RECONCILING AGRICULTURE'S NEEDS WITH WATER QUALITY

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INTRODUCTION

For the last decade, the impact of agricultural practices on our water supplies has been the overriding concern of the Natural and Environmental Resources Division of the American Farm Bureau Federation. Almost every environmental issue we deal with is tempered by this concern. Today I will outline the scope of the problem. Agricultural practices directly and indirectly influence both water quality and water quantity. I will concentrate on water quality issues. Although both surface water and ground water are vulnerable to contamination, our more pressing concerns are with ground water contamination. I will tell you why. I will describe our present dependency on agricultural chemicals and how these chemicals get into the ground water. I will then summarize the state and federal approaches to ground water protection and pesticide regulations. Finally, I will describe some of the ways we are trying to help our farmers deal with this problem.

THE SCOPE OF THE PROBLEM

Most of us think of lakes and rivers when we think of freshwater and drinking water. But if we look at where our freshwater supplies are stored and how rapidly water is exchanged within these systems, we find that approximately 85 percent of our freshwater resources are stored in ice sheets and glaciers with a turnover rate of 8,000 years. The next largest source of freshwater comes from ground water: 14 percent with a turnover rate of 280 years. Lakes and reservoirs make up only 0.5 percent of our freshwater and their turnover rate is 7 years. Soil moisture represents less than 0.3 percent, with a rate of exchange averaging one year. Vapors in the atmosphere make up 0.05 percent with a rapid turnover of 3 months. And finally, river water comprises a mere 0.004 percent of our freshwater, taking about 3 1/2 months to exchange old for new.

Surface Water

With surface water accounting for less than 1 percent of our available freshwater supplies, most of our data on pesticide and nitrate contamination levels comes from monitoring ground water. We do know, however, that agricultural practices can adversely affect surface water quality. Sediment in surface water costs the nation $4 billion to $16 billion annually (Crosson and Ostrov 1988). Cropland erosion is responsible for about one third of this damage.

Some of the nitrogen and phosphorus applied to the soil in fertilizer and manure is carried through run-off and sediment to surface waters, where it promotes the growth of algae. Decay of the algae reduces the water's oxygen supply and thus impairs the quality of the water for recreational and other uses. This process, called eutrophication, remains a major concern with Lake Erie and Lake Ontario (Hurlburt 1988).

The United States is not alone in its concern with surface water quality. The European Commission is planning to put forward proposals covering the protection of fresh and coastal waters from pollution by effluents from livestock farming in Europe by the end of 1988 (Anon. 1988b). Both the UK and Ireland are wrestling with problems caused by silage effluent, slurry and manure storage, and dirty water and runoff from land spreading (Anon. 1988c). In addition, in the UK, fish farms will now come under government jurisdiction because of kills of the native fish population in neighboring streams (Anon. 1988a).

While data on pesticide concentrations are scarce, it is known that surface water concentrations tend to be higher than those in ground water. This is because only highly soluble pesticides leach to ground water, while less soluble chemicals can be carried to the surface water by runoff, and, in some cases, by sediment. In addition, subsurface flow can carry pesticides from ground water to surface water.

Ground Water

Although our data on ground water pollution by agricultural chemicals is hardly more substantial than that for surface water, our concern is much greater. With a turnover rate averaging 280 years, we cannot rely on nature to clean up our mistakes. In many cases, the costs of cleanup are either prohibitively expensive or technically not feasible. Ground water is the main source of drinking water in 32 of our states. Thirty four of our 100 largest cities rely on it. More than 50 percent of our population drink it. Ground water supplies 26 percent of the water for industry and 35 percent of the water for public utilities. And our farmers depend on it: 97 percent of our rural population drinks it, 55 percent of our livestock drink it, and 40 percent of our irrigation water comes from it (representing over 25 percent of the value of all crops produced) (Bruemmer 1985).

Ground water is the water stored underground, beneath the earth's surface. It is stored in the cracks and crevices of rocks and in the pores of the soil, sand and gravel that make up the earth's crust. It originates as rain or snow falling onto the surface of the ground. Some of this precipitation evaporates and some becomes runoff, replenishing rivers, lakes, streams and oceans. The rest soaks into the ground.

As the water moves down through the soil, a portion of it is retained near the surface in the unsaturated zone. Here, the spaces between soil particles hold either air or water. Some of this water is taken up by plants while the rest continues percolating downwards. It passes across the water table into the saturated zone. All of the porous spaces are filled or saturated with water. The water stored in this saturated zone is called ground water.

