were due to be submitted to the DER by January 1, 1985, for all community systems serving more than 1,000 persons (588 systems) and by April 1, 1986, for all smaller community systems (1,789 systems). Samples are to be taken from finished water in the distribution system, not individual wells unless a problem is identified. Analysis is required every 3 years, but it is expected that the number of contaminants for which analyses are required in the future will be reduced substantially, based on known or suspected occurrence in Florida waters. Total estimated triennial cost for statewide monitoring of drinking water for the presence of these synthetic organic contaminants is $2.2 million, or $12.05 per average affected consumer.

TABLE 4-2 Pesticides on Florida's List of 118 Synthetic Organic Chemicals Designated for Monitoring

Aldrin	Endrin Aldehyde
α-BHC	Heptachlor
β-BHC	Heptachlor Epoxide
γ-BHC	Toxaphene
δ-BHC	PCB-1016
Chlordane	PCB-1221
4,4'-DDD	PCB-1232
4,4'-DDE	PCB-1242
4,4'-DDT	PCB-1248
Dieldrin	PCB-1254
Endosulfan I	PCB-1260
Endosulfan II	Aldicarb
Endosulfan Sulfone	Diazinon
Ethion	Malathion
Trithion	Parathion
o,p-DDT, DDE, and DDD	Guthion
Tedion	Kelthane (Dicofol)

In 1984 the DHRS proposed a groundwater survey of all water systems in which EDB had been detected to check for other pesticide residues. This program has just begun in Highlands County and will soon be extended to Palm Beach, Polk, and Jackson counties. Palm Beach County leads the state in the quantity of restricted use pesticides applied (Table 4-3).

For 1983-1984 the state increased the DER's budget 127 percent, of which 82 percent was alloted for groundwater and related programs. Included in the increase were 16 new positions and $2.9 million for groundwater monitoring; 8 new positions and $250,000 for pesticides/water quality activities; 7 new positions and $350,000 for water quality data collection; and $1.15 million for cleanup of EDB and other pesticides.

TABLE 4-3 Widely Used Pesticides in Palm Beach County That May Be Found in Drinking Water from Groundwater Sources

Pesticide	Trade Name	Class	Application	Water Solubility (ppm)	k_{ow}[a]	Acute oral LD_{50} for Rats (mg/kg)
Alachlor	Lasso	Herbicide	Soil	240	434	1,200
Aldicarb	Temik	Insecticide	Soil	6,000	5	0.93
Atrazine	Aatrex	Herbicide	Soil	33	212	1,869
Carbofuran	Furadan	Nematocide	Soil	700	207	8-14
Chloropicrin	Chlor-O-Pic	Fumigant	Soil	2,270	—	25
1,2-D		Fumigant	Soil	2,700	190	2,200
DBCP	Nemagon	Fumigant	Soil	1,000	—	170-300
Ethoprop	Mocap	Nem/Insect	Soil	750	—	62
Ethylene Dibromide	EDB	Insecticide	Soil	4,300	—	146
Ethylenethiourea[b]	ETU	Fungicide	Foliar	—	—	—
Ethyl Parathion		Insecticide	Soil	slight	6,455	4-13
Fenamiphos	Nemacur	Nematocide	Soil	700	—	8
Linuron	Lorox	Herbicide	Soil	75	—	4,320
Metam-Sodium	SMDC, Vapam	Fumigant	Soil	10,000	—	820
Methamidophos	Monitor	Fungicide	Foliar	great	—	30
Methomyl	Lannate	Insecticide	Foliar	5,800	12	17
Methylisothiocyanate	Vorlex	Fumigant	Soil	7,600	—	538
Methyl Parathion	Metacide	Insecticide	Soil	55-60	2,076	14
Mevinphos	Phosdrin			miscible	—	3-12
Monocrotophos	Azodrin	Insecticide	Foliar	miscible	—	18
Oxamyl	Vydate	Insect/Nem	Foliar	10,000	—	5.4
Paraquat		Herbicide	Foliar	great	1	150
Phorate	Thimet	Insecticide	Soil	50	—	823

[a] Octanol water partition coefficient. Represents the distribution of organic solute between a polar and a nonpolar liquid.

