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CONTAMINATION OF BOONE-ST. JOE LIMESTONE GROUNDWATER BY SEPTIC TANKS AND CHICKEN HOUSES

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ABSTRACT

Eighty-one water samples were collected from wells in the Boone-St. Joe limestone aquifer of northwest Arkansas and analyzed for fecal coliform, fecal streptococcus, total coliform bacteria, chloride, phosphate, nitrate and sulfate to determine the degree of contamination. Forty-nine percent of the samples had fecal streptococcus counts greater than 1 colony per 100 ml, 68% had total coliform counts of 1 or more colonies per 100 ml, and 9% of the wells had fecal coliform counts of 1 or more colonies per 100 ml.

Water from wells in Clarksville, Nixa, Noark, Tonti and Waben cherty silt loam soils showed from 83 to 100% bacterial contamination. Nitrate concentrations exceeded 45 ppm in 80% of the wells in Waben soils and in 50% of wells in Nixa soils, with wells in the other soil types having nitrate concentrations of less than 45 ppm. Nitrate, sulfate, and chloride concentrations were all found to be statistically related. Wells closest to chicken houses were found to have statistically greater choloride concentrations. Chloride was also found to be statistically greater in wells with shallow casing. Wells within 150 meters of a photo-lineament were found to have greater fecal coliform contamination than wells farther away. The results indicate the ease at which wells can be contaminated with only shallow casing, in cherty soils, and/or near chicken houses or fractures (photo-lineaments).

INTRODUCTION

The Boone-St. Joe limestone aquifer, an important unconfined aquifer for the residents of rural Benton County, Arkansas, is particularly susceptible to contamination due to the nature of karst hydrology and soil genesis in karst terranes. Although the occurrence and movement of groundwater in karst aquifers are not completely understood, it is generally conceded that water movement principally occurs through fractures, joints, bedding planes, and conduits that have been enlarged by solution (Hamilton, 1947, Davis and DeWiest, 1966). Pollution of the Boone-St. Joe aquifer of northwest Arkansas has been amply documented. Keener (1972), Coughlin (1975), Wagner et al., (1976), and Brooks (1979) all have found bacterial contamination of the area wells. Keener (1972), Brooks (1979), and Willis (1978) also found many wells to be contaminated with respect to chloride (Cl^-), sulphate ($SO_4^=$), phosphate ($PO_4^=$) and nitrate (NO_3^-).

Description of the Study Area: The study area (Fig. 1) is entirely within Benton County, Arkansas, and it is bounded to the north by the Arkansas-Missouri state line; to the south by the Washington-Benton County line; to the west by the Arkansas-Oklahoma state line; and to the east by Beaver Reservoir. The study area is on the Springfield Plateau province of the Ozark Highlands, and it is completely underlain by the Boone and St. Joe limestones of Mississippian age except in those places where stream dissection has cut below the St. Joe to expose older formations. The Devonian Chattanooga Shale is of hydrogeologic significance as it forms an impermeable boundary that perches water within the overlying unconfined Boone-St. Joe limestone aquifer.

In addition to the random sampling of wells throughout the county, well samples were collected from three small chicken farming communities in southeast Benton County, Arkansas (Fig. 2).

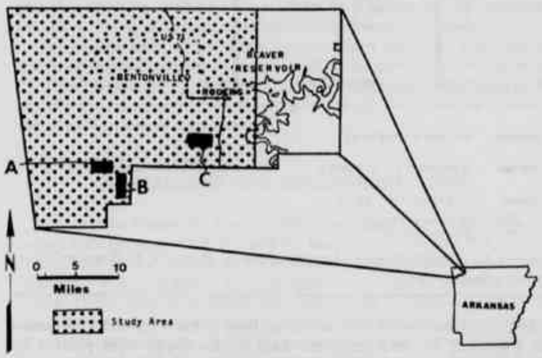

Figure 1. Location of study areas in Benton County, Arkansas, showing location of areas A, B and C.

