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Well-Water Quality Data from a Volunteer Sampling Program: Audubon County, Iowa

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This study presents the results of a countywide volunteer sampling of private well-water. Volunteers collected 231 well-water samples in Audubon County for nitrate-nitrogen (NO_3-N) and total coliform bacteria analyses during September 1988. Questionnaires were completed at all sites to document well construction, age and depth of well, well placement relative to septic system, barnyard/feedlots, location of chemical mixing/tank rinsing, and presence of abandoned wells.

The majority of the wells were large-diameter "seepage" wells; 67% were less than 40 feet (12 m) deep. Seventy-eight percent of the samples were positive for total coliform bacteria. Twenty-four percent of the samples were from wells using cisterns; 93% of these samples tested positive for total coliform bacteria. Twenty-six percent of the wells had NO_3-N concentrations greater than 10 mg/L. Mean NO_3-N concentrations and bacteria positives decreased with increasing well depth. There were no obvious widespread point source problems. The majority of wells were greater than 100 feet (30 m) from an active barnyard/feedlot and greater than 50 feet (15 m) from a septic system; 92% were greater than 50 feet (15 m) from chemical mixing locations. Wells closer to septic systems and feedlots actually showed lower proportions of high nitrate and bacteria positives than those farther away. Seventy-seven abandoned wells were reported; 68% were less than 40 feet (12 m) deep. The NO_3-N and total coliform bacteria results from this large number of observations across the entire county are similar to water-quality results from more detailed, smaller-scale watershed studies within the county.
INDEX DESCRIPTORS: Nitrate-Nitrogen, Total Coliform Bacteria, Audubon County, Water Quality.

A countywide sampling of well-water supplies in Audubon County (Figure 1) for NO_3-N and total coliform bacteria was conducted in September 1988, by personnel from the Audubon County Extension office, the Iowa Department of Natural Resources-Geological Survey Bureau, with the assistance of Exira and Aubudon High School Future Farmers of America (FFA) groups and adult volunteers in the county. The water sampling was done to increase awareness among county residents about the susceptibility of shallow wells to groundwater contamination and to emphasize the importance of periodically testing well-water quality. The sampling was done in coordination with the Integrated Farm Management Demonstration Project (IFMDP) operations in the county. The IFMDP is sponsored by the Iowa Department of Agriculture and Land Stewardship and supported by funds allocated through the 1987 Iowa Groundwater Protection Act.

Training sessions covering proper sampling procedures and the general well-inventory questionnaire used for each site were conducted at both Audubon and Exira High Schools, and at an evening session for adult volunteers on September 14, 1988. In total, 231 samples were collected on September 25, 1988, from sites throughout the county (Figure 2). This report provides a summary of the results.

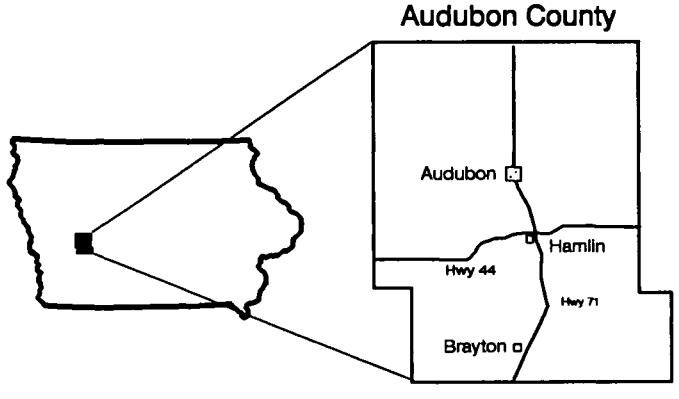

Fig. 1. Location of Audubon County, Iowa.