[b] Degradation product of the ethylene bisdithiocarbamate family of fungicides.

SOURCE: Adapted from "Status Report—Palm Beach County Investigation," memorandum dated January 24, 1985, from Chuck Aller, Environmental Administrator, Pesticid Review Section, Florida DER, to Pesticide Review Council members.

CRITICAL PROBLEMS AND NEEDS

Data and Information Needs

The unique hydrogeology of Florida and the demands being placed on groundwater resources have accentuated problems arising from data gaps. Among the most important of these gaps are deficiencies in data on the environmental fate of important pesticides, on pesticides use, and on the significance of residue levels found in groundwaters.

Environmental Fate Data

The "Report of the Speaker's Task Force on Water Issues" observed that the DACS, which registers all pesticides used in Florida, has authority to require, when deemed necessary, evidence concerning the safety of each pesticide and to refuse to register a pesticide. However, the task force noted that the DACS focused its attention on the safety of pesticides in relation to actual use on crops and that no agency had been given the responsibility to evaluate the possible impact of a pesticide's use on Florida's groundwaters. The department passed a rule in late 1984 to require agrichemical companies to provide additional environmental fate data on specific pesticides beyond that required by EPA if it deemed such data necessary to assess the potential for a pesticide to leach to groundwater.

Pesticide Use Data

A lack of pesticide use data is frequently cited as inhibiting both the ability to monitor groundwater quality and the management of pesticide use to minimize contamination. The DACS has compiled limited data on restricted use pesticides; however, reporting of such pesticide usage by certified applicators are not mandatory, and the response to requests for voluntary reporting has been low (in the 10 to 30 percent range). Moreover, the use data that are received are not site-specific but are summarized by county. Mandatory reporting requirements have been discussed but not adopted.

Significance of Residues

The toxicological significance of trace levels of pesticides detected in groundwater is often a critical unknown. In reviewing "Trends in Ground Water Protection in Florida," Dr. Rodney DeHan of the DER discussed the department's difficulties in setting MCLs for contaminants. He wrote that

> The research on the toxicological, public health and environmental impacts of these hazardous chemicals is beyond the capabilities of the Department. The U.S. Environmental Protection Agency (EPA) must provide the necessary support for conducting basic research needed to evaluate the hazard stemming from the use and disposal of these agents.... In Florida ... one of the highest environmental priorities is the development of "safe" or "acceptable" levels of toxic chemicals in the water resource.

Monitoring Resources and capabilities

Contributing to the lack of data is the resource-intensiveness of monitoring pesticides in groundwater. The analytic capabilities of the DER and the DACS have been overloaded, and facilities of the University of Florida have been relied on for water quality analyses. For this reason, the DER contracted the U.S. Geological Survey to conduct a "statewide assessment of selected trace metal and organic priority pollutants in groundwater used for public water supplies." Furthermore, beginning with the 1983-1984 budget, the state substantially increased the DER's resources for addressing groundwater contamination.

Less expensive, broader analytic techniques would reduce the resources now required to assess groundwater quality. Although the EPA's current Master Analytical Scheme for Organic Compounds in Water will test for a wide range of pesticides, it requires a minimum of 80 hours of laboratory time plus the use of a gas chromatograph-mass spectrometer. Researchers at the University of Florida's Pesticide Research Laboratory are seeking funds for the development of a master analytic (multiresidue) screen for pesticides in water that would be more efficient and less resource-intensive. The proposed screen is a quantitative technique giving accurate concentration levels in the parts-per-billion range for more than 200 pesticides, at an estimated cost of $500 per sample. It would not require a mass spectrometer; instead, capillary column gas chromatography with electron-capture detection would follow chemical derivatization of those pesticides considered non-volatile. The technique would require a preparation time of only 15-20 hours per sample, and an additional 2 hours on the gas chromatograph.

Point Sources

Several potential point sources of pesticide contamination have raised concern in Florida. These sources include formulating facilities where pesticides are mixed and prepared for delivery; sites where EDB was used in fumigation chambers to treat citrus; and backflows from chemigation systems, where pesticides or fertilizers are applied via irrigation water.