The percolation of water down into the saturated zone is called recharge. Recharge typically occurs in upland areas, with the ground water then moving to lowland areas where it is discharged into wetlands, streams, lakes or springs. This movement is very slow, at a rate varying from a few inches per day to a few feet per year.

Whether a particular area of ground water can be used to supply drinking water depends on its ability to store water (porosity) and its ability to transmit it (permeability). The greater the porosity and permeability, the better the area is as a likely source of water.

An underground, saturated, permeable geological formation that produces significant quantities of water is called an aquifer. Aquifers vary tremendously in size and may be anywhere from a few feet to hundreds of feet thick. They may be within a foot of the earth's surface or they may be hundreds of feet deep. The largest aquifer in the U.S. is the Ogallala Aquifer which covers a 156,000 square mile area. By studying the hydrogeological properties of our aquifers, researchers are trying to predict their vulnerability to contamination.

Contamination of Ground Water

It is helpful to remember that agriculture is only one of the many sources of ground water contamination (CAST 1985). Contamination can occur from any number of natural and man-made sources. Some of the nonagriculturally related sources include:

- chemicals leaking from industrial and municipal landfills;
- pits and ponds;
- chemical, oil and petroleum spills;
- leaking underground chemical, oil or petroleum tanks;
- defective underground injection wells;
- careless hazardous waste disposal (every American household produces more than one pound of hazardous waste per year);
- leaking septic tanks;
- disposal of sewage wastes and sludge;
- runoff of de-icing salts;
- discharge from radioactive disposals;
- natural leaching of materials into the ground water;
- natural salt water intrusion, the concentrating effect of salts in the soil, or natural interaction of chemicals in soil to produce harmful substances.

When all of our states and our seven U.S. territories were questioned this year by the U.S. General Accounting Office (GAO), 88 percent of the respondents identified leaking underground storage tanks as their most significant concern (GAO 1988). Municipal solid waste and abandoned hazardous waste dumps were cited by 70 percent of the respondents.

Agricultural chemicals and soil amendments that do have the potential to end up in the ground water can normally be classified within one of four broad categories: fertilizers, organic residues (100 million tons of dry manure per year), pesticides, and organic amendments (including lime, gypsum, and sulfur). Only the first three categories are of great concern (CAST 1985). In the 1988 GAO report, pesticides were identified as significant contamination sources by 49 percent of our states and territories, fertilizers by 46 percent, feedlots by 42 percent, and irrigation by 2 percent (GAO 1988).

Nitrate Contamination

Nitrate contamination of ground water is widespread in the U.S. although levels rarely exceed the safety limit set by the Environmental Protection Agency (EPA). Nitrates develop from nitrogen, an essential element in most living matter. Nitrate contamination can originate from many sources. Possible contributors include animal excreta, human waste, nitrogen fertilizers, naturally occurring deposits of nitrate-containing materials, feedlots, crop residues, and decomposing animal or plant tissue. According to a recent U.S. Department of Agriculture (USDA) report, approximately 10.6 million tons of nitrogen fertilizer is used annually in the U.S. Conventional farming is almost totally dependent on chemical fertilizers, particularly those supplying nitrogen, phosphorus, and potassium. Inorganic fertilizers substantially increase yields per acre even when soil productivity has deteriorated due to soil erosion, compaction, or the removal of crop residue. An estimated 30 to 40 percent of our production results from the use of fertilizers. Some estimate that yields could drop 50 percent per acre per year without the use of commercial fertilizers (Berg 1988). We have seen a gradual accumulation of nitrates in the soils over time, with crops seldom recovering more than 70 percent of added nitrogen. Most crops recover about 50 percent of the nitrogen applied to them. The remainder has the potential to leach into the ground water.

The nitrate-nitrogen contamination from agriculture has been linked to three sources: the land application of nitrogen fertilizer (about 70 percent contribution), land application of manure (about 10 percent) and feedlots (about 20 percent) (EPA 1986a).

Much of the concern about nitrates originates from incidents of methemoglobinemia (blue baby disease) among infants around the country. The first clinical cases were reported from Iowa in 1945 (Hurlburt 1988). If not properly diagnosed, infants under six months of age can die due to lack of oxygen in their bloodstream as a result of ingesting high concentrations of nitrate-nitrogen in their drinking water. Methemoglobinemia remains the only detrimental health effect that has been directly linked to agricultural chemicals in the water supply. However, suggested health effects due to high nitrate-nitrogen levels include fetal malformations, sudden death syndrome in infants, hypertension in children, and gastric cancer in adults (Cantor et al. 1988).

