Kansas Farmstead Well Study
Phase II

IDENTIFICATION OF FACTORS RELATED TO NITRATE AND PESTICIDE CONTAMINATION OF FARMSTEAD WELLS[1]

by

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ABSTRACT

Information about characteristics of the well and conditions around the well from a study of 150 farmstead wells in Kansas was collected as part of a comprehensive study of water quality from farmstead wells being conducted by Kansas State University (KSU) and the Kansas Department of Health and Environment (KDHE), Bureau of Water Protection. This information was compared with measured nitrate-N and pesticides from the wells to determine the effects of characteristics and conditions on the level and likelihood of wells to yield water with nitrate-N less than 4 mg/L, in excess of the Maximum Contaminant Level (MCL) of 10 mg/L, or twice the MCL, or to contain detectable amounts of pesticides.

Results showed that age, method of construction, soil textural class at the surface, and depth to water were all of some importance in influencing the level of nitrate-N. Wells that are more than 70 years old, within 100 feet of a source of potential organic contamination, with a depth of 21 to 99 feet in silty to clayey soil and more than 30 feet from cropland are most likely to have nitrate-N concentrations that exceed the MCL or twice the MCL. Wells on the other end of each spectrum are most likely to provide water with low levels of nitrate-N. Likelihood of pesticide contamination increases substantially with increase in nitrate-N.

A scoring procedure was developed to estimate the likelihood of a well having a concentration of nitrate-N in a particular range of values. The same well scoring procedure can be used to estimate the likelihood of a well containing detectable amounts of pesticides.

INTRODUCTION

A first phase of this study completed in early 1987 (Koelliker et al. 1987 and Steichen et al., 1988) as part of a cooperative project between Kansas State University (KSU), the Bureau of Water Protection of the Kansas

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Department of Health and Environment (KDHE), and the Kansas Water Resources Research Institute, showed that on the average 28 percent of farmstead wells in Kansas yielded water with nitrate-N in excess of the Maximum Contaminant Level (MCL) 10 mg/L and 8 percent contained detectable amounts of pesticides. A second phase was planned and carried out as a cooperative effort between KSU and the Bureau of Water Protection of the KDHE to determine if characteristics of the well and conditions on the farmstead can be related to the average nitrate-N, pesticides, and volatile organic chemicals in well water (Grosh et al., 1988).

This presentation uses data from a subset 150 of the wells included in Phases 1 and 2 to show how the concentration of nitrate and likelihood of finding detectable amounts of pesticides in water from those wells can be linked to factors about the wells and characteristics of the farmstead. A scoring procedure to estimate the concentration of nitrate-N and the likelihood of well water to contain detectable amounts of pesticides is developed and presented.

PROCEDURE

General:

Eighty-four wells were selected and sampled during Phase 2 of the study. Data obtained from 66 of the wells from Phase 1 of the study (Koelliker, et al., 1987) were added to those from Phase 2 get the subset of 150 wells which was used for the work presented herein. The data for the entire subset can be found in Grosh et al. (1988). Wells included from Phase 1 were all that contained detectable amounts of pesticides plus those wells that fit the initial selection criteria for wells developed as part of Phase 2. KDHE personnel sampled the wells and performed the analyses in both phases of the study. Sampling and analyses procedures are described in Koelliker et al. (1987).

Factors about the well and the farmstead that might affect nitrate-N and pesticides in water from the well were chosen collectively by KSU scientists and KDHE personnel assigned to the project as a part of Phase 2. Tables 1 and 2 show the various factors chosen. Wells selected for inclusion in Phase 2 were chosen to obtain a range of values (some high and some low) for the various characteristics identified.

The average concentration of nitrate-N for various ranges of numerical values for each of the factors was considered separately to see if a relationship between average nitrate-N concentrations and the various ranges of numerical values for each of the factors. A similar procedure was used with pesticides except all types of pesticides were lumped together and only the presence of pesticides was considered in the analysis. Actual numerical values used to compare each factor were obtained by visually studying the entire data set on a spreadsheet. The data set was sorted by factors and where breaks in numerical values were noted, or numerical values originally selected to be used in the statistical design for Phase 2 of the study were used. For each factor a graph was prepared to display the results and aid the analysis.