Some sampling is being done at wells near formulation and fumigation sites. To prevent chemigation problems, Florida adopted an "anti-backsiphoning" device rule in November 1984. The device prevents pesticides and fertilizers applied in chemigation systems from back-flowing through irrigation lines and down an irrigation well, where the chemicals could contaminate groundwater. It also prevents the flooding of a chemical supply tank, which could cause chemicals to spill onto the ground. [See American Society of Agricultural Engineers (ASAE), Engineering Practice #409.]

AGRICULTURAL MANAGEMENT STRATEGIES AVAILABLE TO MITIGATE PESTICIDE/GROUNDWATER QUALITY PROBLEMS

The presence of aldicarb residues in groundwater prompted Florida's DACS to ban the pesticide in 1983 for virtually all field uses except potatoes. When this ban was lifted in 1984, a series of restrictions were imposed to minimize groundwater contamination. These restrictions are designed to preserve the benefits of particular aldicarb uses while minimizing the risks of contaminating groundwater. In 1984 EPA's Science Advisory Panel reviewed the potential benefits of site-and use-specific restrictions and their enforceability and concluded that the restrictions were justified. A major goal of Florida's aldicarb monitoring program is to assess the success of the restrictions. As in California, the complex hydrogeology and many different crop uses of pesticides pose a formidable challenge for the design of sire-specific controls.

Experts interviewed at the University of Florida believe that management of sensitive hydrologic areas to prevent contamination of groundwater from agricultural chemicals is technically feasible. They suggested that such management would be accomplished more easily with restricted use pesticides and that environmental fate data could be useful to delineate sensitive areas for specific pesticides.

5

Federal Agencies

U.S. ENVIRONMENTAL PROTECTION AGENCY

Environmental Fate Data

As part of its pesticide registration responsibilities, the EPA's OPP is requesting environmental fate data on selected pesticides with the potential to contaminate groundwater. Some 84 pesticides were the subject of an expanded data call-in program (Table 5-1), which is authorized by section 3(c)(2)(B) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The test data requested include vapor pressure, octanol-water coefficient, water solubility hydrolysis, photodegradation, soil metabolism, mobility, and field dissipation. The EPA requires submission of some data within 6 months and field dissipation study results within 2 years after receipt of the request. This data call-in is in addition to requests for environmental fate data for 51 pesticides undergoing active development of standards or having completed registration standards (Table 5-2).

During the summer of 1984, Holden visited a number of federal agencies in Washington, D.C. The people with whom he discussed groundwater quality and/or pesticide issues included staff from the U.S. Environmental Protection Agency's Office of Pesticide Programs (OPP), Office of Groundwater Protection (OGWP), and Office of Drinking Water (ODW). He also visited a national program leader in water resources, Extension Service, U.S. Department of Agriculture.

TABLE 5-1 Pesticides for Which Data on the Potential for Groundwater Contamination Are Being Called in by the EPA

Ametryn (Evik)	Lead arsenate
Aminocarb (Metacil)	Maleic hydrazide (MH)
Asulam	Mecoprop (MCPP)
Azinphos-methyl (Guthion)	Mefluidide
Bendiocarb (Ficam)	Mercaptodimethur (Mesurol)
Bromoxynil	Metam-sodium (Vapam)
Bufencarb [suspended]	Methyl bromide
Cacodylic acid	Methyl isothiocyanate
Calcium arsenate	Metribuzin
CDAA (Randox)	Mobam
Chlormequat chloride (Cycocel)	Mevinphos (Phosdrin)
4-Chloropyridine N-oxide	Molinate
Chloropropham	Monocrotophos (Azodin)
Crotoxyphos (Ciodr in)	MSMA
Cychloate (Ro-Neet)	Napropamide (Devrinol)
Dalapon	Naptalam (Alanap)
Dazomet	Neburon
DCPA (Dacthal)	Oxamyl (Vydate)
Demeton (Systox)	Oxydemeton-methyl (Metasystox-R)
Desmedipham (Bentanex)	Paraquat
Diazinon	Pebulate (Tillam)
Dicholbenil	Phenmedipham
Dichofop methyl (Hoelon)	Phosmet (Imidan)
1,3-Dichloropropene (Telone II)	Phosphamidon
Difenzoquat methyl sulfate (Avenge	Prometon (Pramitol)
Diflubenzuron (Dimlin)	Promteryn (Caparol)
Dinocap (Karathane)	Pronamide (Kerb)
Dinoseb and salts (DNBP)	Propachlor
Diphenamid	Propam
Dipropetryn (Sancap)	Propanil
Diquat	Siduron
2,2-Dithiobisbenzthiazole	Tebuthiuron
DSMA	Terbutol, terbucarb (Azak)
EBDCs	Terbutryn
Endothall	Thiabendazole
Ethiofencarb (Croneton)	Thidiazuron (Dropp)
Fenamiphos (Nemacur)	Triallate (Par-Go)
Ferbam	Triadimefon (Bayleton)
Fluometuron	2,3,6-TBA (2,3,6-Trichlorobenzoic acid)
Fosamine ammonium (DPX 1108)	Vernolate (Surpass, Vernam)
Fosthietan [discontinued]	Ziram
Isophenfos (Oftanol)	