The recommended EPA safe drinking water level for nitrate-nitrogen is set at 10 parts per million (ppm). According to a recent survey by the USDA, which analyzed hydrogeologic vulnerability to contamination and fertilizer use data, ground water contamination from nitrate-nitrogen appears to be concentrated in the following areas: the central Great Plains; the Palouse and Columbia Basin in Washington; portions of Montana; southwest Arizona; the intensively farmed areas of California; portions of the Corn Belt; southeast Pennsylvania; and parts of Maryland and Delaware (Nielson and Lee 1987). Within these regions, Kansas, west Texas, and southern Arizona have the highest recorded concentrations, with 25 percent or more of the sampled wells exceeding the 10 ppm limit. In some cases, the states' data bases were insufficient to decide if problems existed.

Pesticide Contamination

At present, the extent of pesticide contamination of our ground water cannot be determined. Approximately 79 percent of pesticide use in this country is related to agricultural activities. Potential pesticide contamination problems have been tied to land application (about 90 percent contribution), leaks and spills (less than 5 percent) and inadequate disposal (less than 5 percent) (CAST 1985).

A total of 661 million pounds per year of active ingredients are applied in U.S. agriculture (Berg 1988). There are approximately 1,450 active ingredients used in pesticides. At least 59 of these have a known potential to end up in ground water depending upon the soil type. Two herbicides, alachlor (on field corn and soybeans) and atrazine (on field corn) account for 22 percent of our pesticide use. To produce crops with less loss from disease and insects, agrichemicals are used extensively. U.S. farmers use an average of about 2 pounds of pesticide per acre of cropland. Corn and soybeans are the two crops with the largest amounts of applied pesticides. These two crops account for 62 percent of the total national pesticide use (Berg 1988) but occupy only 30 percent of our cropland. Our farmers compete with 10,000 infectious diseases of plants, 2,000 species of weeds, 1,000 species of nematodes, and 10,000 species of insects. Even with pesticides, crop losses have remained high (between 32 to 37 percent) (Bottrell 1980). Returns on pesticide investments have been estimated at $3 to $5 for every $1 invested in chemical crop control and gross returns on the nation's investment in chemical pest control are estimated at $10 billion or more (Pimentel et al. 1978). It is more difficult to estimate the losses that would occur in the absence of pesticides but Borlaug (1972) warned that a complete ban of pesticides would result in a 50 percent reduction in crop yields and a four to five fold increase in food prices. At the other extreme, Pimentel et al. (1978) estimated that a ban followed by alternative control methods would reduce the current crop yield value by only 9 percent.

At present, no adverse health effects have been directly linked to the presence of pesticides in our water supplies. Suggested health effects, however, include leukemia, multiple myeloma, non-Hodgkin's lymphoma, impaired function of the reproductive, nervous, or endocrine systems, and immune system disorders (Cantor et al. 1988).

Ground water may become contaminated by pesticides at any point in the life cycle of the pesticide (EPA 1986b): its manufacture, distribution in commerce, storage, use on the land, or in industrial settings, and disposal. The sources can be grouped into two categories: point sources and nonpoint sources. Point sources include accidental spills and leaks at manufacturing facilities. They are characterized as concentrated plumes that are relatively localized and thus able to be at least partially cleaned up using current technologies. The parties who are responsible for the incident can often be identified and required to pay for the cleanup. Nonpoint sources are those sources that cannot be easily traced. They include most of our pesticide use to control insects and weeds on agricultural and forest land as well as on homes and gardens and on highway and utility rights of way.

When pesticides are applied to the land, they are carried above, over and through the ground by rainfall, runoff, irrigation, and snow melt. Pesticides dissolved in runoff water are carried to surface water or may enter ground water through a variety of potential routes. Pesticides may also leach into ground water through infiltration at either the site of application or in runoff retention areas. Contamination may also occur when irrigation systems are used to apply pesticides (chemigation). These systems may siphon pesticides back into the ground water well if not equipped with proper safety devices. Other sources of contamination include small but frequent spills at mixing and loading sites on the farm field and improper disposal of small quantities of leftover pesticides and their containers.

Generally, contamination from land application extends over a wide area (a whole farm or farming region) at very low concentrations which may build up over the years of pesticide use. At present there are no techniques available for cleaning up contamination that involves a large geographical area. It is virtually impossible to identify the party or parties who are responsible since pesticide use is a common practice. For these nonpoint or diffuse sources, prevention is the key. Prevention efforts will involve both the regulation of individual pesticides as well as changes in pest control and land management practices. In most cases, where there is widespread low levels of contamination, the only effective means of providing clean water is either to treat the ground water before use or find an alternative supply.