Well Scoring Procedure:

After studying the magnitudes of differences in nitrate-N concentrations for the various factors chosen as predictors of nitrate-N concentration, a set of numerical values which correspond to importance weights was assigned to each factor. The goal was to make high scores associate with high probability of high nitrate-N concentration and low scores associate with low probability of high nitrate-N concentrations. Ideally, if well designed, the score should decrease consistently with decreasing nitrate-N concentration. The values for the various criteria were then summed to form the well score. Total scores could range from 0 to 55. The degree of agreement between well scores and concentrations of nitrate-N in the various ranges of values was then investigated. Well scores for several of the categories were adjusted to improve the agreement between high nitrate-N values and high well scores. A similar procedure was used for pesticides.

RESULTS AND DISCUSSION

Nitrate-N

The distribution of nitrate-N concentrations from the 150 wells used in this presentation is shown in Figure 1. The distribution is similar to that from the random sampling of farmstead wells in Kansas (Koelliker et al., 1987) except that there were more wells with nitrate-N with higher concentrations. Forty-one percent of the wells had nitrate-N of less than 4 mg/L, which we consider to be the background level for wells in Kansas. One-third of the wells yielded water with nitrate-N greater than the MCL of 10 mg/L set for public water supplies and 17 percent exceeded more than twice the MCL (20 mg/L). Average nitrate-N concentration was 12.5 mg/L. Table 1 shows the

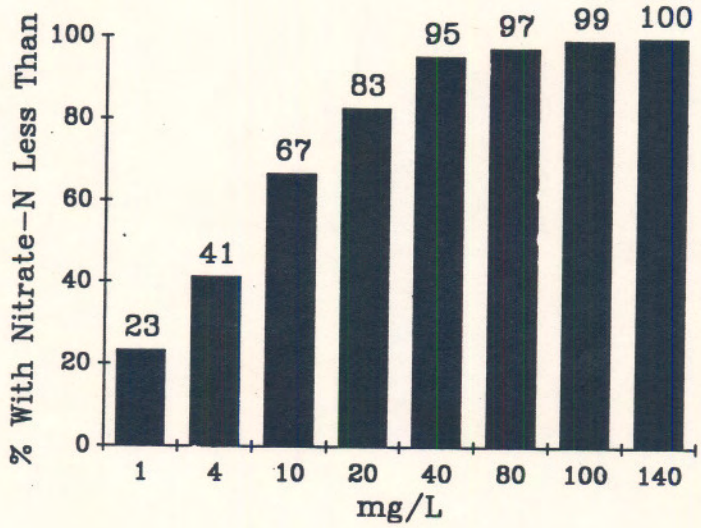

Figure 1. Distribution of the concentration of nitrate-N in wells chosen for Phase 2 of the farmstead well water quality study.

factors that were expected to influence the concentration of nitrate-N and compares the average values of the factors with the three categories of nitrate-N concentrations.

Table 1. Average values for the six predictor factors that were considered to affect nitrate-N concentrations from farmstead wells.

Factor (average value)	Category of Nitrate-N, mg/L		
	less than 4	greater than 10	greater than 20
Percent of total wells	32	33	18
Year well was constructed	1957	1935	1931
Distance to source of possible organic contamination, ft[a]	330	127	104
Depth to water, ft	32	38	40
Soil textural class[b]	2.6	3.0	3.1
Type of construction[c]	2.0	2.0	1.9
Distance to cropland, feet	215	269	295

[a]Sources include septic tanks, feedlots (drylot, confinement building, abandoned feedlots), silo
[b]1=gravely or rocky, 2=sandy, 3=silty or loamy, 4=clayey
[c]1=dug, 2=driven, 3=drilled

Those wells with higher nitrate-N are likely to be older. Wells with nitrate-N greater than 10 averaged 52 years old while those with less than 4 averaged aged only 32 years old. Figure 2 shows the average concentration of nitrate-N and chances of exceeding 10 and 20 mg/L of nitrate-N for three age classes. For those wells constructed more than 70 years ago (13 percent of the total), 88 percent yield water with nitrate-N greater than 10 and 37 percent yield water with greater than 20 mg/L. On the other hand, those wells less than 30 years old (58 percent of the total), 25 percent yield water with nitrate-N greater than 10, but from only 10 percent was it greater than 20 mg/L. Well age appears to be a very important factor. Based upon this study we recommend that wells more than 70 years old be tested for nitrate.