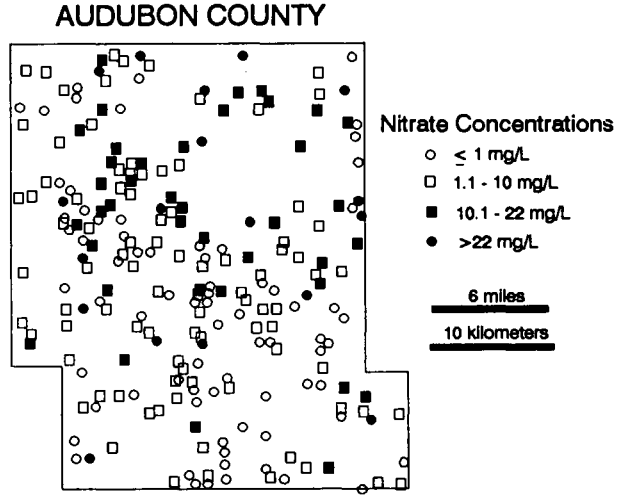

Fig. 2. Distribution of nitrate concentrations as NO_3-N in mg/L for Audubon County.

GEOLOGIC SETTING OF AUDUBON COUNTY

Audubon County is located in the Southern Iowa Drift Plain (Prior, 1991), an area characterized by an integrated stream network and rolling topography. Upland divides are underlain by 20 to 25 feet (6.0 to 7.5 m) of Wisconsinan Peoria Loess overlying a Yarmouth-Sangamon paleosol (buried soil) developed, in part, in the underlying pre-Illinoian till. The paleosol developed in the pre-Illinoian till represents a stratum of greatly reduced permeability compared to the overlying loess. Downward movement of groundwater or percolating soil water is limited at this horizon, and groundwater flow is predominantly lateral towards drainageways and streams. Drainageways are underlain by silty alluvial fills of Holocene age (Bettis and Littke, 1987; Bettis, 1990.) The till sequence beneath the upland loess and stream alluvium in Audubon County varies in thickness from 0 to 370 feet (0 to 113 m). Multiple tills occur within the sequence.

Bedrock in the area is Cretaceous Dakota Sandstone, an important aquifer used as a source of drinking water in portions of western Iowa. Well-log information for Audubon County indicates the Dakota Sandstone lies 35 to 300 feet (10 to 92 m) beneath the land surface, generally at depths >200 feet (60 m), and varies in thickness from 25 to 90 feet (7.5 to 27 m). In local areas southwest of the town of Brayton (south-central Audubon County, Figure 1), the till sequence is absent and loess directly overlies Dakota Sandstone. The depth to Dakota Sandstone, and its thickness in the subsurface in Audubon County, is variable. It is not typically used for domestic/farm wells because of the expense of drilling deep wells and because, if buried to any great depth, the natural water quality is generally poor (Hansen et al., 1992; Runkle, 1986; Munter et al., 1983; Burkart, 1982).

TYPICAL WELL CONSTRUCTION AND SETTING

Most of the rural population in Audubon County use shallow, large-diameter "seepage" wells, generally 20 to 40 feet (6 to 12 m) deep, and three feet (0.9 m) in diameter (Table 1). The wells are usually constructed of stacked concrete curbing with each section 2.5 to 3.0 feet (0.8 to 0.9 m) high; some older wells have brick curbing. The wells are generally open to the water table and allow seepage throughout their depth. Typically a submersible pump or suction pump at the well delivers water through piping to a pressure/storage tank in the well or at the house. From the pressure tank a water line distributes water to the house and to outdoor hydrants around the farm. These wells commonly are located in the middle of row-cropped fields, often 1/4 to 1/2 mile (0.4 to 0.8 km) from the houses they supply. The wells typically are far removed from home septic systems, manure storage, feedlots, and hydrants where pesticides are mixed. The wells are located in areas of groundwater discharge or where groundwater flow converges (in upland drainageways, in low areas on upland positions, or in alluvium along creeks and rivers); these settings maximize sustained seepage to the wells. The wells are typically bored to the loess/paleosol-till contact or alluvium/till contact. They are designed with a large perimeter to provide an increased area of seepage from the surrounding low-permeability sediments, and the large volume also provides a storage reservoir. "Seepage" wells are typical in this part of the state because the bedrock aquifers often are deeply buried and have relatively poor quality water (high total-dissolved solids, including sulfates). The shallow depth and location of these seepage wells make them inherently susceptible to contamination from modern land-surface activities.