SOURCE: Adapted from "Potential for Groundwater Contamination Data Asked on 84 Pesticides," Pesticide & Toxic Chemical News, May 2, 1984, p. 37.

National Groundwater Monitoring Program

The EPA's OPP and ODW are currently in the design phase of a national monitoring plan for pesticides in groundwater. According to "National Pesticides Ground-Water Survey Overview," April 23, 1985, an EPA memorandum, the survey will focus on pesticides in groundwater as a result of agricultural practice. Both private and public drinking-water wells will be sampled and analyzed for approximately four dozen pesticides and a number of transformation products. Roughly 1,500 wells will be sampled once. These wells will be chosen in a three-stage process. In the first stage, counties will be ranked according to (1) their estimated pesticide usage (computed by using Doane Marketing data on pesticide usage and county-level crop acreage data from the U.S. Department of Commerce, Census of Agriculture) and (2) their groundwater vulnerability (estimated by using the National Well Association's recently published DRASTIC ranking scheme). In the second stage, the counties will be segmented, and in the third stage, the wells to be sampled will be chosen. The second-and third-stage operations are not yet settled. Each of the three stages will be designed to ensure statistical validity. The final list of pesticides will be selected

TABLE 5-2 Pesticides with Active or Completed Registration Standards for Which Environmental Fate Data Have Been Requested by the EPA

Acephate (Orthene)	Dicamba
Alachlor	Diclone
Aldicarb (Temik)	Dicrotophos
Amitrole	Dimethoate
Ammonium sulfamate (Ammate)	Disulfoton
Anilazine (Dyrene)	Diuron
Aspon	EPTC
Bentazon (Basagran)	Ethoprop (Mocap)
Bromacil	Fenaminosulf (Lesan)
Butylate (Sutan+)	Fensulfothion (Dasanit)
Carbofuran (Furadan)	Fonofos (Dyfonate)
Carbophenothion (Trithion)	Formetanate (Carzol)
Carboxin (Vitavax)	Hexazinone
Chloramben (and salts)	Linuron
Chlordimeform	MCPA
Chlordimeform hydrochloride	Methidathion (Supracide)
Chloropyrifos	Methomyl
Chloropicrin	Metolachlor
Chlorothalonil	Monuron
Cryolite	Phorate
Cyanazine (Bladex)	Phosalone
Daminozide (Alar)	Picloram
DCNA	Simazine
Dialifor (Torak) [discontinued]	Terbacil
Diallate (Avadex)	Trichlorfon

SOURCE: Adapted from "Potential for Groundwater Contamination," p. 38.

primarily on leaching potential, with previous detection in groundwater and toxicity being considered.

Groundwater samples will be analyzed by multiresidue methods whenever possible. All positives will be confirmed by at least a second analysis. All samples will be analyzed for all pesticides. The primary analyses will be done under contract, with some in-house quality control work. Sampling and analysis are tentatively scheduled to begin in spring 1986 and to be completed by fall 1987, with a final report due in spring 1988. Before the first sample is taken, some sort of health guidelines will be established. Residue levels exceeding those guidelines will be reported to appropriate state agencies. The form of the health guidance remains undetermined, but may be a shortened version of a typical ODW Health Advisory.