Another factor that appears to be important in determining the concentration of nitrate is the distance from a source of potential organic contamination (SPOC) that could produce nitrate. Such sources of potential organic contamination have decaying organic matter such as human or animal wastes that are oxidized to nitrate near the soil surface. Subsequently, nitrate could move into the groundwater with percolating water. As shown in Table 1 wells with higher average nitrate-N concentration had SPOCs which on average were closer to the well. Wells with nitrate-N concentrations greater than 20 averaged 104 feet from a SPOC; those with less than 4 averaged 330 feet from a SPOC. Closer examination of the data showed that 20 percent of the wells within 100 feet of a SPOC (54 percent of the wells tested) yielded water with nitrate-N more than 20 mg/L and 37 percent of the wells within 100 feet of SPOC yielded water with more than 10 mg/L. However, 33 percent of the wells within 100 feet of a SPOC yielded water with nitrate-N below 4 mg/L. Where concentrations of nitrate-N are greater than 20, a SPOC appears likely to be an important contributing factor.

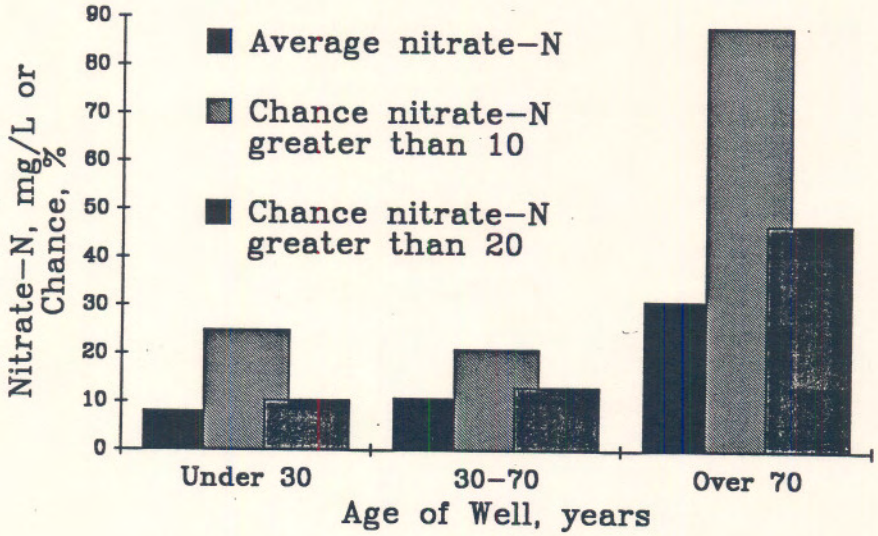

Figure 2. Relationship between age of well and the chances of concentration of nitrate-N exceeding 10 and 20 mg/L.

Figure 3 shows the influence of the distance to a SPOC on nitrate-N concentration and the percent of wells with concentrations greater than 10 and 20 mg/L. Wells within 100 feet of a SPOC showed the highest average concentra-

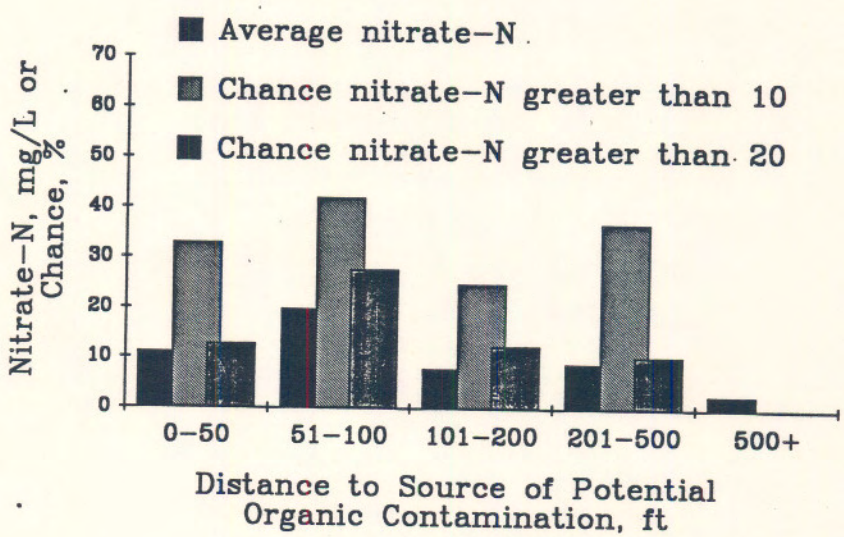

Figure 3. Relationship between distance from well to a source of potential organic contamination such as a feedlot, drylot, septic tank, or silo and the chances of the concentration of nitrate-N exceeding 10 and 20 mg/L.

tions. Those same wells also had the greatest percentage of wells that exceeded the MCL of 10, except that wells from 201 to 500 feet away had about the same percentage. Wells with nitrate-N greater than 20 mg/L were much more likely to be within 100 feet of a SPOC. The wells with least nitrate-N were those more than 500 feet from a SPOC. It also appears that a minimum recommended distance for a well to a SPOC should be about 150 feet. However, a distance of 500 feet or more is the ideal situation.

