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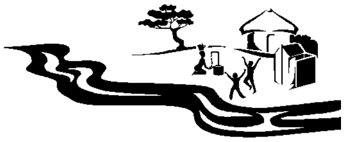
WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS



Shallow aquifer water quality risks

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THIS PAPER REPORTS on investigations into seasonal changes in water quality observed in water supply wells in the Romwe catchment, a small village community in southern Zimbabwe. The Romwe catchment is typical of much of the region, with erratic rainfall which in some years is barely sufficient for the rain-fed farming practised by most of the rural population. As reported at the 22nd WEDC Conference (Batchelor *et al.*, 1996) a collector well - an improved, high-yielding, form of traditional large diameter dug well, as described by Chilton and Talbot (1990) - was constructed in Romwe in collaboration with the Zimbabwean Dept. of Research and Specialist Services, together with a community garden for irrigated vegetables for local consumption and for sale. IH has been continuously monitoring the performance of the well and the impact that productive water points have on village communities (Waughray *et al.*, 1997): the collector well remained in service throughout the 1991/92 drought when all other wells in the catchment and surrounding area went dry.

In stark contrast, the rainy season 1995/96 was exceptionally wet: groundwater levels in the catchment rose above normal levels and a number of pit latrines collapsed. Several incidences of diarrhoeal disease were reported, with a child dying in a neighbouring village reputedly through this cause. A visit was made to the catchment in late May 1996 (some weeks after the cessation of the rainy season) to sample the bacteriological status of a number of the wells, selected randomly but ensuring an equitable spatial distribution to encompass the two main soil types, different distances from the emphemeral surface water channels, proximity to dwellings, and slope. Samples from many of the wells were indeed found to exhibit high coliform counts, although the samples from the collector well, while not entirely 'clean', were of a satisfactory potable quality (i.e. less than 20 colonies/100ml., the WHO-designated 'desirable' standard for rural water supplies).

The large variation in bacteriological quality in well waters within such a small area (about 4.6km^2) and among

Table 1. Water quality parameters measured in May 1996 (I), November 1996 (II) and April (III). R = rim; L and PL = lined and partially lined, respectively.

Well No.	*E.coli* (average colonies/100ml) I	II*	III**	$EpCO_2$ II	III	pH II	III	Gran alkalinity (µEq/l) II	III
1 L, R	1	23	84	80	130	6.97	6.59	3940.97	2671.61
2 (collector well)	1	94	0	60	75	6.8	6.6	3350.27	1536.77
		55	3	54	67	7.03	6.54	3036.42	1289.31
			32			7.03			
3 PL	56	12	0	132	83	6.72	6.6	3648.81	1762.65
5 L	10	43	4	70	138	6.23	6.13	625.74	815.18
6 L, R	23	130	28	62	93	7.08	6.76	3922.66	2853.45
9 PL	43	96	5	42	105	6.43	6.24	589.79	922.93
10 PL	77	64	4	25	64	6.84	6.5	919.42	1071.68
11 PL, R	1	7	6	20	30	7.6	7.23	4248.75	2708.64
13 L, R	33	88	76	81	66	7.07	6.59	4999.72	1360.71
15 (borehole)	3	2	2	118	99	6.85	6.83	4401.27	3585.12
16 L, R	400	500	4	20	152	7.41	6.15	2684.25	1153.36
17 L, R	7	10	0	93	42	7.11	7.45	6304.18	6215.35
18 L, R	7	2	1	63	167	6.93	6.64	2836.42	3753.70
20 PL, R	11	13	2	100	168	6.93	6.58	3084.24	3313.47
22 L	23	70	0	55	114	6.52	6.15	956.80	830.23
23	13	368	1	25	34	7.32	6.63	2733.96	585.03
26	287	500	12	41	99	6.37	5.7	504.19	252.02
28 PL, R	1	3	3	69	144	7.37	7.1	8526.53	9537.87
29 PL, R	64	53	2	35	102	7.45	6.94	5135.10	4577.17
31	249	500	12	39	80	6.43	6.06	404.19	428.42
32	137	3	4	19	32	7.33	6.73	4328.63	2246.77
N6 (piezometer)			0				6.05		812.72
N5 "			0				6.02		407.03
G "			2				7.26		10106.40
K1 "			14				6.65		708.12
K3 "			1				7.26		4503.44