The total cost of this project is estimated to be $5-$6 million. (As of April 1985, the funding for fiscal year 1986 was not certain.) The overall goals of the survey are to

- Characterize the occurrence of selected pesticides in groundwater;
- Determine the relationship between pesticide uses, pesticide characteristics, and field conditions (e.g., soil types) to groundwater and drinking-water contamination;
- Estimate human exposure to these chemicals via drinking water contaminated by normal use.

The OPP believes the development of these data can provide a basis for drinking-water standards and health advisories, label restrictions, regulatory decisions to restrict or ban the use of specific pesticides, and the assessment of the environmental impacts of innovative agricultural practices such as no-till farming and chemigation.

Health Advisories

The need to establish health advisories for pesticides in water was recognized by most of the people interviewed at the EPA. The National Agricultural Chemicals Association (NACA) has taken a strong position encouraging the EPA to establish federal drinking-water health advisories for pesticides. Health advisories provide information on the health effects of unregulated contaminants so that users of the water in question can De assisted in making decisions regarding what action to take if contaminants are detected. Health advisories are developed for various lengths of exposure from 1 day to 2 years, depending on the availability of data. The development of health advisories involves intensive scientific and technical evaluation of available data coupled with peer review by leading toxicologists.

Officials of the ODW indicated that the NACA approach (which is based on acceptable daily intake data and summarized in Chapter 6) makes sense for acute toxicity but may not be appropriate when considering chronic health impacts and multiple exposures. In May 1984 the EPA's OPP and ODW signed an interoffice memorandum of understanding on pesticides in drinking water. One provision of the memorandum establishes procedures for the OPP to supply scientific data for the ODW's use in setting standards for residues in drinking water. A health advisory does not have the same level of regulation as the primary drinking-water standards established under the Safe Drinking Water Act. Primary drinking-water standards have been established for just six pesticides (endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP). Approximately 20 additional pesticides are being considered for inclusion in the National Primary Drinking Water Regulations (Federal Register , October 5, 1983, "National Revised Primary Drinking Water Regulations," p. 45518.)

Multiresidue Analytic Techniques

The OPP staff discussed the need for multiresidue analytic methods to screen water samples for pesticides. The advantages of such screening techniques include the more rapid development of a broad data base, less exposure in sample acquisition and sample analysis, and more comprehensive water quality assessments. Such techniques involve tradeoffs, however, including more time required for sample preparation before analysis, greater expense associated with increased laboratory preparation, and less sensitivity of the analysis. The use of a multiresidue analytic technique would depend on the goals of the sampling program.

A number of multiresidue methods have been developed by the FDA and the USDA. These include a chlorinated hydrocarbon method, an organophosphate method, a phenoxy herbicide method, the Luke method, a carbamate method, and the Pesticide Analytical Method (PAM).

Some of the screening techniques are generally sensitive only to the parts-per-million level and perhaps would not be adequately sensitive for water samples where accuracy in the parts-per-billion range is often desired. However, there seems to be no technical reason why multi-residue screens for pesticides in water with sensitivity to the parts-per-billion level cannot be developed.

Groundwater Protection Labels for Pesticides

The EPA announced in 1984 that it would contract with the Conservation Foundation (CF) to develop pesticide labels that indicate the potential for a specific pesticide to leach to groundwater. The CF was to develop pesticide labeling that would be relevant to growers, indicate potential impacts on groundwater quality, and somehow factor in local soil and hydrologic conditions (see Pesticide and Toxic Chemical News, November 21, 1984, p. 7). However, the project has apparently been canceled by the EPA, illustrating the unsettled nature of pesticide/groundwater policies.

Other EPA Activities

During 1985 the OPP and the OGWP began preparing a strategy statement on pesticides and groundwater. In January 1986, however, this project was combined with a broader effort by the EPA's Office of Pesticides and Toxic Substances to write a strategy on agrichemical management.