Figure 4 shows that wells with depths to water of 10 feet or less had nitrate-N concentrations that were average for the data set. Those wells with depths to water from 21 to 50 feet deep had, on average, the highest concentration of nitrate-N. Wells with depths to water of from 21 to 99 feet are the most likely to exceed the MCL. Those wells 31-50 feet depths to water are most likely to exceed 20 mg/L.

Heavier surface soil textural classes (silt through clayey) were associated with wells with higher nitrate-N concentrations and more wells that exceeded the MCL, as shown in Figure 5. This finding was not as expected. Gravely or rocky soils were slightly more likely to have higher nitrate-N values than sandy soils.

As can be seen from Figure 6, the analysis of type of well construction did not show much difference in nitrate-N concentrations or in chances of exceeding the MCL or twice the MCL. Dug wells are usually older and less likely to be sealed at the surface than the other types, but on the average dug wells were no worse than the others.

Apparently, locating wells in cropland areas decreases slightly the likelihood of very high nitrate levels. Figure 7 shows that wells within 30 feet of cropland had lower average concentrations of nitrate-N, and a lower percentage of those in and near cropland exceeded 20 mg/L concentrations. This would indicate that cropland and associated fertilization is not the most

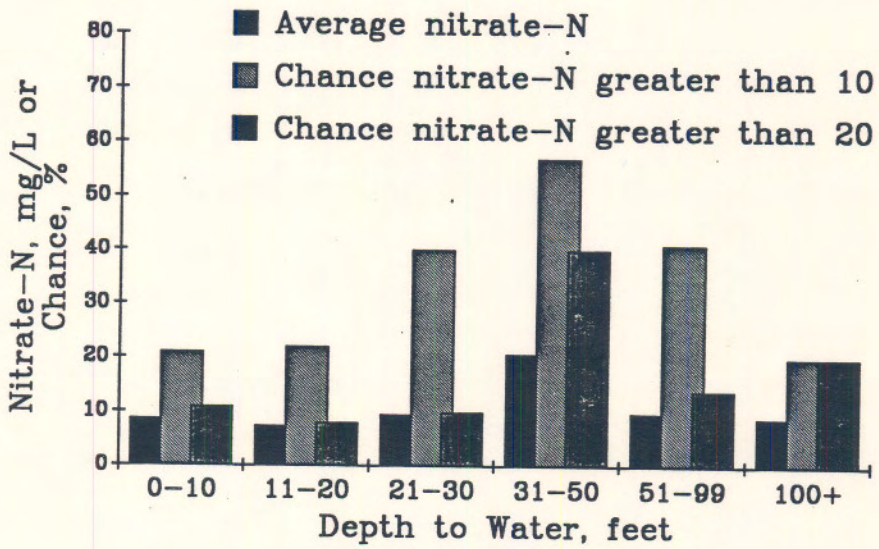

Figure 4. Relationship between the depth to water in wells and the chances of the concentration of nitrate-N exceeding 10 and 20 mg/L.

important source of nitrate in farmstead wells. While fertilization might increase the overall background value of nitrate in groundwater, the level of concentration that results is likely to be less than the MCL. Point sources of nitrate are more likely to be the cause of higher nitrate-N concentrations.

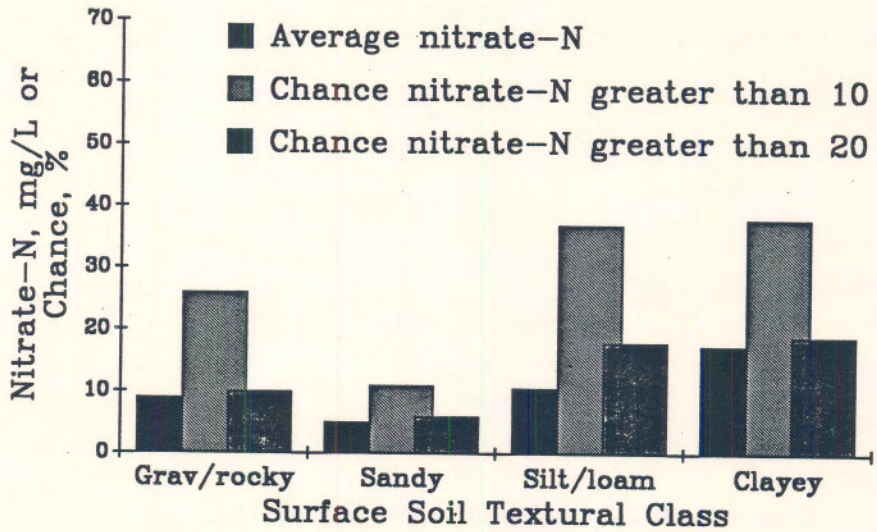

Figure 5. Relationship between soil textural class at the surface around the wells and the chances of the concentration of nitrate-N exceeding 10 and 20 mg/L.