PREVIOUS WATER-QUALITY DATA FROM AUDUBON COUNTY

Existing water-quality data from Audubon County show a high proportion of private water supplies positive for total coliform bacteria and with high NO_3-N concentrations. From 1980 to 1985, 331 total coliform samples and 269 NO_3-N samples from private wells in Audubon County were submitted to the University Hygienic Laboratory (UHL) in Iowa City. Annually, 45 to 69% of the samples tested positive for total coliform bacteria, and 28 to 50% exceeded the U.S. Environmental Protection Agency (U.S. EPA) health advisory level for NO_3-N (10 milligrams per liter [mg/L]). (This standard is enforceable only for municipal water supplies and is considered a health advisory level for private water supplies.)

The Iowa State-Wide Rural Well-Water Survey (Kross et al., 1990), which included 686 sites, showed similar results for bacteria and NO_3-N. The survey showed a significant incidence of high NO_3-N concentrations and samples positive for total coliform bacteria in areas in the state dominated by shallow, water-table wells (i.e., areas in western Iowa, including Audubon County). Seventy-eight percent of the wells <50 feet (15 m) deep in this area had total coliform bacteria present. Thirty percent of the wells <50 feet (15 m) deep reported NO_3-N concentrations >10 mg/L. Approximately 53% of the wells sampled in western Iowa were less than 50 feet (15 m) deep.

Table 1. Depth distribution and type of wells sampled in Audubon County.

Well depth ranges (feet)	Type of well: Number of seepage wells (%)	Number of drilled wells (%)	Not indicated (%)	Total number of wells (%)
0-19	6 (3%)	6 (3%)	4 (2%)	16 (7%)
20-39	72 (31%)	31 (13%)	36 (16%)	139 (60%)
40-99	19 (8%)	15 (6%)	5 (2%)	39 (17%)
100-200	0 (0%)	2 (1%)	2 (1%)	4 (2%)
>200	0 (0%)	4 (2%)	1 (0.5%)	5 (2%)
Unknown	13 (6%)	2 (1%)	13 (6%)	28 (12%)
Total	110 (48%)	60 (26%)	61 (26%)	231 (100%)

Monthly sampling since 1987 of four private wells (all < 50 feet [15 m] deep) in Bluegrass Watershed, a 1,024 acre (415 hectare) watershed in north-central Audubon County has shown similar results; coliform bacteria were detected in 90% of the samples and mean annual NO_3-N concentrations varied from 8.4 mg/L to 10.7 mg/L (Seigley and Hallberg, 1991).

WATER QUALITY ANALYSES AND SAMPLING PROCEDURES

Water-quality samples for this project were analyzed by the University Hygienic Laboratory (UHL) in Iowa City, an EPA certified laboratory. Total coliform bacteria was determined using the Most Probable Number (MPN) method and reported as safe (for zero coliforms) or unsafe (if coliforms were present). The bacteria data were reported as the statistical MPN of total coliform individuals per 100 milliliters of water (APHA, 1985). MPN categories include 0, 2.2, 5.1, 9.2, 16, and 16+. NO_3-N results are in milligrams/liter (mg/L); one mg/L is equal to one part per million (ppm). Nitrate was analyzed by cadmium reduction, using a Technicon auto-analyzer system, and included nitrate (NO_3) plus nitrite (NO_2) (U.S. Method 353.2; USEPA, 1983). Analyses below the quantitation limit for NO_3-N analysis were reported as <0.2 mg/L. For statistical calculations, values below the quantitation limit were given a value of 0.1 mg/L. As noted, all volunteers involved in the water-quality sampling were instructed in proper sampling procedures and directed to flame all hydrants/taps before collecting the sample and to avoid contaminating the bottle. Samples were taken at the kitchen tap and in other instances from an outside hydrant. Indoor taps were run for two to three minutes before sampling and outdoor hydrants for five minutes. A short questionnaire was completed for each well to provide information on well depth, well placement, type of well, location of well with respect to mixing of chemicals and rinsing of tanks, presence of abandoned wells, and treatment systems used for drinking water.