EXTENSION SERVICE—U.S. DEPARTMENT OF AGRICULTURE

The National Program Leader in Water Resources of the USDA Extension Service (ES) is organizing an ES response to groundwater contamination caused by agricultural practices. The efforts include the assessment and characterization of the nature of groundwater problems caused by agriculture, definition of the ES's role in the protection of groundwater resources, and mobilization of the ES's resources in addressing the issue.

The ES has recently organized a Groundwater Task Force that includes eight people, two each from four major regions encompassing the entire United States. This task force is now engaged in a national survey of current ES activity in individual states related to groundwater and is also assessing what specific needs should be addressed by the ES. In addition to contamination of groundwater caused by pesticides, the task force will consider questions about groundwater quantity (amount available as a resource) and salinity. This work is just beginning, so little substantive information has been produced.

6

Agricultural Chemical Companies

TRADE ASSOCIATION

National Agricultural Chemicals Association

The National Agricultural Chemicals Association (NACA) has established an ad hoc committee on groundwater protection. The committee includes representatives from eight chemical companies, and NACA's Director of Environmental Affairs serves as the staff representative.

NACA is concerned that a "chemophobia" has been building in the United States because of increasing public concern about the potential health hazards of industrial and agricultural chemicals. It believes that near hysteria occurs in the public whenever pesticides are detected in groundwater at trace levels; this chemophobia is sometimes exacerbated by irresponsible reporting in the mass media.

NACA asserts that pesticides rarely reach groundwater. By educating farmers about good pesticide management practices, it believes that most, if not all, problems associated with leaching of pesticides to groundwater could be avoided.

The association has addressed the groundwater issue both internally and externally. A NACA-sponsored regulatory conference in April 1984 focused on

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During the summer of 1984, Holden visited representatives of four agricultural chemical companies: Monsanto, FMC, Ciba-Geigy, and Union Carbide. He also interviewed staff members of the National Agricultural Chemicals Association (NACA), the Washington, D.C., trade association representing the agricultural chemical companies.

groundwater, with presentations by representatives of the chemical companies, environmental groups, the EPA, the USDA, the American Farm Bureau Federation, and others. At that conference John Moore, the EPA's assistant administrator for pesticides and toxic substances, encouraged the pesticide industry to "get all the data you can about pesticide products to show whether or not they have a tendency to move into groundwater," NACA appears to be responding to this challenge; the groundwater protection committee is actively involved in the development of a sampling protocol that could be used to monitor groundwater and soils for pesticide residues. NACA believes this protocol is a critical step in ensuring that future sampling yields reliable and useful water quality data.

NACA is also involved in a "preventive program" to reduce the possibility of agricultural chemicals leaching through the root zone to groundwater. The association has widely circulated and promoted a paper outlining good agricultural practices to be followed to avoid contamination of groundwater by pesticides. The paper is available on request at no charge. Additionally, NACA has sent press releases on pesticide management to the agricultural press, and the information has been published in such journals as Farm Chemicals and Agricultural Consultant and Fieldman. NACA is also advocating the development of scientifically rigorous modeling approaches for delineating areas where leaching of agricultural chemicals is likely to occur.

It is strongly believed by NACA that establishment of federal drinking water health advisories for agricultural chemicals is critical. Establishing health advisories for pesticides is a concrete step that NACA believes would help mitigate public panic when pesticides are detected in groundwater. The association maintains that a federally set number system that distinguishes toxic from safe concentrations by assigning a health advisory number will help put into perspective any pesticide residues that might be detected. In NACA's view, this number could be readily determined by using the toxicological data base already required for product registration.

NACA suggests that the acceptable daily intake (ADI) established by the EPA's OPP during the registration process be used to determine health advisories for pesticides in drinking water in the following manner:

$$\text{Health advisory} = \frac{\text{ADI (mg/kg/day)} \times 10 \text{ kg child}}{1 \text{ liter of water/day}}$$

NACA further believes that health advisories should be established initially for those products that have been detected in groundwater and, subsequently, for those products whose chemical properties suggest a high leaching potential.

COMPANIES

Monsanto

At the headquarters of Monsanto Agricultural Products Company, Holden discussed the history of groundwater problems associated with the herbicides alachlor (Lasso) and glysophate (Roundup).

