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# An Assessment of Water Sources Related to Major Systems of Agricultural Land Use in Kentucky

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## An Assessment of Water Sources Related to Major Systems of Agricultural Land Use in Kentucky

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Recent years have seen a greater public concern about the quality of the nation's water resources. While initial concerns targeted point source pollution, the emphasis in recent years has shifted to non-point source pollution, including the effect of general practices used by farmers in agricultural production systems. Since there was no reliable data base on such effects for Kentucky, the state's General Assembly passed legislation during its 1990 session directing the University of Kentucky's College of Agriculture (UKCA) to assess the effect of agricultural practices on quality of the state's waters. As part of the efforts undertaken by the UKCA in this regard, an assessment was made of water sources in major agricultural areas to determine the current level of water quality associated with agricultural practices in those areas. This information was needed to evaluate the question of concern: "**Do non-point agricultural practices such as fertilizer and herbicide use and grazing of pastures by livestock pose a threat to the quality of water potentially serving as human drinking water sources?**"

## Agricultural Patterns in Kentucky

Kentucky is an agriculturally diverse state of about 25 million acres. Nearly half this acreage remains in forest cover of some sort, with the greatest proportions being in the eastern third of the state. Although row crop and animal agricultural systems can be locally important in those areas, they constitute only a small percentage of the total land area. Proportion of land used for agriculture varies across the rest of the state, with the most intense row crop acreage being concentrated in the southern and western third of the state. Cattle are more highly concentrated in the central part of the state where hay and pasture acreage is much greater than row crop acreage. Although beef cattle production, mostly cow-calf, is by far the largest animal production system, dairies are important in some regional areas, and hogs are an important enterprise in some areas where corn is important. The poultry industry has expanded significantly in a few areas with all indications of further expansion in the future.

Water quality concerns in agriculture are largely associated with nitrogen (N) fertilizer use, agricultural chemical use, and animal manure. It is important to define their use and presence in Kentucky's agricultural systems. Nitrogen occurs naturally in all soils, largely in organic form that is replenished each year from recycling and decomposition of vegetative residues. With tillage of soil, some of this organic N is released each year, the amount depending on the nature of the fields being tilled. Nitrogen also enters the soil environment from wild and domestic animal manure, septic systems, N fixation by legumes, and precipitation. Nitrogen fertilizer use is concentrated on tobacco, corn, and small grain production, although smaller amounts are sometimes used on grasslands to increase the production of hay and pastures.

Although tobacco is often fertilized annually at the rate of 300 lbs/A, very little of Kentucky's landscape is being used for the crop. In any given year only about 200,000 acres are grown. Even in the large tobacco producing counties of central Kentucky, there is usually no more than 4% of the landscape used for tobacco, and in most tobacco producing counties it is less than 2%.

Most of the fertilizer N used in Kentucky is on the approximately 1.3 million acres used for corn production, and most of the corn grown in Kentucky is west of highway I-65, being most heavily concentrated in southern counties bordering Tennessee, counties along the Ohio River, and counties in the Purchase Area. In those counties, 10 to 30% of the landscape may be used for corn, and in Union County, the top corn producing county in the state, corn can occupy 30 to 40% of the landscape in any given year.

Kentucky's approximately one-half million acres of wheat are concentrated in the southern counties bordering Tennessee, and in the Purchase Area. Wheat acreage can occupy 5 to 20% of the landscape in these counties, and is grown in rotation with corn and soybeans for the most part. In this rotation, wheat is seeded after corn is harvested, and after wheat harvest the following June-July, the wheat fields are planted to soybeans.

No-tillage planting techniques are widely used, with over 90% of the double cropped soybeans grown in Kentucky being no-tilled in 1994. Nearly half the total corn acreage was no-tilled in 1994, and nearly a fourth of the wheat crop was no-tilled. The proportion of row crops being no-tilled is much higher in some counties. Hickman County, for example, no-tilled over 80% of its corn, wheat, and soybean acreage in 1994. This rotation, widely used in the intensive grain counties, is probably the most environmentally sound cropping system which can be used for effectiveness of soil erosion control and efficient use of fertilizer N.