RESULTS

Well Depth and Well Type

Table 1 lists well depth ranges and the number (and %) and type of wells in each depth category. Sixty-seven percent of the wells were less than 40 feet (12 m) deep and 84% were less than 100 feet (30 m) deep. The wells that were 100 feet (30 m) or deeper were primarily in the southern part of the county where bedrock (Dakota Sandstone) is relatively shallow. At least 48% of the wells sampled were seepage wells (Table 1). The percentage was probably higher since 26% of the well site questionnaires had no response for well type.

Total Coliform Bacteria

Seventy-eight percent of the samples were positive for total coliform bacteria. Only an MPN of 0 is considered a "safe" level of total coliform bacteria. Coliform bacteria are not a health hazard, but their presence suggests that disease-causing organisms may be able to enter the drinking-water supply. Total coliform positives imply that shallow groundwater or surface water has entered the well. Coliforms are common constituents of soils and shallow groundwater and are present in surface water. Other studies have shown that water from wells completed at or near the water table generally are positive for coliform bacteria (Thompson, 1984; Kross et al., 1990).

Cisterns are commonly associated with positive total coliform bacteria counts (Hallberg et al., 1983). According to the well questionnaires, 24% of the samples were from wells using cisterns for water storage (Table 2). Of the samples from wells associated with cisterns, 93% of the samples tested positive for total coliform bacteria, while only 71% of those without cisterns were positive. There was little difference in nitrate.

Table 2. Total coliform bacteria (TCB) and nitrate-N of wells associated with an active cistern.

Category	Number of responses	% positive for TCB	%>10 mg/L nitrate-N
Does have active outside cistern	55 (24%)	93%	29%
Does not have active outside cistern	157 (68%)	71%	24%
No response to either of above	19 (8%)	84%	32%

NO_3-N Results

Table 3 summarizes NO_3-N concentrations for the wells tested. Twenty-six percent of the wells had NO_3-N concentrations greater than 10 mg/L. (Water containing greater than 10 mg/L of NO_3-N should not be given to infants less than six months of age; consumption of water containing elevated NO_3-N concentrations may cause a temporary blood disorder that reduces the ability of an infant's bloodstream to carry oxygen through the body). Figure 2 illustrates the distribution of wells sampled in the county and the NO_3-N concentrations for those wells. NO_3-N concentrations appear to be lower in the southern half of Audubon County. This is related to the deeper wells (≥ 100 feet [30 m]) encountered in the southern part of the county. The Dakota aquifer is more shallow in this region and generally provides good quality water. Hence, more wells are drilled to depth into this bedrock aquifer.

Table 3. Nitrate-N concentrations for wells sampled in Audubon County.

Nitrate-N (mg/L)	Number (%)
<1.1	77 (33%)
1.1-10.0	93 (40%)
10.1-22.0	43 (19%)
22.1-55.0	17 (7%)
>55.0	1 (0.4%)

Table 4 compares the percent of samples positive for total coliform bacteria, percent of wells greater than 10 mg/L NO_3-N, and the mean NO_3-N for the various well depth ranges. The overall mean NO_3-N and percent of samples positive for total coliform bacteria or >10 mg/L for NO_3-N decrease with increasing well depth range for all well types. This trend has also been noted in many other studies (Hallberg and Hoyer, 1982; Detroy et al., 1988; Kross et al., 1990; Thompson, 1990). Only the well depth category 0-19 feet (0-6 m) had an overall mean NO_3-N concentration above the drinking water standard of 10 mg/L. With each increasing well depth range, a smaller percentage of samples were reported as unsafe for NO_3-N or total coliform bacteria. Over half (56%) of the wells less than 20 feet (6.1 m) deep had NO_3-N concentrations >10 mg/L and 94% were unsafe for total coliform bacteria. There was no significant difference for drilled wells versus seepage wells, when analyzed by depth category.