METHODS AND MATERIALS

Whenever possible, samples were collected at outdoor faucets nearest to the wells; other samples were collected at indoor faucets. In all cases, a representative sample was obtained by running the faucet for a minimum of 5 minutes so that all samples were taken while the well pumps were operating. Faucets were flame sterilized before sampling to reduce the possibility of sample contamination by the faucet. Sample sizes of 300 ml were taken for bacterial analyses and stored immediately on ice. Samples were analysed the same day for total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) bacteria. Bacteria were isolated by the membrane filter technique (APHA, 1976). Two plates were cultured for each sample and for each bacteria type corresponding to filter volumes of 10 and 50 ml. Colonies were cultured and counted using the media, incubation conditions, and enumeration techniques described in *Standard Methods for the Examination of Water and Wastewater* (APHA, 1976).

Chemical analyses were made for nitrate (NO_3^-) sulfate ($SO_4^=$), chloride (Cl^-) and phosphate ($PO_4^=$) using standard methods modified by Hach (Hach Chemical Co., 1975). Chemical analyses were

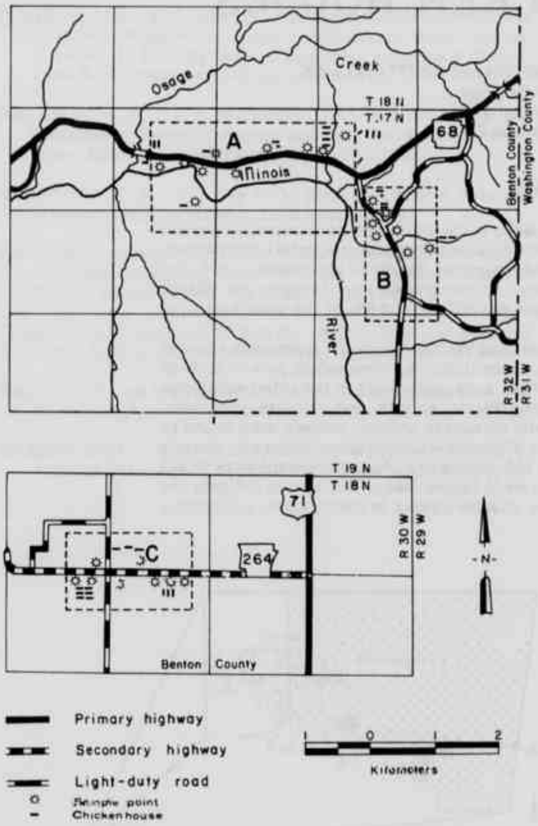

Figure 2. Detailed map of study areas A, B, and C in Benton County, Arkansas.

performed only on 29 samples taken from areas A, B and C as shown in Figure 2. Photo-lineaments used in this study were plotted by Rezaie (1979) using black-and-white low altitude photographs with a scale of 1:20,000 and color IR, U2, 1:120,000 scale photographs. Distances from the sample points to the nearest chicken house and photo-lineament were measured as the straight-line distance using 7.5 minute topographic quadrangle maps and a ruler. Soil types were determined using 1:20,000 scale soil type types from the *Soil Survey of Benton County, Arkansas* (USDA, 1977). All statistical analyses were executed by Statistical Analysis System (Barr et al., 1979) computer techniques.

RESULTS

Bacterial Analyses: Although TC, FC, and FS bacteria are not a direct threat to public health, their presence in drinking water and the implication of fecal contamination, especially for FC and FS, are adequate causes for alarm. Therefore the USEPA (1976) has recommended drinking water limits such that coliform bacteria (FC, TC) should have counts of less than 1 colony per 100 ml. A large number of wells sampled exceeded the USEPA recommended levels for FC and TC bacteria (Table 1). Samples analysed for TC had the following results: 1) 68% ($^{45}/_{66}$) had counts of one or more colonies per 100 ml and 2) 20% ($^{13}/_{66}$) had counts of 100 or more colonies per 100 ml. Of wells sampled, 9% ($^{6}/_{62}$) had FC counts of one or more colonies per 100 ml. Fecal streptococcus counts greater than 1 colony per 100 ml were found in 49% ($^{20}/_{41}$) of the wells.