Before 1979, relatively little systematic water monitoring was focused on ground water. Testing of pesticides for their potential to leach through the soil and contaminate ground water has also been very limited. Most pesticides on the market today were registered for use before environmental fate testing was routinely required. The general belief before 1979 was that ground water was protected from pesticide contamination by chemical degradation processes in and on the soil and by impervious layers of subsoil, rock, and clay. The discovery of DBCP, a soil insecticide, in numerous wells in California's Central Valley was the first big step in dismantling this long-held belief (EPA 1986b). DBCP-contaminated ground water was subsequently found in Arizona, Hawaii, Maryland, and South Carolina. It was traced to normal agricultural practices in these states.

The same year that all of this was happening, another pesticide, aldicarb, was found in wells on Long Island, New York. It was traced to the normal approved use of this pesticide on potato fields to control insects and nematodes. In 1980, aldicarb was found in the Central Sands region of Wisconsin, again as a result of the use of this pesticide on potato fields. Since then, aldicarb has been found in wells at levels of concern in eleven other states.

The most serious case of pesticide contamination began in 1982 with the discovery of ethylene dibromide (EDB) in two California wells and three wells in Georgia. By the end of the following year, EDB contamination had been discovered in sixteen different counties in California, Florida, Georgia, and Hawaii. EDB has been described by the National Cancer Institute as the most potent cancer causing substance ever found in their animal test program. EPA issued an immediate emergency suspension of all EDB use as a soil fumigant in September, 1983.

At least 17 pesticides have been found in the ground water in 23 states as the result of routine agricultural use. At last count, a total of 73 pesticides had been detected in the ground water of 34 states. The largest number of pesticides have been detected in California, New York, and Iowa but this is probably a function of closer monitoring in those states. Concentrations of pesticides are usually low, ranging in most cases from 0.1 to 1.0 milligrams per liter.

In a 1987 U.S. Department of Agriculture report on ground water contamination from agricultural chemicals, the authors looked at 38 pesticides and their potential to pollute the ground water (Nielsen and Lee 1987). They estimated that approximately 12 percent of our counties have a high contamination potential due to high rates of pesticide use and soil conditions favorable to leaching. Another 25 percent were judged to have moderate potential. These figures, however, represent only potential risks, not actual findings of pesticide contamination in the ground water. A survey of U.S. wells is currently being undertaken by the U.S. Environmental Protection Agency. It is scheduled for completion in 1990 and should provide much-needed information about the pervasiveness of pesticides in ground water at the national level.

SOLUTIONS

Federal Legislation

The protection of our nation's ground water is looked at by many as the major environmental challenge. Over the last 25 years, numerous laws have been enacted to protect our environment (EPA 1986b): the Clean Air Act amendments of 1963, 1965, and 1970; the National Environmental Policy Act of 1969; the Clean Water Act of 1972; the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) amendments of 1972; the Safe Drinking Water Act of 1974; the Resources Conservation Recovery Act (RCRA) of 1976; the Toxic Substances Control Act (TSCA) of 1976; and the Comprehensive Environmental Response, Compensation and Liability Act (Superfund) of 1980. In addition to these, the Environmental Protection Agency (EPA) was established by Congress in 1969.

Despite all of this activity, no comprehensive federal statute deals specifically with ground water protection in a coordinated and consistent manner. At last count, there were sixteen federal laws which provided some regulatory authority to various departments for some type of ground water protection activity.

Federal policy makers have three basic options in their attempts to deal with the ground water protection issue. They can:

- make regulatory changes based on current statutory authority;
- amend specific environmental statutes to address ground water issues; and
- enact comprehensive ground water legislation.

Option one, regulatory changes based on current authority, was utilized in 1985 when EPA approved implementation of its Ground Water Protection Strategy (GPS). It is designed to (a) strengthen state ground water programs (through grants and technical assistance); (b) look for current inadequacies in its protection strategies (through surveys to determine the extent of contamination); and (c) create a policy framework for guiding EPA programs (by adopting guidelines for consistency within programs).

The second option used by Congress has been to amend current laws with specific references to ground water. The 1984 amendments to the Resource Conservation Recovery Act (RCRA) directed the EPA to develop a regulatory program to address the problem of leaking underground storage tanks. Congress also attempted to amend the Clean Water Act of 1972 in 1985 to establish grants for funding state ground water protection programs and activities. The bill was vetoed for budgetary reasons. Superfund, which provides a resource pool of money to clean up hazardous waste sites, was reauthorized in 1986. In 1984, EPA added six agriculturally contaminated ground water sites to the National Priority List. It is also expected that ground water protection language will eventually be added to FIFRA. Possibilities include specific provisions about the protection of ground water from pesticide contamination and a farmer exemption from pesticide ground water contamination liability unless negligence is proven.