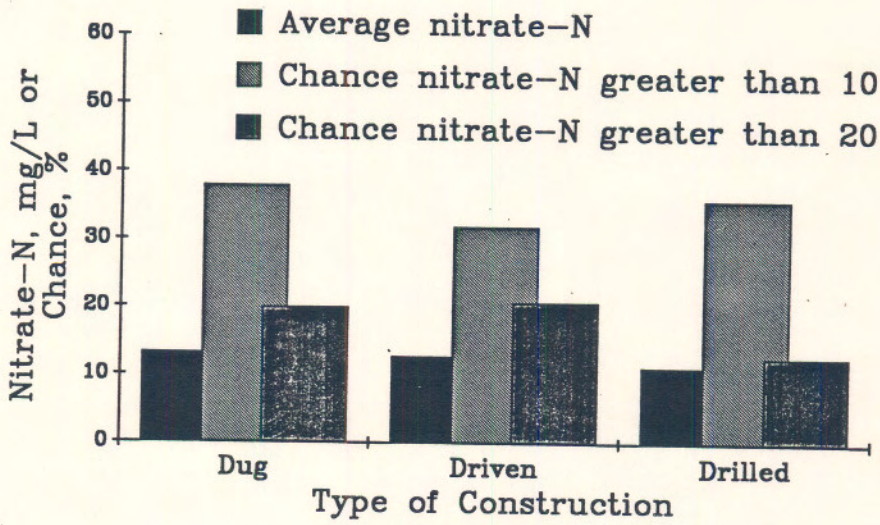

Figure 6. Relationship between the type of construction of wells and the chances of concentration of nitrate-N exceeding 10 and 20 mg/L.

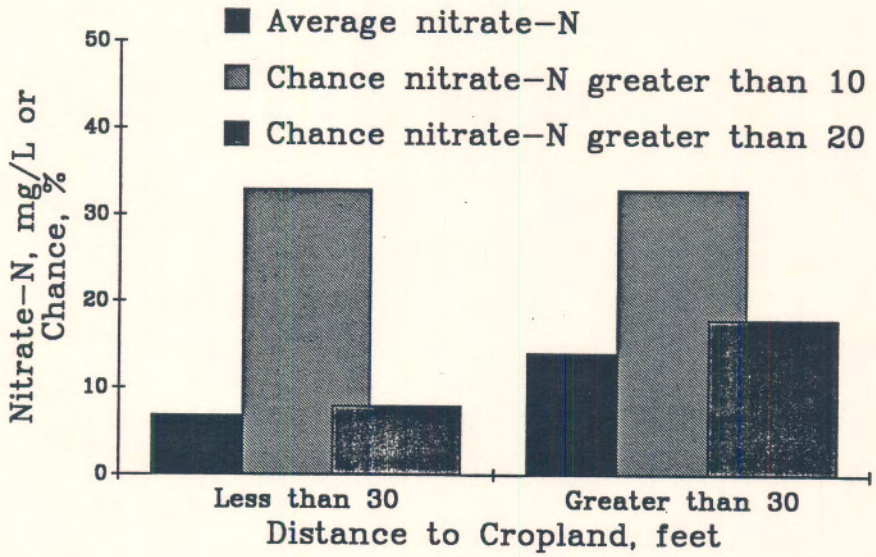

Figure 7. Relationship between the distance to cropland from the wells and the concentration of nitrate-N and the percent of wells exceeding 10 and 20 mg/L.

Overall, it appears that nitrate-N in water from farmstead wells in Kansas is related to certain factors about the well and conditions on the farmstead. The wide variability in concentrations and conditions make direct statistical analysis of these effects unproductive. It also appears that the several factors may be related to one another. For example, a very old well is likely to be near the center of the farmstead where it is close to several SPOCs, is a dug well, and is distant from cropland or pasture. As a result such a well is likely to be high in several of the important factors that make high nitrate-N values more likely. This lack of independence of factors complicates statistical analysis. The simpler approach presented here does not consider this mutual dependence.