Most of Kentucky's annual approximately 1.3 million acres of soybeans are also grown in the western third of the state, and as previously mentioned, are commonly grown in rotation with corn and wheat. Since soybean is a leguminous crop, it is capable of utilizing N directly from the air (approximately 78% of the air is made up of gaseous N), thus practically no fertilizer N is applied.

With respect to agricultural chemicals, of the total active ingredients contained in all the herbicides and other pesticides used in Kentucky, nearly 90% are in herbicides. And, herbicide use on just two crops, corn and soybeans, constitutes 85% of the total active ingredients in all agricultural pesticides used in the state. Although horticultural crops are locally important from the standpoint of fertilizer and agricultural chemical use, their production occupies only a very small fraction of the state's landscape.

Except for grain production in the southern counties bordering Tennessee, the Purchase Area, and counties bordering the Ohio River downstream from Owensboro, Kentucky, agriculture is of general nature, with beef and tobacco production generating half the state's agricultural income.

## Methodology Used For the Assessment Study

Since the nature of Kentucky's underlying geologic deposits directly affect the nature of soils which have developed, and since the nature of the soils developed directly affects the land use patterns which have developed, the decision was made to study dominant farming systems within physiographic regions of the state where agriculture is most important. Eight sites were selected for study: one in the Inner Bluegrass Area, two in the Outer Bluegrass Area, one in the Eastern Pennyroyal Area, one in the Western Pennyroyal Area (one additional spring from another similar site in the Western Pennyroyal Area was also included in the study), one in the Purchase Area, and two in the nearly level bottomlands of the Western Coalfields Area. The sites selected in the Western Coalfields

Area were fields with subsurface drainage tiles that represent the intensively row-cropped area of that region, while the sites at all other locations were small watersheds where there was no evidence of urban or suburban influence. University of Kentucky soil scientists and hydrogeologists examined each site to identify the nature of the underlying geologic deposits and soils and land use patterns, to ensure that they were representative of the physiographic area, and to locate water sources for sampling which appeared directly affected by the surrounding land use patterns. Individual water source sites were sampled monthly for 3 years, and land use patterns, N fertilizer use, and herbicide use were documented for each of the 3 years. Table 1 summarizes the nature of the 8 locations sampled. Samples were analyzed for nitrate-N, atrazine, alachlor, metolachlor, fecal coliform, and fecal streptococci content. Sources sampled included 29 springs, 12 wells, 14 streams, and 11 tile lines. More detailed hydrogeologic studies were conducted by UK's Institute For Mining and Minerals Research and the Kentucky Geologic Survey at 4 of the study sites, but their results are not presented in this report.

## Results From the Assessment Study

Data on numbers of samples above and below EPA's drinking water MCL levels for nitrate-N, atrazine, alachlor, and fecal bacteria are summarized across all 8 assessment locations in tables 2 and 3.

### *Nitrate-N Content of Samples*

Of the 865 total samples taken from 29 different springs, 15 percent exceeded the EPA's drinking water standard limit of 10 parts per million (ppm) nitrate N. Two springs may have been affected by point source pollution of N due to dumping tobacco stalks, and a dairy cattle loafing area. When they were removed from the calculations, 9% of the total number of samples exceeded 10 ppm.

Average nitrate N concentration for springs in the Inner and Outer Bluegrass regions was 6.2 ppm, with great variability among the springs. In these regions, relatively small proportions of the landscape are used for the fertilizer N requiring crops of tobacco, corn, and small grains as compared to the proportion used for pasture and hay production. In contrast, springs from the Pennyroyal, where acreages of corn and wheat are proportionally higher, averaged 5.7 ppm nitrate N. The one spring sampled in the Purchase Region, another area with large acreages of corn and wheat, averaged less than 1 ppm nitrate N.