Option three for Congress is comprehensive ground water legislation. Such a statute will likely be patterned after other federal environmental statutes and encourage the development of state ground water protection programs in return for grants and technical assistance from the federal government. State programs would have to meet certain EPA established guidelines. Some of the questions Congress will have to wrestle with include:

- What should we protect: all ground water, drinking water, potential drinking water, or all three?
- What standard of protection should be used: a standard based on health, health and technology, unreasonable risk, or simply zero contamination (non-degradation)?
- What should be the scope of concern and should it be prevention or response-oriented?
- If prevention prevails, should we consider the benefits of agricultural chemicals and balance those with the risks? Should chemicals found to be leachers be restricted for use nationwide, regionally, or in site-specific cases?
- What should the response be if the health standard is exceeded? What response is appropriate if the contamination is detected but at levels that currently do not pose a risk?
- Who should be liable for response, including cleanup, alternative water supplies, damages, etc.?
- What is the appropriate federal and state role?

There is a fourth option for Congress as well: addressing environmental concerns in farm policies. The conservation title of the Food Security Act of 1985 (the 1985 Farm Bill) served notice to the agricultural community that farm policy has shifted to a concept based on the common good. Many are now suggesting that the 1990 Farm Bill will make an even more direct link between environmentalists and other common interests (Richardson 1988; AFBF 1990 Farm Program Study, 1988). Among the probabilities:

- Nitrogen management will be addressed as a matter of special priority across a broad policy front.
- Provisions within the commodity and crop insurance programs will be augmented to offer incentives for rotations and adoptions of integrated pest management (IPM).
- The roles of state and federal government agencies will be reassessed. Specifically, the roles of states in setting water quality goals and defining practices farmers must adopt to reach those goals will be re-examined. New federal funding may also be forthcoming, possibly through non-point-source pollution-control goals.

Legislative approaches to nitrogen management were recently offered before the House Subcommittee on Department Operations, Research, and Foreign Agriculture (Richardson 1988). They include the following:

- Place a high enough tax on nitrogen fertilizers so that overall use is reduced; taxes collected would be used to conduct research.
- Require certification of farmers and fertilizer applicators so they will apply fertilizers economically to minimize risks.
- Prescription fertilization: require universities to give prescriptions for a range of management plans.

Nitrogen management will not be an easy problem to address. The nitrate Safe Drinking Water Standard is currently set at 10 ppm nitrate-nitrogen. Studies have shown that crops such as corn grow best with soil nitrate-nitrogen levels that are two to four times above this standard (Colburn 1986).

<u>State Legislation</u>

In the absence of a comprehensive Federal Statute on Ground Water Protection, many states have moved toward implementation of ground water protection legislation to protect aquifers within their states. Currently, ground water legislation has been enacted in Wisconsin, California, Arizona, Iowa, Mississippi, Illinois, Connecticut, and Nebraska. Further legislation concerning aquifer protection zones is being considered in Connecticut. Legislation was attempted in South Dakota, Tennessee, and Massachusetts. The National Agricultural Chemical Association expects twelve more states to try next year (A. T. Hart, personal communication).

So far, two of our states, Iowa and Minnesota, have passed laws establishing certification programs for soil test labs. They hope to standardize soil analysis and reporting methods and provide cost effective fertilizer recommendations for farmers, based on land grant university research.

According to the General Accounting Office, 52 percent of our states have set numeric standards for ground water contaminants, 76 percent have narrative standards (some states have both types of standards), and 32 percent of our states have no set standards (GAO 1988). The report concludes that the existence or absence of standards is not related to the types of ground water problems within a state or the extent to which a state relies on ground water for its drinking water. Their best explanation for the lack of correlation is that "the development of standards is based on the political orientation of a state." As far as active programs dealing with agricultural contamination, 10.5 percent of our states report no activity, 14 percent report little activity, 38.5 percent report some activity, 26 percent report moderate activity, 9 percent report great activity, and one state reports very great activity (GAO 1988).

The disposal of pesticide containers is beginning to be regulated. Maine requires a deposit on restricted use metal pesticide containers. Iowa and Minnesota have some language in various bills regarding this issue. New York is moving toward deposit and return. And Connecticut is trying out a $300,000 cost-share pesticide disposal program in three counties. The trend is toward waste reduction laws and plastic containers.