Pesticides

Nine of the 84 wells (11 percent) sampled in Phase 2 contained pesticides (Grosh et al., 1988). Eleven percent is within statistical limits of the 8 percent found in the random sampling in Phase 1 (Koelliker et al., 1987). A total of 16 of the 150 wells (11 percent) in the data subset used herein contained detectable amounts of pesticides.

Average values of the various factors about the well and farmstead that might be related to pesticide contamination are shown in Table 2. Average distance to the pesticide mixing area is less for wells with detectable amounts of pesticides. Spills or small losses might be more likely around the mixing area. Dug wells were more likely to have detectable amounts of pesticides than other types of wells. Average distance to the farm shop from wells with detectable amounts of pesticides was only half as great as for those that did not have detectable amounts of pesticides. The surface soils around the wells with pesticides is more porous than around those without pesticides. These soils might allow pesticides to move more quickly in percolating waters to groundwater than would heavier soils. Wells with pesticides have average

nitrate-N concentrations almost twice as high as those without pesticides. This would lead to the same conclusion drawn for nitrate-N, that contamination of most farmstead wells with nitrate and pesticides is probably from point sources rather than from applications at agricultural rates onto cropland.

Table 2. Comparison of average values for wells with and without detectable amounts of pesticides for the five factors included in pesticide selection criteria plus other factors considered pertinent.

Selection factor	Presence of pesticide contamination	
	detected	not detected
Presence of pesticide reported, percent	11	89
Distance to cropland, feet	518	447
Distance to pesticide mixing area, feet	323	425
Depth of well, feet	35	37
Type of construction[a]	1.75	2.01
Reported spill near well, percent	25	25
Distance to farm shop from well, feet	189	390
Surface soil textural class around well[b]	2.2	2.9
Average nitrate-N in well water, mg/L	20.3	11.6

[a]1=dug, 2=driven, 3=drilled
[b]1=gravely or rocky, 2=sandy, 3=silty or loamy, 4=clayey

Dug wells were over three times as likely to be contaminated with a pesticide as driven wells. Drilled wells were twice as likely to be contaminated as driven wells.

Those wells which had detectable amounts of pesticides averaged 20.3 mg/L of nitrate-N while those without averaged 11.6 mg/L. While not statistically significant, there is a greater chance of a well having detectable amounts of pesticides if nitrate-N levels are high. Of the 16 pesticide-contaminated wells, 11 (62 percent) had nitrate-N greater than 10 mg/L and 7 (44 percent) had nitrate-N greater than 20 mg/L. This compares to 33 and 17 percent, respectively, in all the wells in the data subset.

Figure 8 shows the chances of a well having detectable amounts of pesticides present for various concentrations of nitrate-N. It can be seen that a low concentration of nitrate-N is a good indication of the absence of pesticides and a high a concentration of nitrate-N is cause for concern about pesticide contamination.

Well Scores

Nitrate Results

The scale used to score the six predictive factors is shown in Table 3. The relative values are based to a major extent upon the relative differences in the average nitrate-N concentration in each range of values for each of the six factors, as shown in Figures 2-7. The possible well scores range from 0 to 55. Well scores were divided in increments of 10 over the range from less-than-10 to greater-than-50. Next, the percent of wells with the various

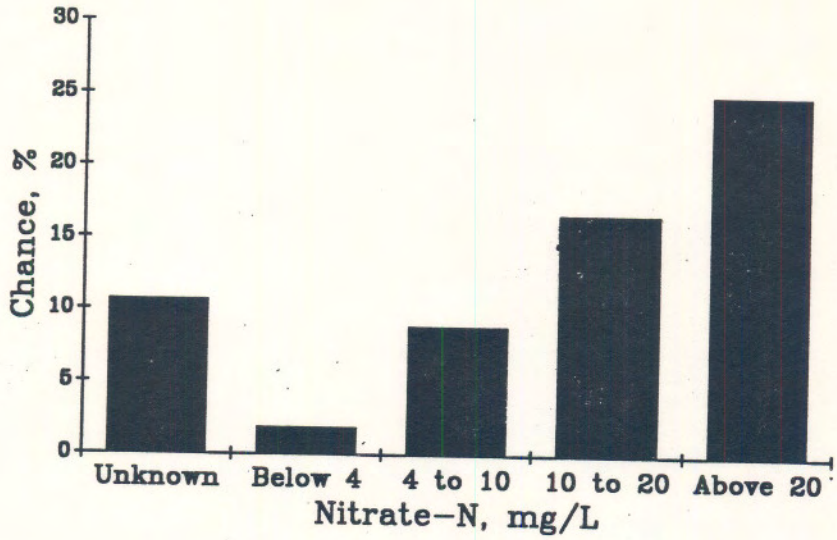

Figure 8. Chances of farmstead well water having detectable amounts of pesticide present if nitrate-N concentration in the water is known.

concentrations of nitrate-N in each of the increments of scores was determined. These chances are shown on the bottom of Table 3. Separate increments for less-than-10 and 11-20 are not listed because both increments had nearly identical distributions of the chances of nitrate-N.

