OCCURRENCE OF NITRATE IN WELL WATERS

Principal Investigator
T. E. Larson

Project Director
Laurel Henley

Illinois State Water Survey

Final Report
Project 65-05G
University of Illinois Water Resources Center

Supported by
Office of Water Resources Research
U. S. Department of Interior
June 1966

INTRODUCTION

In recent years, considerable interest has been expressed in the nitrate content of water supplies. Much of this interest is due to recent articles published in scientific journals, magazines, and newspapers concerning the hazards of excessive nitrate to both humans and livestock. Even though it has not been shown that chemical fertilizers are responsible for high nitrate in waters, the increased use of such fertilizers has been a factor in stimulating this interest.

It was the purpose of this project to study the occurrence of nitrate in well waters in Illinois by relating nitrate occurrence to well depth, to the source of the water, to the physiographic divisions of the state, and to the geographical location of the well. Selected locations within the state containing high nitrate concentrations were correlated with geologic information on soils and subsoils.

The State Water Survey has been making chemical analyses of water in Illinois since 1895. The results of these analyses are on IBM punch cards, and about 9000 analyses contain determinations for nitrate. This is the source of most of the data used in this study.

In all references to nitrate concentration in this study, the nitrate is expressed in mg/l as NO_3.

ANALYSIS AND RESULTS

An IBM printout was prepared from the punch-card files showing ground-water analyses in which nitrate was determined, along with the well location, the depth, the probable source of water (drift, limestone, sandstone), and other available pertinent information. These analyses were first grouped by well depth (0-25, 26-50, 51-100, 101-200, and over 200 feet), and the analyses within each of these groups were then ranked in order of decreasing nitrate content. These data were plotted on logarithmic-probability coordinates to permit an evaluation of the relation between well depth and nitrate occurrence throughout the state.

Table 1 shows that 87 percent of the samples from wells of 0 to 25 feet in depth contained a nitrate content of 1 mg/l or more; 56 percent contained 10 mg/l or more; 28 percent contained 45 mg/l or more; and 13 percent contained more than 100 mg/l. The results clearly show a decrease in the nitrate content as the depth increases, indicating that the shallow wells are more likely to contain excessive nitrate concentrations than the deeper wells.

The analyses were then segregated according to well-depth range and nitrate content (6-10, 11-40, 41-100, and over 100 mg/l). By the use of assigned symbols for each range of nitrate concentration, the locations of the wells were plotted on overlay maps of the state, one for each of the selected

depth ranges. These overlay maps readily provided information regarding the geographic location of the samples with unusual concentrations of nitrate.

These maps indicated that high nitrate concentrations (41 mg/l and over) were fairly well scattered throughout the state, with the exception of three areas. Two of the three areas of somewhat greater density, the Troy Grove area in LaSalle County and the Ancona area in Livingston and LaSalle Counties, were areas of rather extensive local sampling. Almost every available well in these two areas had been sampled. In the third area, the southern half of Whiteside County, many shallow sandpoint wells of 30-foot depth or less are in use.

Since this original IBM printout contained more than one analysis for some of the wells, at this point all analyses except one for each well were removed from the study. Each analysis selected to be retained was considered a representative sample of the ground water for that well.

All of the retained analyses (about 7000) were then segregated by well depth (0-50, 51-200, and over 200 feet) within each area of exposed glaciation (figure 1), and ranked in order of decreasing nitrate content. The data were again plotted on logarithmic-probability coordinates, and results are shown in table 2.

It is interesting to note that the frequency of occurrence of higher nitrate content is greater in the Illinoian glaciated area which was not covered by the later Wisconsinan glaciation.

The analyses were then further segregated by well depth within each phsiographic division of the state, ranked in order of decreasing nitrate content, and again plotted on logarithmic-probability coordinates to evaluate the relation between well depth and nitrate content within each phsiographic region. The results are shown in table 3. Figure 2 shows the physiographic regions (M.M. Leighton, George E. Ekblaw, and Leland Horberg, "Physio etc.," Illinois State Geological Survey, Report of Investigation 129, 1948).

