# AGRICULTURE AND GROUNDWATER QUALITY

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## Introduction

Intensive row-crop agriculture in the corn belt area of the Midwest United States is the foundation of the region's economy. Major increases in agricultural production in this region have occurred in the past thirty years due in part to extensive use of pesticides (herein, the term pesticide is used to include herbicides and insecticides) and inorganic fertilizers. In Iowa, inorganic nitrogen fertilizer use has increased from an average of 13 lbs/acre in 1955 to 139 lbs/acre in 1988. Similar increases have been seen in the other corn belt states. Nitrogen used on corn averaged *158*, 146, 163, 139, and 132 lb/acre in 1988 in Ohio, Indiana, Illinois, Iowa, and Missouri, respectively. In this same five state region, 98% of the corn acreage received herbicide treatment and 34% insecticide treatment in 1988. Depending on the actual pesticide compounds used, the rates for herbicides and insecticides would be about 3 and llb/acre, respectively. Use of this ag-chemical technology has resulted in increased production at lower per-unit costs. Ag-chemical use does represent cost to the producer. On a typical Iowa farm, total fertilizer costs for corn represented about 14% (8% for nitrogen fertilizer only) and pesticides represented 8% of the total $344/acre production costs in 1989. However, these inputs normally provide significant increases in crop yield and subsequent income. For example, addition of nitrogen fertilizer to continuous corn often more than doubles yield compared to no nitrogen added.

In the past, considering only economic costs, there was little difference between an "economically optimum yield" and maximum yield. Hence, if one was to error on inputs, it was good insurance to error on the side of higher chemical use. Now with the water quality concerns arising from the detection of pesticides and nutrients in groundwater (primarily herbicides and nitrates) and the increasing desire to design alternative agricultural systems that are more sustainable, there is a need to reevaluate and modify current farming practices, taking into account costs beyond simply the dollar value of inputs.

Nitrate nitrogen levels above the existing drinking water standards and detectable levels of pesticides have been reported in most of the corn belt states. As an example of pesticide contamination, a one-time sampling of all public water supplies in Iowa (Iowa DNR, 1988) found 16% of the 217 wells that were less than 100 feet deep contained detectable levels of pesticides. For wells of 100-1000' depth, 6% of the 413 wells tested contained detectable levels of pesticides. None of the *105* wells tested that were deeper than 1000' were found to contain pesticides. For comparison, 61% of the 41 public water supplies using surface water sources were found to contain pesticides, and the concentrations of pesticides were generally higher in surface water than in groundwater supplies. In 1987, the Illinois Public Health Department sampled wells at 80 of 1500 agricultural chemical facilities statewide.

Results showed that two-thirds of the wells sampled were contaminated (Illinois Farm Bureau, 1989). A more recent sampling of 160 private rural water supply wells in four counties in north-central Iowa revealed detectable levels of pesticides in water from only 1 well.

## Research Issues

Further research on the determination of the main source of pesticide contamination is needed. Whether the pesticides are leaching through the soil as nonpoint source contamination (i.e., pesticide-treated fields) or coming from "point sources," such as areas of chemical spills or improper disposal that may exist around places where pesticides are handled, is not known. It is known that atrazine, a longer-lived herbicide, can leach through the root zone, although usually at concentrations less than 1 micro gram / liter (ppb); however, when a number of different pesticides are detected and at significantly higher concentrations, the question has to be raised as to point sources in the vicinity. This type of research is critically needed in order to develop cost-effective management methods to prevent further groundwater degradation.

Another issue that needs and is getting further attention is the role that macropores, or preferential flow paths, play in the transport and fate of ag-chemicals in the environment. Macro-pores or channels or cracks certainly have the potential to allow surface-applied chemicals to move deeper into the soil more quickly than if water had to flow through the soil matrix as "plug flow." However, these macropores also have the potential of allowing water from the soil surface to move through the soil, bypassing chemicals that may be within the peds or soil aggregates, and therefore actually decrease chemical leaching. The role that conservation tillage plays in the formation of macropores is very important and needs to be resolved in order to be able to continue to promote conservation tillage as an environmentally sound soil conservation practice.

Relative to the fate and transport of ag-chemicals in the soil/groundwater system, little is known about the potential existence of various attenuation processes. The rate of attenuation reactions for both nitrate and pesticides is not completely understood. Are the trends of decreasing concentrations of contaminates with depth that are often observed in well sampling simply the result of the chemicals not having had enough time to move deeper, or are attenuation processes such as denitrification, pesticide degradation, and adsorption significant factors also?

Much of the current research on transport of ag-chemicals has focused on the shallow "rooting zone." For corn, this is assumed to be the first five feet of soil. The processes of transport in the vadose zone below the rooting depth until the water table is reached and the processes of transport within the groundwater zone have received much less research. In the groundwater system, for example, an improved understanding of the effects of the small-scale anisotropic conditions found in many unconsolidated aquifers on contaminant transport is critical for the prediction of the transport of ag-chemicals. Adsorption and biological degradation of pesticides with the low organic matter aquifers is not fully understood.