From the bacterial analysis of 50 wells and springs (presumably in small communities in Washington and Benton counties of Arkansas), Keener (1972) reported that: 1) 42% had FS counts of 1 or more colonies per 100 ml, 2) 74% had FC counts greater than 1 colony per 100 ml, 3) 20% had TC counts greater than 100 colonies per 100 ml, and 4) 16% had FC counts of one or more colonies per 100 ml. Coughlin (1975) investigated a 100 sq mile area in northcentral Washington County, Arkansas, and reported that TC bacteria were present in 80% of 61 well and spring water supplies sampled. Therefore the results of Keener (1972) and Coughlin (1975) are in agreement with this study in demonstrating that the Boone-St. Joe aquifer is grossly contaminated with respect to bacteria levels.

Table 1. Results of bacterial analyses of water samples from wells in Benton County, Arkansas.

Bacterial Group	Number of Samples	Range (colonies / 100 ml)	Mean (colonies / 100 ml)	Std. Dev. (colonies / 100 ml)
FC	63	0 - 170	3.2	21.5
FS	43	0 - 530	28.9	86.0
TC	66	0 - 780	69.4	154.5

Chemical Parameters: Chloride (Cl^-) may be regarded as a pollution indicator in carbonate terranes (Nutter, 1973). In unpolluted limestone areas, the Cl^- concentration rarely exceeds 35 ppm, and it is commonly much lower (Hem, 1970). The USEPA (1976) recommends an upper limit of 250 ppm Cl^- in drinking waters. Chloride concentrations of 29 wells sampled in areas A, B, C, (Fig. 2) ranged from 2 to 44 ppm with a mean value of 14 ppm and a median value of 10 ppm (Table 2). Therefore, the groundwater is essentially uncontaminated with this ion.

Nitrate (NO_3^-), phosphate ($PO_4^=$) and sulfate ($SO_4^=$) are also commonly used as indicators of ground water quality. The USEPA (1976) recommended limits for NO_3^- and $SO_4^=$ in drinking water are 45 ppm and 250 ppm, respectively. No limit has been established for $PO_4^=$. In the 29 wells samples in areas A, B, and C, NO_3^- concentrations ranged from 1 to 96 ppm with a mean value of 29 ppm and a median value of 21 ppm (Table 2). Of those wells, 24% ($^{7}/_{29}$) had NO_3^- concentrations greater than 45 ppm.

Sulfate concentrations ranged from 0 to 47 ppm with a mean value of 13 ppm and a median value of 11 ppm. Phosphate concentrations ranged from 0.2 ppm to 3.2 ppm (Table 2). For the wells in areas A, B, and C the NO_3^-, Cl^-, and $SO_4^=$ concentrations are statistically correlated at $\alpha < 0.10$. This indicates that the concentrations of these anions are expected to increase together since a single pollution source is likely to contribute all of these ionic species. Willis (1978) and Brooks (1979) reported similar correlations.

Soil Relationships: The soil types found in the study area and the percentages of contaminated wells found in each type are given in Table 3. Wells were judged to be contaminated if the FC, FS or TC counts were 1 colony or greater per 100 ml. An examination of *Soils Survey of Benton County, Arkansas* (USDA, 1977) reveals that all soil types in the county suffer moderate to very severe limitations for

Table 2. Results of bacterial and chemical analyses of water samples taken from 29 wells in areas A, B, and C in Benton County, Arkansas.

Variable	Number of Samples	Range	Mean	Std. Dev.
Well Depth ft.	23	14 — 1000	178	222.5
FC col./100ml	14	0 — 15	1.4	4.1
FS col./100ml	8	0 — 56	15.9	19.4
TC col./100ml	12	0 — 760	93.6	228.7
NO_3^- p.p.m.	29	1.3 — 96.3	29.0	26.4
PO_4^- p.p.m.	29	0.20 — 2.37	0.72	0.61
Cl^- p.p.m.	29	1.5 — 43.5	14.2	11.8
$SO_4^=$ p.p.m.	29	0.0 — 47.0	13.1	11.8

Table 3. Bacterial contamination of well water samples with respect to soil type.