The results show that the Mt. Vernon Hill Country which coincides with the southern portion of the Illinoian drift sheet has the highest percentage of analyses of 45 mg/l and over in wells of 0 to 50 and 51 to 200 feet in depth. The Shawnee Hills Section has the highest percentage of the 45 mg/l concentrations in the wells of over 200 feet in depth.

To study the relation between nitrate content and source of water (drift, limestone, and sandstone), the analyses were then segregated by source within each glaciated area and also in each physiographic region, ranked in order of decreasing nitrate content, and plotted on logarithmic-probability coordinates. The results are shown in tables 4 and 5.

Waters from all three sources are shown to contain higher nitrate contents at all concentrations in the undisturbed Illinoian glaciated area than in the Wisconsinan glacial area. The Mt. Vernon Hills physiographic region is noted to contain the highest percentage of drift and sandstone wells with nitrate contents of 45 mg/l and over.

LOCAL AREA STUDIES

At several places in Illinois, every available well within a localized region has been sampled. Two of these regions were selected for a comparison of nitrate concentrations with soils in the area.

In one area of Livingston County, 46 wells within 12 to 13 square miles were sampled. Twenty-six of these samples showed nitrate concentrations greater than 15 mg/l, and in 23 of these the nitrate was greater than 45 mg/l.

In another area of about 25 to 30 square miles in Iroquois County, only 3 of 201 samples showed nitrate concentrations greater than 15 mg/l. Two of the three samples showed nitrate greater than 45 mg/l.

County soil maps* of the University of Illinois Agricultural Experiment Station show the top soil in both areas to be largely brown silt loam. The soils are quite similar, and are reported to have a nitrogen content of 5000 to 6000 pounds per acre per 2,000,000 pounds of soil in the top 6 inches or so. The organic content ranges from 55,000 to 65,000 pounds per acre per 2,000,000 pounds of soil.

The big difference between the two areas was in the depths of the wells. In the Iroquois County area where the nitrate content was low, three wells were less than 25 feet in depth with nitrate concentrations ranging from 0.3 to 62.5 mg/l, and 21 wells were 26 to 99 feet in depth with nitrate ranging from 0 to 11.1 mg/l. The remaining wells were 100 feet or more in depth, but largely less than 200 feet, and the nitrate was less than

*Soil Reports 22 and 72

10 mg/l and usually less than 5 mg/l, except for one. A well with a depth of 189 feet had a nitrate content of 46.8 mg/l. It is possible that this well had a leaking casing or an improper well pit.

In the Livingston County area, 9 wells were less than 26 feet in depth with nitrate ranging from 1.6 to 438 mg/l; 26 wells were from 26 to 99 feet in depth with nitrate from 1.3 to 660 mg/l; and 7 wells were over 100 feet in depth with nitrate ranging from 1.3 to 193 mg/l. In this area, 13 of the samples showed more than 100 mg/l nitrate, 8 more than 200 mg/l, 5 more than 300 mg/l, 3 more than 400 mg/l and 1 over 600 mg/l.

This suggests that the problem in the Livingston County area may be either a top-soil or top-of-the-well problem. Either nitrate is being leached from the top soil, or unsanitary conditions exist in the vicinity of the well.

FIELD STUDY

Field trips were made to two villages in Logan County that had a history of high nitrate in municipal wells. Samples collected at one of the villages showed a nitrate content of 40.9 mg/l in a 96-foot well, and 37.7 mg/l in a 105-foot well. Previous analyses had shown even higher nitrate contents (as much as 123 mg/l in the 96-foot well). The dissolved oxygen content of the water was found to be 2.4 mg/l from the 96-foot well and 7.2 mg/l from the 105-foot well. Because

dissolved oxygen is normally absent in ground-water samples, this is an abnormal condition. The construction of the 105-foot well was of gravel-pack design. Because of the high dissolved oxygen content and nitrate content of the water being pumped from this well, it is assumed that much of the water originates from a shallow sand and gravel formation and is flowing to the screen through the gravel pack. Well construction data were not available for the 94-foot well, but the same condition may exist.

