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Survey of Farm Wells for Nutrients and Minerals, Ontario, Canada, 1986 and 1987

R. Frank,[1] N. Chapman,[1] and R. Johnson[2]

[1]Agricultural Laboratory Services Branch, Ontario Ministry of Agriculture and Food, Guelph Agriculture Centre, Guelph, Ontario, N1H 6N1, Canada and [2]Ridgetown College of Agricultural Technology, Ontario Ministry of Agriculture and Food, Ridgetown, Ontario, N0P 2C0, Canada

According to the Council of Science and Technology (CAST, 1985) 50% of the whole population and 85% of the rural population of the USA use groundwater as their main source of drinking water. This is probably the same for rural living Canadians. A 1985 US Geological Survey indicated that at least 20% of the wells were contaminated with nitrate fertilizer (Madison and Brunett, 1985). Hallberg (1986) reported that in 14 counties in the state of Iowa over 40% of well waters exceeded the EPA maximum contamination level of 10 mg/L for nitrate-nitrogen. In a further 47 counties over 20% of well water exceeded this criterion. In Ontario, Hill (1982) reported high nitrate levels in well waters collected from a major potato growing area in the Province.

In 1978, Canadian guidelines were prepared on drinking water standards by a Federal-Provincial Advisory Committee (Health and Welfare, Canada, 1979). The present study was intended to determine 1) the extent of farm well contamination with plant nutrients especially nitrate, and 2) the extent of contamination with naturally occurring salts, chlorides and sulphates and earth-elements calcium and magnesium in order to assess drinking water quality.

METHODS AND MATERIALS

In 1986 and 1987, 180 farm wells and 4 urban water supplies were sampled with cooperators across Southern Ontario. Each cooperator completed a questionnaire on the type, location and characteristics of his or her farm water supply. Representative samples of water were collected in 4.5 L bottles. The samplers were requested to first run the water for a short period to empty the metal pipes and then collect their samples over a 5 to 10 minute period. Samples were collected over two weekends, one in late November and the second in mid December, in both 1986 and 1987. The water samples were kept cool until delivery to the laboratory within two days of collection.

Samples were analysed for the following nutrient ions in 1986: Ca, Cl, K, Mg, NO_3, and SO_4, and total salts; in 1987 NO_3 was again determined. The pH of the water was determined in 1986. Methodology used for these determinations were approved procedures

Send reprint request to Dr. R. Frank, Agricultural Laboratory Services Branch, OMAF, Guelph Agriculture Centre, Guelph, Ontario, Canada N1H 6N1

described in the AOAC (1984).

RESULTS AND DISCUSSION

The 180 wells surveyed in 1986 and 1987 were located in 20 of the 39 counties across Southern Ontario a region where the majority of agricultural activities occur within the province. Almost half the wells were located on clay type soils, 30% on sandy or gravel loams and the remainder on silt loams (Table 1). The majority of wells (133, 74%) were near the farm house or building and grassed. Thirty eight (21%) were located in cultivated fields. Most wells were protected by cement or steel caps. The urban water supplies were where the farm was on a municipal water supply.

Table 1. Conditions around the 180 wells tested in 1986-87.

Soil Surface	Wells (Nos.) 1986	1987	Location	Well (Nos.) 1986	1987
Clay and clay loam	47	40	Grassed, near buildings	75	58
Silt loam	21	18	Field	27	11
Sandy - gravel loam	35	19	Other	1	8
Total	103	77		103[1]	77[1]

[1]93% were protected by cement, steel or other protective cover, only 7% had no cover.

The results of water quality analyses for Ca, Cl, K, Mg, SO_4, total salts and pH appear in Table 2 and 3. In Table 2 the mean and standard deviation for each of the eight parameter are given for seven categories of wells, based on the construction, dug versus drilled, and on depth. The data show the highest levels of K in the shallower farm wells and in urban drinking water. This was not observed in the data for other parameters. In the case of sulfates, the highest levels were found in waters of drilled wells 45 and 60 m deep and in shallow dug wells. With chlorides and total salts the highest levels were in shallow surface wells and drilled wells 15-60 m deep. Calcium and magnesium contents showed no specific trends.