Summary of Well Questionnaire

The well questionnaire completed at each site included questions about the distance of the well from feedlots, septic systems, and abandoned wells to analyze associations with possible sources of NO_3-N and bacteria. Table 5 indicates that more than 80% of the wells were greater than 100 feet (30 m) from an active barnyard/feedlot and greater than 50 feet (15 m) from a septic system. Only a small percentage (5%) of the wells were less than these suggested minimum lateral distances from feedlots and septic systems (Chapter 49.52, Iowa Administrative Code, 1986). We did not attempt to have volunteers judge whether or not the wells were located directly downgradient from the feedlot or septic system. Wells less than 100 feet (30 m) from an active barnyard/feedlot and less than 50 feet (15 m) from a septic system actually had a lower percent of wells unsafe for total coliform bacteria or NO_3-N than wells located greater than 100 feet (30 m) from a barnyard/feedlot and greater than 50 feet (15 m) from a septic system (Table 5). This trend is probably not significant because the direction of gradient from the well to the feedlot or septic system was not indicated, and because of the small sample size of wells less than 100 feet (30 m) from a feedlot or less than 50 feet (15 m) from a septic system. It does suggest that there is no obvious dominance of such factors influencing water quality.

Table 5. Water quality (nitrate-N) and total coliform bacteria (TCB) of wells based on distance of the well from barnyard/feedlot and septic system.

	Number of responses (%)	% positive for TCB	% >10 mg/L nitrate-N
Well <100 feet from feedlot and <50 feet from septic system	10 (5%)	60%	0%
Well >100 feet from feedlot and >50 feet from septic system	175 (83%)	78%	27%
Well <100 feet from feedlot and >50 feet from septic system	21 (10%)	76%	29%
Well >100 feet from feedlot and <50 feet from septic system	5 (2%)	80%	20%

A 1987 survey conducted in six of the twelve townships in Audubon County by Iowa State University Extension reported 195 abandoned wells located on 37% of the farms surveyed (Padgitt, 1988). The responses to our well sampling reported a total of 77 abandoned wells from 26% of the included sites (Table 6). Most abandoned wells were of

Table 4. Percent of samples positive for total coliform bacteria (TCB) and percent of wells >10 mg/L for nitrate-N for the various well depth ranges.

Well depth (feet)	Type of well	% positive for TCB	%>10 mg/L nitrate-N	Mean nitrate-N (mg/L)
0-19	Drilled	100%	67%	16.7
	Seepage	100%	50%	10.7
	Not indicated	75%	50%	11.4
	Total	94%	56%	13.2
20-39	Drilled	73%	26%	8.7
	Seepage	83%	32%	8.9
	Not indicated	86%	17%	5.0
	Total	82%	27%	7.9
40-99	Drilled	53%	13%	3.4
	Seepage	74%	16%	5.8
	Not indicated	80%	0%	1.2
	Total	67%	13%	4.5
100-200	Drilled	100%	0%	<0.2
	Not indicated	0%	0%	<0.2
	Total	50%	0%	<0.2
>200	Drilled	25%	0%	<0.2
	Not indicated	0%	0%	<0.2
	Total	20%	0%	<0.2
Unknown	Drilled	50%	50%	13.7
	Seepage	92%	38%	7.1
	Not indicated	62%	31%	5.6
	Total	75%	36%	6.9

Table 6. Depth of abandoned wells and distance of abandoned wells from active wells and corresponding total coliform bacteria (TCB) and nitrate-N of active wells.

Well depth range of abandoned wells (feet)	Number of abandoned wells (%)	% positive for TCB	%>10 mg/L nitrate-N
0-19	5 (6%)	100%	0%
20-39	48 (62%)	79%	42%
40-99	5 (6%)	100%	40%
>99	1 (1%)	100%	0%
Well depth unknown	18 (23%)	72%	39%
Total	77	84%	38%
Distance of active well to abandoned well (feet)			
0-49	9 (12%)	100%	44%
50-99	5 (6%)	80%	60%
100-499	22 (29%)	86%	36%
500-1000	24 (31%)	71%	25%
>1000	13 (17%)	65%	41%
Distance not indicated	4 (5%)	75%	25%
Total	77	84%	38%

Table 7. Location of chemical mixing relative to well and corresponding water quality of well.