Samples collected from a 104-foot well in the other village showed a nitrate content of 24.7 mg/l and a dissolved oxygen content of 3.6 mg/l. It was also a gravel-pack well, so it is likely that the water being pumped from that well was entering from the upper formation.

CONCLUSIONS

The study has shown that excessive concentrations of nitrate are more likely to be found in shallow wells (50-foot depth or less) than in deeper wells. Twenty-three percent of the samples taken from shallow wells contained 45 mg/l or more of nitrate.

Excessive concentrations of nitrate are more likely to be found in drift wells than in limestone or sandstone wells.

High nitrate concentrations were fairly well scattered throughout the state except for three areas.

Well construction is an important factor in the nitrate content of well waters. Any construction that allows surface

water or water from a shallow depth to enter the well is more likely to contain excessive nitrate concentrations.

Because only a limited number of personnel were available for this study, no attempt was made to correlate nitrate concentration with various soil types and with proximity to common sources of nitrate in farm wells such as barnyards, feedlots, manure piles, and septic tank fields.

Table 1. Well Depth Versus Nitrate Content

(Percent of the analyses with nitrate equal to or greater than the concentration shown)

Number of analyses	Depth of wells (ft.)	Concentration (mg/l as NO_3)			
		1	10	45	100
480	0-25	87	56	28	13
926	26-50	80	40	20	10
1568	51-100	64	18	5.0	1.8
2042	101-200	61	11	3.0	0.7
3828	over 200	55	5.0	0.6	0.1

Table 2. Well Depth Versus Nitrate Content in Glaciated Areas

(Percent of the analyses with nitrate equal to or greater than the concentration shown)

Area	0-50 ft in depth					51-200 ft in depth					Over 200 ft in depth				
	No. of Anal.	Conc. mg/l as NO_3				No. of Anal.	Conc. mg/l as NO_3				No. of Anal.	Conc. mg/l as NO_3			
		1	10	45	100		1	10	45	100		1	10	45	100
Wisconsinan Glacial	585	80	44	18	8.7	2052	62	11	2.1	0.7	2139	55	4.5	0.5	0.1
Illinoian Glacial	617	84	48	27	16	752	66	23	9.0	3.2	411	55	6.8	1.3	0.6
All other areas	77	100	57	21	8.0	108	78	24	8.0	1.0	87	67	8.2	1.8	0
Entire state	1279	84	47	23	12	2912	65	15	4.1	1.3	2637	57	5.0	0.6	0.1

Table 3. Well Depth Versus Nitrate Content in Physiographic Areas

(Percent of the analyses with nitrate equal to or greater than the concentration shown)

Physiographic division	0-50 ft in depth					51-200 ft in depth					Over 200 ft in depth				
	No. of Anal.	Conc. mg/l as NO_3 1	10	45	100	No. of Anal.	Conc. mg/l as NO_3 1	10	45	100	No. of Anal.	Conc. mg/l as NO_3 1	10	45	100
Bloomington Ridged Plain	369	78	41	18	11	1124	61	10	1.8	0.7	565	54	2.1	0.2	0
Chicago Lake Plain	6	*	*	*	*	34	37	0	0	0	377	56	1.3	0.5	0.4
Coastal Plain	12	*	*	*	*	17	*	*	*	*	16	*	*	*	*
Galesburg Plain	124	90	50	22	12	155	70	22	11	4.0	270	54	6.5	1.1	0.5
Green River Lowland	98	92	60	28	8.5	16	*	*	*	*	25	67	15	0	0
Kankakee Plain	29	73	57	30	11	324	72	8.8	0.9	0.6	115	48	6.0	0.7	0
Lincoln Hills Section	28	100	53	18	4.3	22	*	*	*	*	3	*	*	*	*
Mt. Vernon Hill Country	81	92	66	40	20	121	82	40	19	8.0	69	56	3.2	2.2	1.8
Rock River Hill Country	37	90	53	4.8	0	158	78	41	10	2.2	269	68	19	2.3	0
Salem Plateau Section	11	*	*	*	*	21	*	*	*	*	7	*	*	*	*
Shawnee Hills Section	26	100	59	24	13	41	80	32	6.2	0	38	69	13	3.8	0
Springfield Plain	412	81	44	27	16	476	63	19	5.8	2.2	73	62	12	1.3	0
Wheaton Morainal Country	46	69	21	5.7	5.0	396	54	2.4	0.4	0	788	54	2.2	0	0
Wisconsin Driftless Section	0	*	*	*	*	7	*	*	*	*	23	*	*	*	*