All wells with scores greater than 50 had at least 10 mg/L of nitrate-N and 67 percent of them exceeded 20 mg/L. A consistent trend was evident, i.e., as scores decreased the likelihood of high nitrate values decreased and the chance of low concentrations increased. Ninety-five percent of the wells with scores of 20 or less have nitrate-N lower than 10 mg/L.

Of particular interest is the distribution of the percent of wells in each well score range. Figure 9 shows this distribution. Only about 15 percent of the wells have scores over 40 while nearly 30 percent have scores of 20 or less. The 15 percent of wells with scores above 40 contain two-thirds of all the wells with nitrate-N above 20 mg/L which are of most concern. The 30 percent of wells with scores of 20 or less are not expected to be a concern with nitrate contamination.

This scoring technique is simple to use and provides a quick method to estimate likelihood of a farmstead well having nitrate-N levels at or above the MCL. While the data subset is relatively small, it appears to represent adequately a cross-section of farmstead wells in Kansas. In lieu of testing, using this scoring technique should be considered another way to screen wells for high concentrations of nitrate-N. Wells that produce scores of 40 or greater should be tested, particularly if young children, pregnant women, or young livestock are likely to drink the water. Only periodic testing can assure the knowledge of the quality of any water supply.

Table 3. Numerical factors used to compute the well score for predicting nitrate-N concentration or chance of detectable pesticide in farmstead well water.

Procedure

1) Determine a well score by choosing the appropriate value for each of the six factors listed below.
2) Sum the values to get the final score.
3) Find the total well score in one of the ranges for well scores below. Follow across to the right to find the chance of nitrate-N level and pesticides based upon the well score.

Factors to evaluate:			Score
1. Age of well in years:			_____
	Greater than 70	20	
	30 to 69	5	
	Less than 30	0	
2. Method by which well was constructed:			_____
	Dug	5	
	Driven	0	
	Drilled	3	
3. Depth to water surface, feet:			_____
	Less than 10	0	
	10 to 20	2	
	20 to 50	10	
	Greater than 50	0	
4. Soil texture at the surface:			_____
	Gravely/rocky	5	
	Sandy	0	
	Silty/loamy/clayey	10	
5. Distance to cropland, feet:			_____
	Up to 30	0	
	Greater than 30	2	
6. Distance to feedlot, septic tank, livestock holding pen, or other source of livestock wastes, feet:			_____
	Up to 100	8	
	Greater than 100	0	
		TOTAL	_____

	Chance of nitrate-N in mg/L, %				Chance of detectable pesticide, %
Well score	Greater than 20	10 to 20	4 to 10	Less than 4	
Below 21	2	5	31	62	2
21 to 30	11	26	34	30	11
31 to 40	21	15	36	28	11
41 to 50	42	25	25	8	17
Above 50	73	27	0	0	36

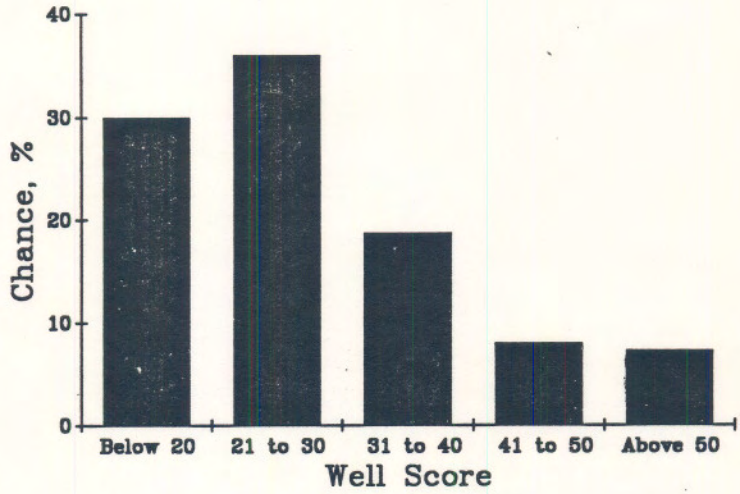

Figure 9. Distribution of farmstead wells by well scores.