The issue of "best management practices" to control nonpoint source pollution has already received a lot of attention in the research community. However, the word "best" is an overstatement because it implies we know more than we actually do about the impact of various "best management practices" on groundwater quality. Certainly there is still need for further field verification of the effectiveness of currently recommended practices under varying field conditions. Furthermore, there is room for development of improved farming practices or agricultural systems. Significant new research is being initiated in this area of concern under the banner of sustainable agriculture. While sustainable agriculture is much broader than agricultural chemical impacts on groundwater, changes in farming practices will be necessary to answer the chemical concerns.

The design of new agricultural practices or systems is affected by the performance standards that are applied. For water quality impacts, the major question is what are the appropriate water quality standards for use in developing new practices. Most agricultural chemicals do not have established drinking water standards or maximum contaminant levels. Some of the chemicals have health advisory levels established. How should these various standards be applied to design of new practices? For example, will health advisories that are being established for the more modern pesticides be the criteria against which to measure best management practices, or will agricultural drainage be required to meet the drinking water standard? Should concentration standards be applied to individual grab samples collected or to longer-term average concentrations? These are important questions that will require interdisciplinary research teams in several disciplines including engineering, economics, health professions, political science, and others.

**Research Initiatives**

To meet the need for additional groundwater quality research, there are two new research activities on the horizon. They are the USDA Midwest Water Quality Initiative and the USGS Mid-Continent Herbicide Initiative. These major new programs are related in that significant cooperation between the two lead agencies and US EPA is taking place. In the USDA initiative, emphasis is being placed in four areas:

- An assessment of the effects of existing management systems (with respect to pesticides, nitrogen, cultural practices, crop and livestock systems, and water management) on the water quality of agricultural drainage;

- The development of new management systems, chemical application technology, and diagnostic tools (such as a soil-nitrate test), resulting in improved water quality;

- The development of fundamental information useful in further improved practices and systems for water quality control (e.g., data on mass accountability, preferential water flow and chemical transport, and biological pest control); and

- Model development and utilization for making policy and management decisions.

For the USGS Mid-Continent Herbicide Initiative, studies have been planned to investigate the effects of agriculture on the occurrence of herbicides in ground and surface water. The herbicide atrazine has been chosen as the focus chemical because of its widespread continuous use and the frequency with which it has been detected in groundwater. The objective is to answer the key question: What happens to atrazine after its application? The studies are considering physical, chemical, and biological processes that can affect the transformation, transportation, and storage of atrazine. Included are various environmental factors, which can vary over time and space, such as soil pH, atrazine application rate, depth to water. A research matrix has been developed that uses a mass-balance concept to account for the distribution of atrazine in the environment and to identify additional research needed. Information gained is to be used to provide the scientific basis to guide institutional decisions to mitigate water contamination.

The purpose of this paper has been to outline some of the concerns with the proper use and management of agricultural chemicals. Additional research is needed in order to assist the farmers in facing the critical issues of improved management in the future. University researchers have an important role in finding solutions to the issues discussed above.

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# HAWAIIAN ISLANDS GROUNDWATER: A NEW BALL GAME

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Without groundwater sources, the Hawaiian Islands would not have been as vital as they are today—a very popular vacation destination for millions of global visitors, a booming commercial hub of the Pacific, a strong agricultural producer, and an important national defense base.

The beginning of a changing era was the year 1879 when James Campbell sponsored the drilling of a well that struck artesian water on Oahu. That copious groundwater source was the impetus at that time for sugarcane cultivation as a large scale mechanized agricultural industry. More important, it is the high quality of groundwater—potable without treatment—that makes it the premier and most economical source for Hawaii's drinking water supply. Groundwater provides 99+% of the drinking water for Honolulu with its present population of 838,000 and 90% of all water uses including irrigated agriculture. Although it is self-evident, ocean imposes freshwater self-sufficiency for each island.

As a part of Hawaii's artesian water centennial (1879-1979), the University of Hawaii Water Resources Research Center documented in a book a century of progress in exploration, discovery, and study of Hawaii's remarkable aquifers. That book provides a benchmark of the state of the Hawaii groundwater resources.

Now, a century plus ten years later, a new ball game is being played regarding allocation of water for use and contamination of water sources. Three major issues are the talk of the town and preoccupy the water professionals in Hawaii today.

**(1) Water Allocation**

Hawaii finally got its first state water code in 1987 to manage the state's water resources by regulation of the uses of water. The code spells out who may develop water from what sources, at what quantity, for what purpose, and for how long. A state water commission is vested with the authority to allocate water by a permit system. Are the great expectations fulfilled by a document that is perfect or a disaster? The answer is neither. Perhaps to the surprise of no one, the legislation is generally regarded as a masterpiece of compromise. It is a compromise between two traditional opposing water resources management approaches—free market and regulation— and a compromise among strong, vested interests in Hawaii. The water commission needs to provide fairness and wisdom to make an imperfect legislation work.

**(2) Organic Contamination of Groundwater**

While the water code addresses primarily