There were 12 wells in the study, from which 404 samples were taken during the study period. Of these samples, 13% exceeded 10 ppm nitrate N. Two of the 5 deep wells sampled in the Purchase Area averaged just under 11 ppm nitrate N while the other three deep wells averaged about 4 ppm, nearly the same as the average of the 5 wells sampled in the Pennyroyal Region. The 3 wells sampled in the Bluegrass Region averaged just over 3 ppm.

There was little difference found in streamflow content of nitrate N among the regions, with the average of the 14 streams sampled ranging from 2 to just over 3 ppm. Of the 422 samples taken from the 14 streams, 2% exceeded 10 ppm.

Flow from tile lines, which represents water movement from the field surface to a depth of about 3 feet, is not used for drinking water purposes. Average nitrate N content of the 11 tile lines studied in two intensively cropped bottomland fields in the Western Coalfield Area was 6.7 ppm. One field where soils were more poorly drained than the other had very low levels because of higher rates of denitrification. For the 293 samples taken from the 11 tile lines, 34% exceeded 10 ppm while 28% contained less than 0.3 ppm.

It did not appear that row crop intensity had much of an effect on nitrate N content of the water samples taken during the 3-year assessment period. Also, no relationship was found between N fertilizer use in the study areas and nitrate N content of water samples taken during the 3-year assessment period. In fact, nitrate N content of springflow in one of the study areas was higher following soybean production than following corn production.

### *Herbicide Content of Samples*

While presence of the widely used corn herbicide, atrazine, could consistently be detected in springs, streams, and tile lines draining fields where it had been used, average content exceeded the EPA's drinking water standard of 3 parts per billion (ppb) in 3% of the 864 spring samples, 11% of the 422 stream samples, 3% of the 404 well samples, and 13% of the 293 tile samples. In study sites where atrazine use was substantial, it was commonly found at levels below 2 ppb, which increased to over 3 ppb for only a few weeks following application and then dropped back to lower, but detectable, levels for the remainder of each year. One of the two tiled fields has been used continuously for corn production for over 40 years, and has been treated with atrazine every year since it became commercially available in 1957. Fewer than 20% of the 121 total samples taken from 5 tile lines sampled over the 3-year sampling period from that field tested higher than 3 ppb atrazine.

Although some alachlor detections were made, most samples contained less than the 2 ppb sensitivity level of the immunoassay analytical technique used. Of the 864 spring samples tested, only 3% were in excess of 2 ppb. For streams, 8% of the 414 samples were above 2 ppb, and 5% of the 293 tile line samples tested over 2 ppb. Alachlor was not detected in any of the 399 well samples above 2 ppb.

Except for some tile samples, metolachlor was not detected in any other samples tested at levels significantly higher than zero.

### *Fecal Bacteria Content of Samples*

High average bacterial population for both fecal coliform and fecal streptococci was found in all streams. In the regions with springs, the averages were similar and smaller than for the streams. On the whole, wells were much cleaner except for the Blue Grass Region which showed a fairly high average. This was due to one shallow, hand dug well. Bacteria counts exceeded EPA's MCL level in nearly all samples we took, except those from some of the deeper wells.

## Summary

The agricultural use of fertilizer N and herbicides did not appear to cause increased levels in the water sources we tested during 3 years of continuous monthly sampling as compared to the initial levels measured when the assessment began. At some sites where elevated levels were noted, it was found that this was likely related to point source pollution rather than non-point source pollution.

Contents of agricultural chemicals in tile flow, which represented movement of water from the surface through only about 3 feet of soil, was much more related to surface application of herbicides and N than content of deeper groundwater. Even in this case, where heavy textured soil provided for high potential of denitrification, there was little nitrate-N found.

Deep wells, in general, contained low to moderate levels of nitrate-N and little, if any, herbicide. There was some variation in this, depending on the physiographic region. A few springs were consistently higher in nitrate-N than 10 ppm, probably due to point source contamination with tobacco stalks and animal manure.

The use of atrazine and alachlor resulted in levels higher than MCL's for a few weeks following application, in some of the water sources tested. The presence of atrazine pulses found in some water samples shortly after application indicates a rapid movement from the surface to shallow groundwater, whereas the lack of coincidental nitrate-N pulses following fertilizer N application suggests little movement of fertilizer nitrate-N into the groundwater levels.