Maximum Desirable Concentrations (MDC) have been established for Ca, chlorides, sulfates and pH (Ontario Ministry of Environment, 1983). No waters exceeded the Ca concentration of 500 mg/L and only one exceeded the MDC for pH (Table 3). In the case of sulfates two readings were observed over the MDC at 600 and 800 mg/L, both occurred in drilled wells and the depths were 27 and 48 m deep respectively. Chlorides exceeded the MDC of 250 mg/L in 15

Table 2. Water quality parameters for 103 rural well waters and 3 urban waters analysed in 1986.

Well description	Number wells	Depth (m) mean ± SD	pH	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sulfate (mg/L)	Chlorides (mg/L)	Total Salts (ms)[1]
Sand points (1.5-7.5)	5	4.5± 2.4	7.9±0.2	87±9	16± 9	6± 5	63± 22	134±102	0.76±0.21
Dug (2.4-15)	25	6.8± 4.0	7.8±0.3	107±77	24±14	31±63	69±94	53±30	0.72±0.18
Drilled (8.4-15)	9	11.9±2.7	8.1±0.3	56±51	18±7	20±34	19±27	91±118	0.72±0.34
Drilled (15-30)	30	23.6±4.0	7.8±0.6	66±67	18±18	23±52	35±110	157±161	1.02±0.66
Drilled (31-45)	19	35.1± 3.3	7.3±2.0	35±20	15±12	7±11	19±36	189±315	0.92±0.82
Drilled (45-60)	8	52.9± 4.5	7.9±0.2	85±94	27±19	7±13	12±16	14±16	0.50±0.38
Drilled (60-100)	7	81.0±10.9	8.1±0.3	40±27	18± 9	2± 1	12±16	14±16	0.50±0.38
Urban water	3	-	7.8±0.3	109±112	14±10	47±77	25±11	28±14	0.28±0.07
Water Quantity Optimum Guidelines				6.5 - 8.5	<200	NS	<2	<200	<100 1.0
Maximum Desirable Concentration			8.5	500	NS	NS	500	250	NS

[1]ms - millsiemens
NS - not specified

Table 3. Maximum Desirable Concentrations (MDC) of seven water quality measurements and frequency distribution of different concentration levels found in 103 wells and 3 urban water supplies, Southern Ontario, 1986.

Parameter	Maximum Desirable Concentration	Level/ Number	Content in Water						Maximum Reading
			Below MDC					Above MDC	
Ca^{++}	500	mg/L	0-50	51-100	101-200	201-300	301-500	501+	375
		Number	55	23	23	4	1	0	
Cl^{-}	250	mg/L	0-25	26-50	51-100	101-150	151-250	251+	1280
		Number	36	22	12	11	10	15	
K^{+}	NS[1]	mg/L	0-4	5-20	21-100	101-200	201-300	NS	313
		Number	63	22	16	3	1	-	
Mg^{+1}	MS	mg/L	0-5	6-25	26-50	51-75	75-100	NS	95
		Number	18	61	25	1	1	-	
SO_4^{--}	500	mg/L	0-25	26-50	51-100	101-200	201-500	501+	800
		Number	63	23	15	2	1	2	
Total salts	NS	millisiemens	0-0.5	0-6-1.0	1.1-2.0	2.1-3.0	3.1-4.0	NS	3.5
		Number	32	49	29	3	1		
pH	8.5	Level	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.5	8.5-9.0	8.6+	8.7
		Number	3	0	61	41	1	1	

[1]No standard specified

wells. One sand point well 3.6 m deep contained 260 mg/L of chlorides. The remaining 14 were all drilled wells ranging from 9 to 50 m deep the two highest levels of 1280 and 670 mg/L were in wells 36 and 20 m deep respectively. The following is a summary of the readings above 250 mg/L chloride.

Sand point	3.6 m	260 mg/L
Drilled wells	9 m	309 mg/L
	15-16 m	264, 468 mg/L
	20-21 m	353, 365, 400, 670 mg/L
	24 m	306 mg/L
	33 m	350, 390 mg/L
	36 m	444, 535, 1280 mg/L
	50 m	283 mg/L

The highest chloride readings appeared in wells at 36 m.