We are also seeing the appearance of Proposition 65 clones. California's Prop. 65 (the Clean Water Act) requires the publication of an annual list of cancer-causing chemicals and reproductive toxicants and prohibits the discharge of any chemical on the list. It was a ballot initiative, not legislation, and was voted upon by all of the citizens of California. Half of our states have ballot initiatives. Once passed, the initiative goes into law and only the people can change it. Hawaii is looking at similar legislation only it also includes immunotoxicants as well. Tennessee, Missouri, Illinois, New York, and Massachusetts are all considering shorter versions which eliminate the "no discharge" provision but which include "right-to-know."

<u>Farmer Initiatives</u>

A wide variety of agricultural management practices can minimize the threat of ground water contamination. Some are broadly applicable to most sites and farming situations; other practices are appropriate only in specific circumstances; and still others hold promise but are as yet untested.

<u>Nitrogen Management</u>

Best management decisions for nitrogen (N) vary widely, even on an individual farm, because site-specific cropland and environmental and economic factors result in numerous management options. For example, a farmer must weigh the possibility of a greater risk of nitrogen loss if fertilizer is applied in the fall against the possibility that higher prices, poorer weather, and soil conditions may limit N fertilizer options in the spring. Some options (from Jackson et al. 1987):

1. Fertilizer Management
   a. proper rates to minimize excess nitrates at the end of the season (requires knowledge of yield potential, yield goal, soil organic matter, past history, cropping practices, tillage, and economics).
   b. timing of application: fall versus spring application.
   c. split applications: labor, energy, and equipment intensive but permits adjustments of rates based on early season weather and tissue/soil tests.
   d. fertilizer through irrigation water: avoid with shallow rooted plants and on crops grown on ridges.
   e. placement: banding near the seed during planting, placement in ridges for crops planted using "till-plant" ridge tillage, may reduce leaching potential.
   f. nitrification inhibitors: effectiveness depends on weather, environment, soil, and management. Savings often do not justify the expense of inhibitors.
   g. slow-release forms of N: currently not economical due to high cost and problems matching release rates to crop needs.
   h. foliar application: reduces amount of N used but may increase the number of applications needed.
   i. better overall management: improved calibration of equipment, more even distribution of fertilizer, and continual adjustment of application rates in response to in-field conditions.
2. Soil and Tissue Testing
   a. N indices of the soil: currently lack consistency in our determinations of percent of N released.
   b. testing for residual nitrate at the start of growing season: sampling so far is difficult and results are variable. In theory, nitrate in profile at planting is same as fertilizer N.
   c. tissue testing: usually too late for current crop but can serve as a general diagnostic guide to modify fertilizer rate recommendations.
3. Crop Waste and Residue Management
   a. manures: better land application management is needed since manure is often regarded as a waste rather than a nutrient resource. Nutrient concentrations tend to be variable.
   b. alfalfa, other legumes: research indicates that nitrogen credit is important. Plowing down an excellent stand of alfalfa would

supply enough N for a corn crop the next year and for a partial crop the subsequent year.

c. cropping sequence: legumes in rotation.
d. conservation tillage: a high amount of crop residue (specifically, carbonaceous residue) on the soil surface affects the N cycle by increasing immobilization. Soil injection of N can be used.
e. municipal sewage sludge: although a good source of slowly available N, loss of nitrate by leaching may occur when N is released from waste during time when crop needs are low. State regulations govern loading rate based on N and heavy metals content.
f. winter cover crops: theoretically can capture excess N after harvest but fall season must be long enough to allow crop to grow.
g. interseeding with legumes: a possibility but legumes tend to start late and grow poorly in shaded rows. Weed control is difficult.
h. deep rooted crops to retrieve N: alfalfa is a good example.
i. alternative agriculture: involves increased use of rotations and organic wastes. So far, the environmental benefits do not offset the economic disadvantages of the system (Crosson and Ostrov 1988).

4. Limitations on Fertilizer Use
   Although a possibility through state legislation, the N mass balance cannot be predicted with sufficient accuracy to justify limitations set by rules.
5. Improved Recommendations
   The technology exists to improve N fertilizer recommendations using computer-assisted modeling and in-field fine tuning of application rates.

Pesticide Management

Best Management Practices involving pesticides revolve around the use of non-chemical practices such as crop rotation, resistant varieties, cultural practices, and biological control, and a more judicious use of chemical control measures by monitoring fields more closely. By far the most important approach is the adoption of an integrated pest management philosophy (Sorensen 1988).

