Tritium variability of repeated samplings of well waters in Southern Ontario

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Thirteen wells in a glacial aquifer in southern Ontario were sampled for ^3H and solute chemistry in 1976, 1988, 1994 to follow movement of the tritium Bomb spike through an aquifer in southern Ontario. Tritium values show that present-day recharge to all wells occurred after the 1963 Bomb spike. Wells are deemed to be recharged rapidly if their tritium activity for a particular sampling is concordant with the tritium-vs-time plot for local precipitation. Non-concordance is due to wells receiving a significant component of recharge from tritium-dead water of underlying bedrock.

The solute chemistry portrays an aquifer system that is particularly susceptible to contamination by road salting. Two different well fields in Kitchener/Waterloo urban area have registered increases of chloride from 2.60 mN in 1976 to over 7.10 mN in 1994. In the more rural well field an increase of the Cl-to-Na molar ratio over time indicates that the aquifer is being impacted by potash fertilization.

Introduction

This short paper is an update of the 1991 paper by Fritz *et al.* in which they reported major-ion chemistry and analyses of stable and radioactive isotopes on the same wells sampled in 1976 and again in 1988. The 12-year interval between these 2 samplings is very near the half life of tritium, 12.43 years. This spread provides a convenient way to correct for tritium decay when judging whether the peak of the bomb spike, corresponding to mid-1960s precipitation, has passed by a well intake. A well is deemed to be intercepting the front end of the bomb spike if its 1988 tritium activity is greater than one half that of the tritium activity in 1976. When analytical uncertainties associated with tritium analyses for these 2 years were rigorously applied, then only one of the 13 wells (K26) met this criterion (Fritz *et al.*, 1991).

Sampling and analytical methods, as well as locale and subsurface geology were discussed by Fritz *et al.* (1991). The 13 wells are located in 4 well fields: Greenbrook (wells K1, K2, K5, K6), Strange (K13), Parkway (K31, K32, K33), and Mannheim (K21, K22, K24, K25, K26). All but the Mannheim well field are located within the urban area. There is less than a 10 km separation between any 2 well fields. The wells are screened in glaciofluvial material that is texturally heterogeneous with sizes ranging from fine clay to cobbles. Hydraulic conductivities are quite variable in these sediments, but a figure of 1.5×10^{-4} m/s quoted for the deeper portion of the Greenbrook field by Beland (1977) is probably typical of the screening depths of all 13 of these production wells. These glacial sediments (60–80 m thick at the well characterized Greenbrook field) rest on dolomitic limestone of Ordovician and Silurian age. Screen depths range from 20 to 47 metres.

Results and discussion

In order to gauge the recharge dynamics of an aquifer by repeated measurements of tritium activities over a period of years, each well's ^3H activity must be compared with the historical record of tritium in the local rainfall. Within this respect there are two kinds of behavior. If a well water's tritium for a particular year is the same or even slightly higher than the tritium in local precipitation for that particular year, then recharge is relatively rapid. Wells K1, K5, K13, K22, K24, K25, K31, and K32 are examples as their 1976, 1988, and 1994 ^3H activities fall within the range of tritium in local rainfall during those particular years.

In contrast to these 'fast response' wells are those whose tritium activities are not concordant with the tritium-*vs*-time plot of local precipitation. Wells K2 and K6 have consistently low tritium activities due to their screens being close to underlying bedrock having tritium-dead water; however, increased pumpage of K2 draws an

TABLE 1. Chemical* and tritium analyses of 13 wells in southern Ontario sampled between 1976 and 1994