*Data ommitted because of less than 25 analyses

Table 4. Source Versus Nitrate Content in Glaciated Areas

(Percent of the analyses with nitrate equal to or greater than the concentration shown)

Area	Drift Wells					Limestone Wells					Sandstone Wells				
	No. of Anal.	Conc. mg/l as NO_3				No. of Anal.	Conc. mg/l as NO_3				No. of Anal.	Conc. mg/l as NO_3			
		1	10	45	100		1	10	45	100		1	10	45	100
Wisconsinan Glacial	2245	64	18	5.1	2.4	1254	58	7.7	2.1	0.4	824	58	6.5	1.8	0.7
Illinoian Glacial	1079	75	34	16	8.5	280	61	15	5.9	1.3	361	66	23	14	7.3
All other areas	127	85	40	14	3.9	85	84	25	10	2.8	45	67	12	0	0
Entire State	3451	69	24	8.8	4.3	1619	62	9.8	3.1	0.6	1230	61	12	5.3	2.6

Table 5. Source Versus Nitrate Content in Physiographic Areas

(Percent of the analyses with nitrate equal to or greater than the concentration shown)

Physiographic division	Drift Wells					Limestone Wells					Sandstone Wells				
	No. of Anal.	Conc. mg/l as NO_3				No. of Anal.	Conc. mg/l as NO_3				No. of Anal.	Conc. mg/l as NO_3			
		1	10	45	100		1	10	45	100		1	10	45	100
Bloomington Ridged Plain	1472	63	16	5.0	2.4	237	66	4.2	1.2	0.8	261	63	8.2	3.7	2.0
Chicago Lake Plain	12	*	*	*	*	128	50	0.9	0	0	119	56	0	0	0
Coastal Plain	28	73	31	11	0	17	*	*	*	*	0	*	*	*	*
Galesburg Plain	201	84	40	18	8.7	219	57	11	3.2	0.9	82	53	4.7	2.1	1.7
Green River Lowland	109	88	55	25	7.5	13	*	*	*	*	12	*	*	*	*
Kankakee Plain	281	73	12	3.4	1.5	114	58	14	3.2	0	59	39	6.0	3.0	2.3
Lincoln Hills Section	40	86	37	8.0	0	12	*	*	*	*	1	*	*	*	*
Mt. Vernon Hill Country	71	83	53	26	11	8	*	*	*	*	189	76	33	19	9.8
Rock River Hill Country	105	84	39	1.8	0	117	78	42	14	2.9	140	63	16	3.0	0
Salem Plateau Section	14	*	*	*	*	20	*	*	*	*	3	*	*	*	*
Shawnee Hills Section	44	90	49	19	7.2	23	*	*	*	*	38	66	13	0	0
Springfield Plain	807	72	30	15	8.0	53	68	27	14	4.1	90	58	23	14	8.0
Wheaton Morainal Country	266	53	4.9	0.6	0.5	645	55	2.8	0.4	0	233	47	2.7	0	0
Wisconsin Driftless Section	1	*	*	*	*	13	*	*	*	*	3	*	*	*	*