Pesticide Results

A relationship exists between the well score for nitrate and the probability of detectable amounts of pesticides. Figure 10 shows the percent chance of detectable amounts of pesticides for various ranges of well scores. Again, the problem wells are associated with high scores and the uncontaminated are associated with the low scores.

As shown earlier, chances of a well containing pesticides increases with increasing concentrations of nitrate-N. Attempts to incorporate a well score for pesticides plus the fact the nitrate-N level was known as a way to improve power of predicting the presence of pesticides showed little improvement. If nitrate-N is greater than 10 mg/L and there is reason to suspect pesticide contamination, then testing for the suspected pesticide/s would appear prudent.

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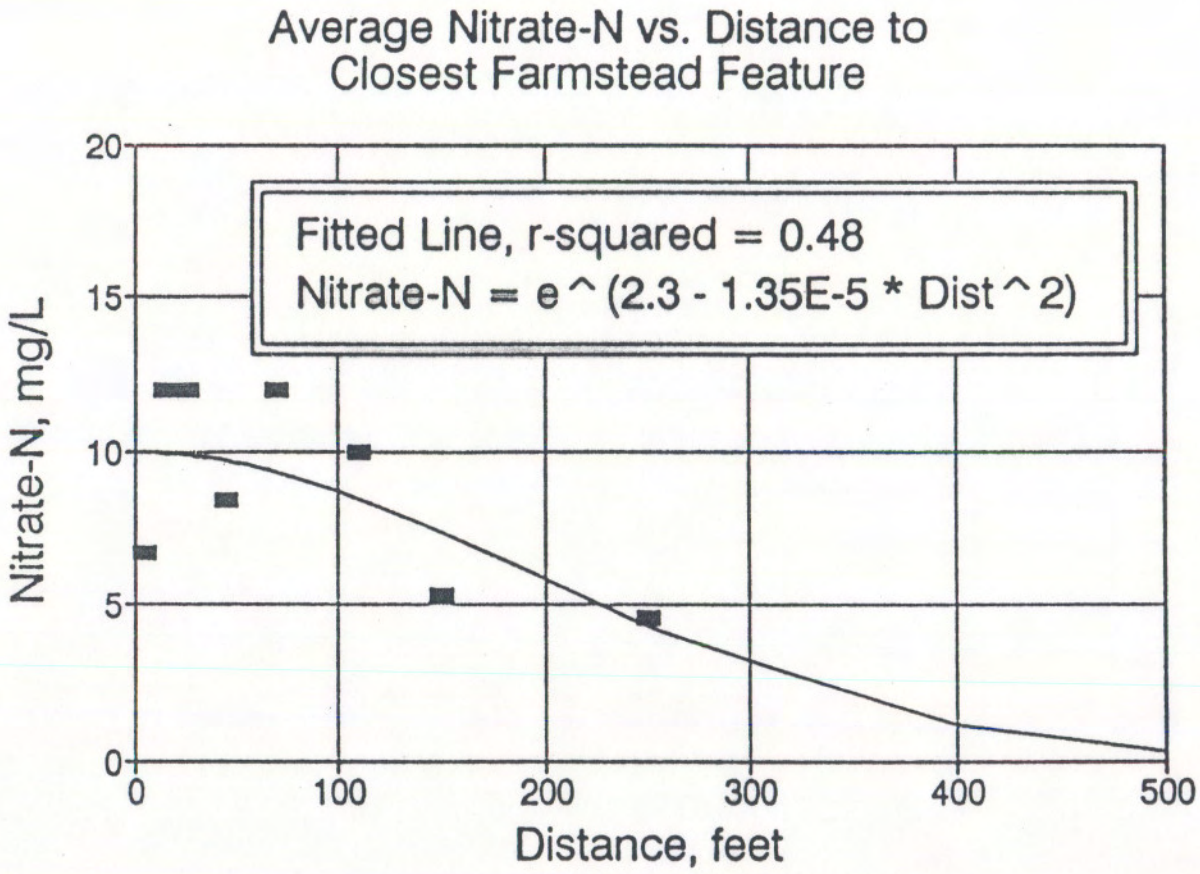

Figure 3. Effect of closest distance from the well to a farmstead feature associated with nitrate-N on (A) measured and predicted average nitrate-N concentration of nitrate-N in water and (B) the measured percent chance of nitrate-N exceeding the MCL.