Name	Symbol	Description	% contaminated
Britwater	BtC	gravelly silt loam	100% (2/2)
Captina	CnB	silt loam	57% (4/7)
Clarksville	CuF	cherty silt loam	100% (4/4)
Elsah	Eg	cherty silt loam	100% (1/1)
Enders	Eof	stony loam	100% (1/1)
Healing	He	silt loam	— (0/0)
Linker	LrC	fine sandy loam	100% (1/1)
Nixa	NfC	cherty silt loam	86% (6/7)
Nixa	NfD	cherty silt loam	83% (5/6
Noark	NoD	cherty silt loam	100% (1/1)
Noark	NoE	cherty silt loam	100% (1/1)
Noark	NoF	cherty silt loam	75% (3/4)
Peridge	PeB	silt loam	100% (2/2)
Peride	PcC	silt loam	100% (1/1)
Secesh	Se	gravelly silt loam	17% (1/6)
Tonti	TsC	cherty silt loam	88% (14/16)
Waben	WeC	cherty silt loam	100% (1/1)

the safe operation of septic tank filter fields. Based on the results of this study, it is inferred that a large number of septic tank systems in the area do not function adequately. Water from wells located in cherty silt loam soils (Clarksville, Nixa, Noark, Tonti and Waben) had the highest percentages of contamination. Water from wells in Secesh and Captina silt loams had the lowest relative contamination. This difference may be due to the presence of chert as indicated in a study by Stafford (1979). His results indicated increased permeability of soils with chert when compared with expected permeabilities of silt loams not containing chert.

Statistical Relationships: The Spearman Rank Correlation (Siegel, 1956; Barr et al., 1979) procedure was applied to the data to test the following relationships for statistical significance: 1) bacterial counts vs proximity to photo-lineaments, and 2) bacterial counts vs proximity to chicken houses. The Spearman Rank Correlation procedure was also applied to the data from areas A, B and C to test the following relationships for statistical significance: 1) bacterial and chemical results vs chicken house proximity, 2) bacterial and chemical results vs well depth, and 3) bacterial and chemical results vs well casing depth.

Wells within 150 m of photo-lineaments were found to have greater FC counts (correlation, $\alpha = 0.109$), but not the wells of 300 m; however, this initial correlation is based on only 6 FC counts of 1 colony or greater per 100 ml. Statistically significant correlations were not found for FC, FS, and TC counts and chicken house proximity within 150 m or 300 m. Keener (1972) found no significant relationships between TC counts and wells within 50 ft of septic tanks.

Chloride concentrations were statistically greater in wells near chicken houses based on 29 observations (correlation, $\alpha = 0.08$), and in wells with shallow casing based on 11 observations (correlation, $\alpha = 0.05$). No other significant correlations were found.

The general lack of statistical relationships may be a function of the poor reproducibility of defined photo-lineaments (Podwysocki, 1975 and Siegal, 1977), lack of information on where chicken wastes are stored and spread in relationship to nearby wells, and/or possibly the small number of wells sampled.

CONCLUSIONS AND RECOMMENDATIONS

Wells of the Boone-St. Joe aquifer show a high degree of contamination with respect to FS, FC and TC bacteria counts and NO_3^- concentrations as the results of this and previous studies demonstrate (Keener, 1972; Coughlin, 1975; Wagner et al., 1976; Brooks, 1979; Willis, 1979). Poultry manures and septic tank systems are the most ubiquitous possible sources of pollutants entering the groundwaters of rural Benton County. A high percentage of wells were found to be contaminated with FS and TC bacteria both near to and far from chicken houses. This suggests that many wells are being contaminated by septic tank systems, surface runoff or both. However, heavy applications of manure some distance from chicken houses but in the vicinity of a recharge zone (such as a sink hole) can cause considerable groundwater contamination.

Photo-lineaments do not appear to have a controlling influence on hydrologic properties (Rezaie, 1979) or to have a relationship to groundwater contamination in the Boone-St. Joe aquifer. The lack of correlations between photo-lineaments and contaminates may be due to inaccuracies in the definition of photo-lineaments. The relationship of well contamination to soil type indicates that wells in cherty soils are highly susceptible to contamination. A detailed investigation of soil characteristics and degree of contamination is strongly suggested.

As preventative measures, residents of rural Benton County, Arkansas, should consider a greater spacing of wells and septic tank filter fields (Keener, 1972), modifications of the standard filter field design (Stafford, 1979), and routine monitoring of groundwater quality. Deeper casing depth in wells is also recommended as a means to lessen the probability of contamination.

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