Well/Year		T°C	pH	Na$^+$	K$^+$	Ca^{2+}	Mg^{2+}	Cl$^-$	SO$_4^{2-}$	HCO$_3^-$	TU
K1	1976	9	7.18	1.73	0.03	5.88	3.04	2.54	2.78	6.02	101±12
	1988	11	7.32	2.33	0.06	6.28	3.50	2.83	2.82	6.66	35±2
	1994	10	7.12	4.70	0.08	7.62	3.13	6.41	1.84	7.21	26±2
K2	1976	9	7.27	0.57	0.03	6.50	4.02	0.35	5.90	4.39	2±8
	1988	10	7.71	1.06	0.04	6.28	3.88	0.58	5.76	4.98	7±1
	1994	10	7.17	1.80	0.04	5.87	3.10	2.09	1.55	7.02	16±1
K5	1976	9	7.04	1.62	0.08	6.84	3.66	2.60	2.98	6.55	94±9
	1988	10	7.24	3.78	0.06	6.62	3.26	4.64	2.02	6.94	48±3
	1994	11	7.15	5.68	0.09	8.01	3.36	7.18	2.30	7.27	30±2
K6	1976	9	7.26	0.36	0.03	5.02	3.30	0.31	3.96	4.58	14±7
	1988	10	7.43	0.45	0.03	4.88	2.94	0.38	3.44	4.75	5±1
	1994	9	7.37	0.55	0.04	5.49	2.88	0.62	3.88	5.02	8±1
K13	1976	9	7.44	0.24	0.04	4.42	2.28	0.46	1.26	5.02	105±8
	1988	10	7.35	0.81	0.05	4.38	2.34	1.09	1.16	5.54	36±3
	1994	9	7.22	1.35	0.07	5.66	2.21	2.00	1.22	6.03	24±2
K21	1976	8	7.38	0.26	0.04	4.02	2.32	0.29	1.20	5.07	40±8
	1988	11	7.23	0.76	0.04	3.88	2.42	0.49	1.14	5.40	24±2
	1994	9	7.29	0.54	0.04	4.43	2.40	0.65	1.29	5.49	13±1
K22	1976	8	7.20	0.41	0.05	5.46	2.42	0.61	2.16	5.41	91±10
	1988	12	7.11	0.79	0.06	5.40	2.44	1.12	1.60	5.92	40±3
	1994	7	7.15	1.45	0.06	5.44	2.07	1.68	1.31	5.69	25±2
K24	1976	9	7.26	0.31	0.04	4.98	2.50	0.63	1.60	5.04	84±9
	1988	9	7.03	0.68	0.05	4.70	2.24	0.82	1.22	5.40	42±3
	1994	9	7.22	1.11	0.06	5.18	2.15	1.40	1.22	5.66	23±2
K25	1976	9	7.31	0.30	0.03	4.26	2.10	0.32	0.98	4.8±3	
	1988	11	7.33	0.34	0.03	3.74	2.04	0.37	0.84	4.98	44±3
	1994	9	7.30	0.49	0.04	4.48	1.97	0.77	0.87	5.14	28±2
K26	1976	9	7.37	0.27	0.03	4.14	2.28	0.40	0.92	4.81	73±6
	1988	11	7.07	0.30	0.03	3.88	2.26	0.52	0.84	5.03	49±3
	1994	9	7.30	0.41	0.04	4.75	2.16	0.75	0.83	5.32	26±2
K31	1976	9	7.16	0.93	0.03	5.90	3.56	1.58	3.74	4.84	99±7
	1988	9	7.20	3.51	0.04	5.76	3.38	4.35	2.64	5.59	46±3
	1994	10	7.13	4.12	0.05	6.93	3.08	5.02	2.94	5.81	25±2
K32	1976	9	7.19	1.29	0.04	8.02	4.02	2.08	6.10	5.12	85±9
	1988	10	7.30	3.66	0.05	8.76	3.84	4.25	6.46	5.57	38±3
	1994	10	7.16	4.83	0.05	9.95	3.80	5.91	6.55	5.41	23±2
K33	1976	9	7.01	0.94	0.03	6.06	3.58	1.55	3.74	4.83	60±7
	1988	10	7.19	2.00	0.05	6.98	3.54	2.50	4.88	5.21	32±2
	1994	10	7.16	2.38	0.05	7.12	3.28	3.17	4.21	5.50	17±1

*Solute concentration in milliequivalents per litre.
1 Tritium Unit (TU) = 1 atom ^{3}H/10^{18} atoms hydrogen = 3.2 pCi/kg H_2O.

increasingly larger component from the shallow aquifer as evidenced by increases in Cl$^-$ and ^{3}H from 1988 to 1994. It might be argued that since (TU$_{1988}$/TU$_{1976}$) > 0.5 for wells K21, K26, and K33, then the 1963 bomb spike had yet to reach these wells by 1988. However then this explanation is now discounted because the 1994 sampling showed that the tritium of all 3 of these wells had decreased substantially.

Repeated sampling of well waters for major-ion analysis proves to be particularly helpful in assessing anthropogenic activity. Solute character is dominated by dissolution of calcite, dolomite, and gypsum. All the well waters are saturated with respect to calcite, and their pCO$_2$ values fall in a range from 0.0085 to 0.022 atm. This similarity in chemical character facilitates spotting contaminants. This is especially true of the 3 wells in the Parkway field where chloride has risen from 1.60 to 5.00 mN between 1976 and 1994. All other urban wells (except K2 and K6 which draw predominantly from bedrock) have also registered increased levels of chloride–due no doubt to road salting operations. The 5 wells of the rural Mannheim field are not impacted. However, their Cl/Na molar ratios being greater than 1 points to the influence of potash fertilization upon this segment of the aquifer.