Alachlor is a versatile herbicide and a profitable product for Monsanto. It is used extensively for pre-emergent control of annual grasses and some broadleaf weeds in corn and soybean production. An estimated 30 percent of field corn and soybeans grown in the United States are treated with alachlor. It was first marketed in 1969 and made huge gains in the market during the 1970s. Sales of alachlor have leveled off in the 1980s, although the herbicide remains an important product for the company.

Monsanto believes that alachlor does not pose a serious threat to groundwater quality. Alachlor has been detected in trace amounts (0.6-14.0 ppb) in groundwater in Nebraska, Iowa, Wisconsin, and Ontario, Canada, after normal field applications. It has also been detected in surface-water in Iowa and Ohio (as well as in eight other states) at maximum concentrations of approximately 100 ppb. The sampling undertaken by Monsanto to quantify groundwater problems associated with the production and application of alachlor has been limited largely to monitoring at manufacturing plants and to supporting work at the Water Quality Laboratory, Heidelberg College, Tiffin, Ohio. In this work, surface-water quality in agricultural watersheds in northwestern Ohio has been monitored for specific pesticides including alachlor. However, no groundwater monitoring of agricultural lands for alachlor was reported by Monsanto despite the handful of detections of the herbicide in groundwater.

Glysophate is another important herbicide that Monsanto feels poses no threat to groundwater. The possibility that field-applied glyphosate might be chemically altered to a chemical of concern (nitrosoglysophate) has been reviewed by both Monsanto and the EPA and is considered very unlikely.

FMC

The main topic of discussion during interviews at the FMC Corporation concerned carbofuran (Furadan), a widely used carbamate insecticide/ nematocide that has been detected in groundwater.

Carbofuran was first detected in groundwater in Suffolk County, New York, in 1979. As noted in Chapter 2, some 5,100 groundwater samples have been analyzed for carbofuran. It has been detected in about 30 percent of the samples; in 5 to 6 percent the concentration equaled or exceeded the New York health standard of 15 ppb. In Wisconsin, 78 samples have been analyzed for carbofuran, and only 2 detections of the compound have been reported, with the highest concentration at 7 ppb. The sensitive hydrologic conditions of Suffolk County, which contributed directly to the leaching of aldicarb, also influenced the migration of carbofuran to groundwater. FMC removed the product from the market in Suffolk County in 1980.

FMC has taken partial responsibility for the degradation of groundwater quality on Long Island, and, where contamination has occurred from the use of carbofuran, FMC has joined with Union Carbide in installing and recharging granular activated carbon systems for domestic water supply wells.

In response to the groundwater contamination on Long Island, FMC established a research area near Salisbury, Maryland, where conditions were considered worst case (that is, homogenous sandy soils, low organic matter content, shallow water table, and so on). Soil and foliar applications of carbofuran were made to plots in which corn and potatoes were planted. Monitoring wells were installed downgradient and upgradient of the plots, and vacuum lysimeters were used to take soil/water samples. After 12 to 16 months, carbofuran was detected in groundwater samples taken from the monitoring wells. The highest concentration of the compound (30 ppb) was detected in corn plots; concentrations ranging from 1 to 10 ppb were detected in potato plots. The higher concentrations detected were from granular soil applications rather than from foliar applications.

These findings prompted FMC to initiate a $100,000 monitoring study in March 1984 to evaluate the leaching potential of carbofuran in various crops (corn, soybeans, tobacco, cotton, and peanuts) at two sites—one in Maryland and the other in North Carolina. The study is being supervised by O'Brien and Gere, Inc., an engineering consulting firm in Syracuse, New York. The objective is to generate crop-specific data on the potential of carbofuran to leach below the root zone and impact groundwater. FMC also hired another consulting firm, Roux Associates, Inc., of Huntington, New York, to develop an environmental sensitivity assessment for pesticide application. The purpose of this assessment is to identify areas where soil, hydrogeologic, and climatic conditions may allow field-applied pesticides to be transported to groundwater. Major agricultural counties in 13 states including New York, Wisconsin, and Florida were selected for evaluation to determine areas vulnerable to groundwater contamination by pesticide applications.