Little or no data were found in the literature on water quality parameters other than nitrate and phosphorus for drinking water in Ontario to compare the results collected in this survey. Since many parameters have no specified water quality standards and those that did were for maximum desirable concentrations and not health standards so suggesting no public concerns for these parameters. The levels of those ions that exceeded the MDC, namely chlorides and sulfates were considered to be natural occurring and not the result of human activities.

Nitrates were analysed in 1987 and these results appear in Table 4. In 1986, 16 wells (15.5%), had nitrate concentrations above

Table 4. Nitrate nitrogen concentration in 180 farm wells and four urban supplies across Southern Ontario, 1986-87.

Item	Waters Analysed (Nos.)	Wells with Nitrate (mg/L)[2] <0.1	0.1-1.0	1.0-10	11-20	21+	Highest Conc.
1986							
Dug	33	3	7	8	10	5	55
Dug/drilled	2	0	0	1	1	0	17
Drilled (<30 m)	29	8	13	8	0	0	4.1
Drilled (>30 m)	39	24	10	5	0	0	10
Urban	3	2	1	0	0	0	0.5
1987							
Dug[1]	20	6	5	4	2	2	43
Dug/Drilled	2	0	0	1	1	0	18
Drilled (<30 m)	27	14	8	6	0	0	2.6
Drilled (>30 m)	27	13	10	4	0	0	1.7
Urban	1	1	0	0	0	0	0.1
Total	184	71	54	38	14	7	

[1]Includes three sand point wells (1986) and two sand ponit wells (1987)
[2]The Maximum Acceptable Concentration is 10 mg/L (Health and Welfare, 1979).

the Maximum Acceptable Concentration (MAC) listed by Health and Welfare, Canada (1979). All the contaminated wells were either surface sand point wells or shallow dug wells under 10 m deep. The only exception was a well that had been converted to a deep well by drilling into the base of the wells. Most of the 16 wells were on sandy loam soils on farms located in the corn-soybean growing areas of southwestern Ontario. In 1987 five wells were above the 10 mg/L MAC. The five wells (6.6%) included a 3.6 m dug well with 42 mg/L, a 7.5 m well with 17 mg/L on first test and subsequently 43 mg/L, two 10 m wells with 15 and 17 mg/L and a dug well drilled to 15 m with 18 mg/L. All five wells were located on sandy loam soils, located at the edge of fields and close to the farm buildings or the home.

In a recent hydrogeological survey by Gillham (1988) he stated that many surficial aquifers in southern Ontario were contamined by nitrate to concentrations above the current drinking water limit. He pointed out that because of the uncertainty in the health effects of nitrate, the severity of the problem remains in question. Our findings indicate that the nitrate problem is confined to shallow or dug wells and hence the problem can be resolved by taking drinking water from drilled wells. This would not resolve the high chloride levels that were found mainly in drilled wells.

REFERENCES

Association of Official Analytical Chemists Inc (1984) Official Methods of Analysis, 1111 North 19th St, Arlington, Virginia. 22209.

CAST (1985) Agriculture and groundwater quality. CAST Report No. 103. May, 1985, 62 p.

Gillham RW (1988) Nitrate contamination of groundwater in Southern Ontario: A hydrogeological perspective. Proceedings of workshop on Agricultural Chemicals and Water Quality in Ontario, November 1988, Kitchener, Ontario, Canada.

Hallberg, GR (1986) Agrichemicals and water quality. In Agrichemicals Management and Water Quality. Board on Agriculture, National Academy of Science/National Research Council, Washington, DC.

Health and Welfare, Canada (1979) Guidelines for Canadian Drinking Water Quality, 1978. Supply and Services Canada, Hull, Quebec, Canada.

Hill AR (1982) Nitrate distribution in the groundwater at the Alliston region of Ontario, Canada. Groundwater 20:696-702.

Madison RJ and Brunett JO (1985) Overview of the occurrence of nitrate in groundwater of the United States. In US Geological Survey Water Summary 1984, USGS Water Quality Paper 2275, pp. 93-105.

Ontario Ministry of Environment (1984) Ontario Drinking Water Objectives, Water Resources Branch, 135 St. Clair Ave. W., Toronto, Ontario, Canada M4V 1P5.

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