Integrated Pest Management (IPM) looks at pest control from a broader perspective than just attempts at eradicating the pests that threaten the crop. It is the informed selection and use of pest control actions that will result in a good crop and an undamaged environment. In developing IPM programs, scientists introduced two key concepts into the farming community. First, they developed the idea of economic thresholds. Since plants evolved along with pests, they can tolerate a certain amount of damage. Pest populations only need to be controlled when the cost of that control is justified. That can be predetermined by knowing the kind of damage the pest does, how resilient the plants are, and how much the crop is worth. Thus, the farmers were now given some sort of threshold number that could trigger preventative measures: for example, 15 loopers per sweep net sample or 3 mites per leaf. And second, to make sure decisions were made in a timely manner and with up-to-date information, intensive monitoring of pest populations was encouraged. Suitable and rapid monitoring techniques were developed.

Slowly, the word "integrated" began to dominate the thinking in IPM. Researchers found that something as seemingly innocent as irrigating the crop or adding more fertilizer might make the plants look more inviting to certain insects (bad) while creating a fuller canopy, crowding out competing weeds (good). The focus of IPM kept expanding to keep pace with the knowledge base: from the goal of managing the pest to managing the crop and ultimately to managing the acroecosystem. And, along the way, the computer became an indispensable tool to help the researchers collect data, store it, process it, and refine predictions. Nowadays, computer programs can continually readjust economic thresholds to reflect the market price of the commodity. And farmers can get advice not only on when pests should be controlled and which techniques to utilize, but also on how many acres and which crops to plant.

Currently, IPM programs enable our farmers to incorporate all of the pest control techniques that are in our arsenal into an integrated program, choosing those techniques that are the least damaging to the environment. Unfortunately, IPM programs are not always available because they are site-specific and require an intensive research effort to develop. IPM is also hampered by misconceptions. It is not pest control without pesticides at one end of the spectrum nor is it pest control simply using better timing of pesticide applications on the other end. Permanent pest suppression can sometimes result through the successful establishment of predators and parasites, environmental modifications, changes in cultural practices, or in the development of resistant crop varieties. In all cases, chemical pesticides are used only when necessary and appropriate.

Best management techniques for pesticide use (CTIC 1988) include:

1. Use pesticides effectively by utilizing an integrated pesticide management (IPM) approach to pesticide use.
   a. Know key pests and the crop's economic threshold.
   b. Monitor fields so developing pest problems can be pinpointed.
   c. Before applying pesticides, make sure that infestation levels warrant chemical treatment. Pesticides should be applied only if they will increase profits, not just yields.
   d. Time applications carefully. Consider the life cycle of the pest and current weather conditions to maximize control.
   e. Consider crop rotation to eliminate persistent and recurring insects and weeds.
   f. Use pest resistant varieties of crops.
   g. Equip harvesters with weed seed killers to reduce inadvertent spread of weed seeds.
2. Use non-leaching pesticides when possible.
   a. Know pesticide characteristics that increase their leaching potential: high water solubility, low soil adsorption capability, and long persistence in the soil.
   b. Be familiar with EPA's list of pesticides which are leachers or potential leachers.
   c. Choose the pesticide with the lowest leaching potential when more than one chemical will do the job.
3. Know the on-site characteristics of each field and what properties promote pesticide leaching.
   a. Sandy soils are more likely to leach than soils high in clay or organic matter.
   b. Leaching is more rapid and deeper in coarse or light textured soils than in fine or heavy soils.
   c. Pesticides can be transported at higher volumes through porous soils. Macropores (worm tunnels) and shrinkage cracks may promote rapid leaching. Conversely, they may allow water to quickly bypass pesticides trapped in the organic layer.
   d. Areas with high rainfall or irrigation rates have large amounts of water passing through the soil and are more susceptible to leaching.
   e. Areas with shallow water tables and a permeable unsaturated zone above the ground water are highly susceptible to leaching.
4. Do not apply pesticides when environmental conditions are unfavorable.
   a. Avoid application when heavy rainfall is predicted.
   b. Do not irrigate in large quantities after application.
5. Use application technology to reduce leaching potential.
   a. Reduce the quantity of pesticides by optimizing spray drop size. Drops that are too large tend to run off plant surfaces. Drops that are too small are highly susceptible to drift.
   b. Reduce the quantity of applied pesticide by enhancing the "cling" of foliar applied chemicals to the plant surface. Adjuvants such as stickers and electrostatic sprayers that apply a charge to spray droplets can be utilized.
   c. Use anti-backsiphoning devices with chemigation to avoid direct well contamination.
6. Prevent pesticide accidents and spills.
   a. Establish buffer zones to protect points of possible direct ground water recharge (well, sinkholes, irrigation ditches) from pesticide contamination.
   b. Do not mix, handle, apply, or dispose of pesticides in the immediate vicinity of a well or a Karst sinkhole.
   c. Channel pesticide contaminated runoff away from sinkholes or plant buffer strips around them.
   d. Use proper pesticide storage facilities. They should have concrete floors, be well ventilated, posted clearly with signs, and locked.
   e. Calculate chemical needs as closely as possible.
   f. Dispose of pesticide containers safely.
   g. Use refillable bulk containers and closed system chemical transfer systems.