All streams, as well as shallow groundwater associated with some springs, were contaminated with fecal coliform and fecal streptococci, resulting from both domestic livestock and from wild animals.

Extension Soils Specialist

**Table 1. Characteristics of assessment study sites**

| *Physiographic Area* | *Size (Ac)* | *Geology/Soils* | *% of Acres Used For:* Corn | Tobacco | Wheat | Soybean | Other | *Type Livestock* |
|---|---|---|---|---|---|---|---|---|
| Inner Bluegrass | 1,443 | Limestone-Shale; Karst; Soils Shallow to 4-8 ft thick over bedrock | 9 | 2 | 1 | 6 | 82 | Beef |
| Outer Bluegrass (1) | 360 | Limestone-Shale; Slightly Karst; Soils Shallow to 4-5 ft thick over bedrock | 4 | 1 | – | – | 95 | Dairy/Beef |
| Outer Bluegrass (2) | 460 | Limestone-Shale; Slightly Karst; Soils 2-6 ft thick over bedrock | 5 | 35 | (17) | 25 | 35 | Hogs/Dairy |
| Eastern Pennyroyal | 597 | Limestone-Siltstone-Shale-Sandstone; Soils Shallow to 6 ft thick over bedrock | 11 | <1 | – | – | 88 | Dairy |
| Western Pennyroyal | 1,154 | Limestone; Strongly Karst; Soils greater than 5 ft thick over bedrock | 50 | – | (34) | 34 | 16 | Hogs/Dairy |
| Western Coalfields (1) | 180 | Shale-Siltstone-Sandstone-Limestone; deep, poorly-drained soils formed in thick alluvial/lacustrine deposits | 17 | – | – | 83 | – | none |
| Western Coalfields (2) | 240 | Shale-Sandstone-Limestone; Deep, somewhat poorly drained soils formed in thick alluvial deposits | 78 | – | – | 22 | – | none |
| Purchase | 737 | Thick loess overlying coastal plains deposits; soil thicker than 5 ft formed in loess | 26 | – | (42) | 53 | 21 | hogs |

Av. of 3-years land use; other includes hay/pasture, forest, and farmsteads; Numbers shown in parentheses are acres which were double-cropped.

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**Table 2. Nitrate-N, Atrazine, and Alachlor content in water taken from 8 agricultural land use sites in Kentucky, 1991-1993.**

| | *$NO_3$-N* | | | *Atrazine* | | | *Alachlor* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Number of Samples* | | | | | | | | |
| *Water Source* | *Taken* | *Below MCL* | | *Taken* | *Below MCL* | | *Taken* | *Below MCL* | |
| Springs (29) | 865 | 740 | (85.5%) | 864 | 838 | (97.0%) | 845 | 820 | (97.0%) |
| Wells (12) | 404 | 351 | (87.0%) | 404 | 392 | (97.0%) | 399 | 399 | (100.0%) |
| Streams (14) | 422 | 414 | (98.0%) | 422 | 376 | (89.0%) | 414 | 381 | (92.0%) |
| Tiles (11) | 293 | 193 | (66.0%) | 293 | 255 | (87.0%) | 293 | 278 | (95.0%) |
| All (66) | 1,984 | 1,698 | (85.6%) | 1,983 | 1,861 | (94.0%) | 1,951 | 1,878 | (96.0%) |

EPA's MCL levels: $NO_3$-N = 10 ppm; atrazine = 3 ppb; alachlor = 2 ppb.

**Table 3. Fecal coliforms in water from 8 agricultural land use sites in Kentucky, 1991-1993**

| | |
|---|---|
| Springs | Nearly all samples exceeded MCL |
| Streams | Nearly all samples exceeded MCL |
| Wells | Nearly all samples from shallow wells exceeded MCL; most samples from deep wells were below MCL |
| Tiles | Nearly all samples exceeded MCL |

EPA's MCL level is less than 1 colony per 100 ml.