Ciba-Geigy

Holden visited with representatives of Ciba-Geigy's Agricultural Division to discuss the history of groundwater problems associated with the use of three herbicides produced by Ciba-Geigy—atrazine, simazine (Princep), and metolachlor (Dual).

Few detections have been reported of atrazine, simazine, and metolachlor residues in groundwater samples. Atrazine has been detected in groundwater in Iowa, Nebraska, and Wisconsin, most commonly in concentrations less than 3 ppb (an exception is the point source in Rusk, Wisconsin, mentioned in Chapter 3); simazine, which is considerably less mobile than atrazine, has been detected in groundwater only in California at low concentrations (3 ppb); and metolachlor has been detected only in Wisconsin's groundwater at a maximum concentration of 55 ppb at a point source. Virtually all the groundwater detections of these herbicides have been at concentrations below health standards established in the various states. All three pesticides have low acute toxicities (greater than 2,000 mg/kg LD_{50} for rats), and one of the Ciba-Geigy representatives pointed out that the LD_{50} rate for simazine (5,000 mg/kg for rats) is greater than the LD_{50} for table salt. There was no mention by Ciba-Geigy of ongoing groundwater monitoring studies on any of these pesticides.

Ciba-Geigy representatives believed health advisories were critically needed. They noted that atrazine and simazine are among the pesticides being considered by the EPA for inclusion in the National Primary Drinking Water Regulations (NPDWR). The representatives noted that if the current minimum detection limit (MDL) for a chemical were made the basis for establishing its maximum contaminant level (MCL), a company would have no motivation for improving analytic capabilities. On the other hand, an MCL set below an MDL is impractical from a regulatory perspective.

Ciba-Geigy officials viewed Wisconsin's preventive action limits (PALs) to be an intelligent regulatory action. Similarly to the concept of health advisory numers, PALs provide a number that can trigger a regulatory response before a crisis situation exists and decisions must be made in a highly charged political atmosphere. The Ciba-Geigy representatives believed the lead time provided by PALs could prevent the occurrence of unnecessarily harsh regulatory responses.

Union Carbide

The purpose of Holden's visit to Union Carbide Agricultural Products was to discuss the company's perspective on the problems caused by the leaching of its product aldicarb (Temik) to groundwater. Aldicarb has been detected in the groundwater of 15 states, with the most serious incident, as described in Chapter 2, having occurred in Suffolk County, New York.

Union Carbide representatives stressed that the detection of pesticide residues in groundwater does not necessarily constitute contamination. That is, detectable levels of certain chemicals in water do not necessarily mean that the water is contaminated in the sense that it is not potable. Acceptable residue levels for pesticides in food have been established by the federal government, prompting the Union Carbide representatives to ask why such levels could not be established for pesticide residues in water.

Union Carbide representatives also questioned the toxicological validity of the EPA's unofficial regulatory health guideline for aldicarb of 10 ppb. The toxicology data base for aldicarb is one of the most extensive on record, according to Union Carbide. Additionally, the World Health Organization has established a higher ADI than the one established by the EPA. On the basis of the procedure approved by the EPA's Scientific Advisory Panel in June 1983 for deriving a health advisory from an ADI, Union Carbide contends that the EPA's health advisory of 10 ppb for aldicarb should be revised to between 30 and 50 ppb.

Company representatives pointed out that the environmental data base for aldicarb is extensive and now includes approximately 20,000 water and soil samples analyzed by Union Carbide. The detection of aldicarb residues in drinking water has been limited to a few sensitive hydrologic areas and is not an extensive national problem. The label restrictions established in Wisconsin after the detection of aldicarb in the groundwater of the Central Sands region were cited as a sensible and reasonable reaction to a problem that can most likely be managed by moderate changes in agricultural practices. In this regard, Union Carbide said pesticide manufacturers should be directly consulted by the EPA or state regulatory agencies if pesticide residues are detected in groundwater. Cooperation between the regulated industry and the regulatory agencies, if a problem is detected, can foster the development and exploration of remedial options.

Agrichemical companies are becoming more aware of environmental factors that can potentially contribute to the transport of their products to groundwater. It would appear that through responsible assessment of the potential for transport of their products to groundwater, and because of a desire to limit corporate liability, such companies are becoming partially self-regulating.

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