*Data ommitted because of less than 25 analyses

FIGURE 1. AREAS OF EXPOSED GLACIATION

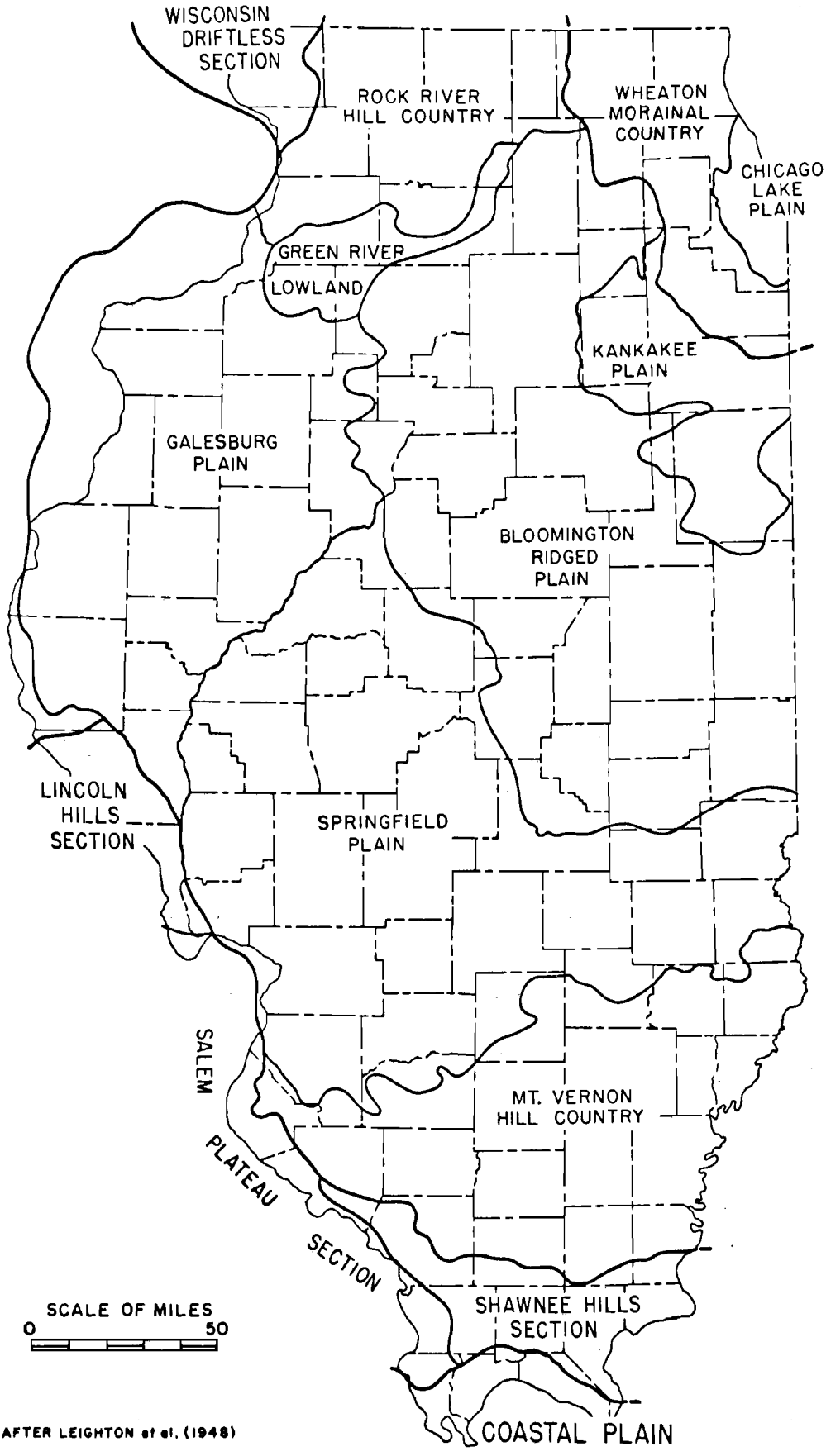

FIGURE 2. PHYSIOGRAPHIC DIVISIONS