Farm Bureau's Approach to Ground Water Problems

The American Farm Bureau Federation has been actively involved in ground water issues for almost a decade. We have comprehensive policies on ground water quality and quantity, agricultural chemical usage, integrated pest management, and future agricultural research needs. These policies are drafted by our active farmer and rancher members during our policy development process. This process takes roughly eight months and is repeated on an annual basis to keep our policies relevant to current events.

On ground water quality problems, Farm Bureau has taken the lead among farm organizations with its Groundwater and Environmental Quality Self-Help Checklist for Farmsteads and Farm Fields. The "Checklist" is a fifteen page booklet of questions about pollution problems that can occur around farms. A year in development, the checklist was particularly designed to be used in group meetings where twenty minutes are set aside for everyone to fill in their answers to the questions. The checklist analyzes on-farm water supplies and directs the farmer's attention to potential problems. It provides suggestions on best management techniques, proper storage and handling of agricultural chemicals, safe disposal and application of chemicals, and advice on water testing. It also provides a form that can be filled out on an annual basis to keep track of water quality on the farm.

The Checklist is currently being used by 34 of our state Farm Bureaus and 9 more plan to use it soon. Montana, North Dakota, and Rhode Island have mailed a copy to every farmer member. Delaware and Ohio plan to do the same. Other state Farm Bureaus are using the Checklist in cooperation with their state health departments, Soil Conservation Service or Cooperative Extension Service. The USDA is considering mailing out Checklists to every Cooperative Extension agent, Farmers Home Administration (FmHA) office, Agricultural Stabilization and Conservation Service (ASCS) office, and Soil Conservation Service office in the U.S. Our ultimate goal is to get a checklist into the hands of every farmer in the country.

With regard to integrated pest management (IPM), we are encouraging the widespread use of IPM among our members. We are also aggressively promoting use of IPM through member education and legislative initiatives. So far, six states have passed some form of IPM legislation. Rhode Island taxes agricultural chemicals to collect funds for IPM research. California can permit use of restricted pesticides with approved IPM programs. Wisconsin can prescribe IPM tactics to protect vulnerable aquifers. Vermont has expanded the efforts of its Cooperative Extension Service in IPM. Iowa has set up demonstration farms and field studies which utilize IPM techniques. Connecticut has set aside funds for IPM research. Two more states are trying to pass legislation to encourage the use of IPM: Massachusetts and New York.

On the federal level, we are hopeful that the promotion of IPM programs will be incorporated into the new version of FIFRA, the 1990 Farm Bill, into any federal pesticide or ground water legislation, into agricultural research bills and perhaps as separate legislation.

Farm Bureau is also supporting the use of biotechnology to help solve environmental concerns. Although not a magic bullet, some of these new technologies can potentially help researchers develop disease resistant plants, plants with nitrogen-fixing capabilities, herbicide-resistant plants (focusing on environmentally safe herbicides), plants with weed-suppressing capabilities, insect resistant plants, animal vaccines for insect-borne diseases, and enhanced microbial control agents to control insect pests, weeds, and plant pathogens. All of these possibilities will decrease our dependency on agricultural chemicals. In addition, the new technologies can engineer microbes to degrade some of our more environmentally persistent chemicals.

CONCLUSION

Our country is dependent on ground water and we are rapidly developing an understanding of the importance of protecting it. What this means to agriculture is that ground water quality issues will dictate the ways our farmers can farm in the future. Right now we are in a transition period. We are trying to modify our chemically intensive agriculture while minimizing the economic impact on our farmers. With the right combination of research and education, we may be able to pull it off (AFBF Farm Income Study 1987). If not, our farmers, and ultimately, our consumers and the environment will suffer.

ACKNOWLEDGEMENTS

I would like to thank my colleague, Jim Porterfield, for reviewing this manuscript, supplying me with useful information during its preparation, and applying his considerable knowledge of computer-generated graphics to create slides for use in my presentation.

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