Location of chemical mixing relative to well (feet)	Number of responses (%)	% positive for TCB	%>10 mg/L nitrate-N
0-19	5 (2%)	40%	20%
20-49	1 (0.4%)	100%	100%
>49	98 (42%)	88%	34%
>49 & mix in a field	56 (24%)	77%	23%
>49 & mix at other location	58 (24%)	79%	34%
No response	13 (6%)	64%	18%

similar depth to the operating wells; 68% of the abandoned wells were less than 40 feet (12 m) deep and 23% were of unknown depth. Many of the seepage wells are developed in loess and till, which are considered aquitards by most definitions, because they are relatively fine-textured and slowly permeable. Wells in such materials tend to plug up over time and become unusable. Also, during drought years many original shallow wells went dry. A new seepage well was bored, somewhat deeper, and in a better setting to promote seepage (upland drainageways or in alluvium along the small creeks). Table 6 lists the depth of abandoned wells and distance of abandoned wells from active wells and corresponding water quality of active wells. No apparent trend between well depth of the abandoned well and the percent positive for total coliform bacteria or percent unsafe for NO_3-N for the corresponding active well was detected. Of the abandoned wells, 18% were less than 100 feet (30 m) from the active well (Table 6), but the majority were more distant.

Table 7 summarizes the location of chemical handling with respect to the operating well. Ninety-two percent of those questioned mix farm chemicals 50 feet (15 m) or more from their active well. As noted, these wells are often not in convenient locations for chemical mixing or other activities. Many seepage wells do not even have a hydrant at the well head. In ongoing watershed monitoring in the county, the distance to hydrants where chemicals are mixed or rinsed averages nearly 1/4 mile from the water-supply well.

Water Treatment Systems and Previous Water Quality Testing

Table 8 provides information on home water-treatment systems. Seventy-five percent of those questioned use no treatment system. The most commonly used treatment systems are a water softener (11%), a carbon/charcoal or iron filter (6%), reverse osmosis unit (5%), distillation (1%), or chlorination (1%). In most cases, it was not indicated whether the sample was taken before or after water treatment so little analysis is possible.

Almost half of the participants (48%) had tested their water previously. Of those who had, 59% recalled safe NO_3-N concentrations and 49% reported safe bacteria levels.

SUMMARY

A countywide volunteer sampling of private well-water supplies for NO_3-N and total coliform bacteria was conducted in Audubon County in September 1988. The majority of the rural population in Audubon County relies on shallow, large-diameter seepage wells. Sixty-seven percent of the wells were less than 40 feet (12 m) deep; 84% less than 100 feet (30 m) deep. Seventy-eight percent of the well-water samples were positive for total coliform bacteria; 26% had NO_3-N concentrations greater than 10 mg/L. The percentages of samples unsafe for total coliform bacteria and NO_3-N are similar to previous water quality data for this area. NO_3-N concentrations and the proportion of samples positive for total coliforms decrease with increasing well depth.

The well-inventory questionnaires provide a large number of observations for the county which supplement more detailed, smaller-scale studies of water quality in the region (Seigley and Hallberg, 1991). The questionnaires from the sites suggested no obvious, widespread point-source problems. Seepage wells are typically distant from chemical mixing areas, septic systems and barnyard/feedlots which could contribute to groundwater contamination problems at a well head. Yet the seepage wells are prone to contamination because of their shallow depths, because they are typically open to the water table, and typically are situated in the midst of row-cropped fields.

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Table 8. Water treatment systems, total coliform bacteria (TCB) and mean nitrate-N concentrations.

Type of water treatment system	Number of wells	Mean TCB (MPN)	Mean nitrate-N (mg/L)
Softener	26 (11%)	5.1	5.5
Filter (carbon/iron)	14 (6%)	2.2	1.7
Reverse osmosis	11 (5%)	2.2	5.0
Distillation	3 (1%)	9.2	5.2
Chlorination	3 (1%)	2.2	2.0
No treatment	174 (75%)	16	8.0

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