*The collector well was sampled for *E.coli* on three different occasions during the November study

**The collector well was sampled for *E.coli* on two different occasions during the April study

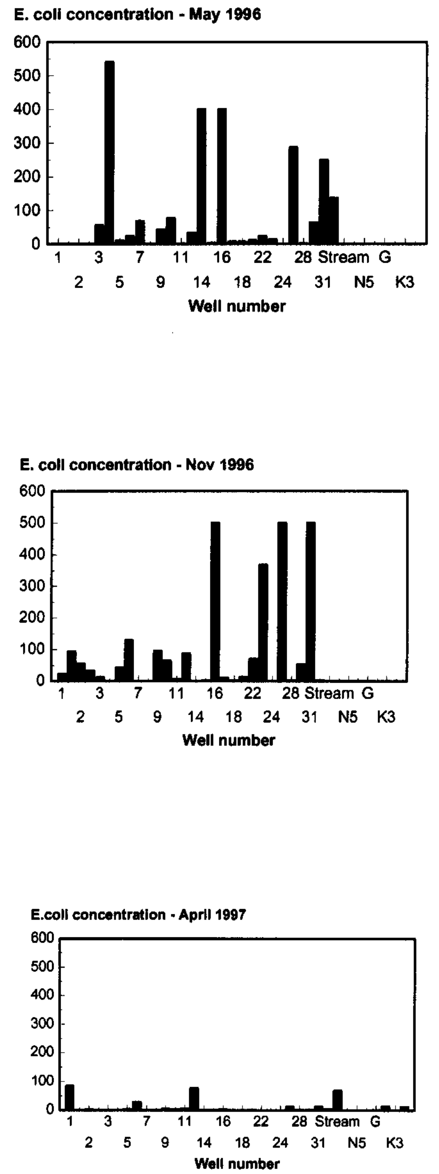

Figure 1. Bacteriological quality of wells (No. of colonies/100 ml)

wells of largely similar construction and subject to essentially similar user practices poses many questions about the causes and routes of pollution. In particular, is it related to the hydrological behaviour of the catchment or could anthropogenic activities alone be responsible?

A follow-up visit to the catchment was made in November 1996, timed to coincide with the onset of the 96/97 rainy period. The first rain event of the season (19mm) took place three days before the first samples were collected. A second major event (28mm) took place during the second sampling day, with more minor events (6-10mm) on subsequent days. Surface water was collected in the main stream channel after the second event but active flow did not establish itself during the sampling period.

All the wells sampled during the May visit were revisited and additional qualitiative notes made on their condition, constructions details, and proximity to sources of pollution. Two wells had collapsed since the May 1996 visit and one was completely dry. The collector well was sampled on three separate occasions. A further repeat sampling was made at the beginning of April 1997, at the end of what has been a fairly wet rainy season.

Sampling

At each site measurements were made of temperature and conductivity and samples collected in sterile bottles both for bacteriological analysis and for simple acid titrations to determine Gran alkalinity (Gran alkalinity, $Alk_G \approx HCO_3^-$ - H^+ concentration in μEq/l units) concentrations. Additional samples were collected and sealed immediately for transport back to the UK for stable isotope analysis. All samples were transported in a light-proof bag to protect against UV degradation.

Each day's sampling routine was organised so that no more than one hour elapsed before pH determination at the field base lab and subsequent Alk_G determinations, and no more than two hours elapsed between collection of samples and start of bacteriological monitoring procedures. Three replicate 50ml samples were taken for each well for *E. coli* colony counts using a DelAgua portable incubator test kit. Alk_G determinations were carried out on 50ml aliquots taken from the bulk sample brought back from each well and titrated against 0.1N H_2SO_4. Critical volumes dispensed were noted at 0.05 ml intervals closest to pH 4.5, 4.0 and 3.0 and from these values dissolved CO_2 concentrations were calculated with respect to atmospheric pressure, expressed in Table 1 as $EpCO_2$. This chemical sampling was extended during the April 1997 visit to include determinations of NO_3-N, NH_4-N and PO_4 concentrations of well waters using a portable colorimeter. These determinations were also carried out at the field base 'lab' after the bacteriological procedures but still within 4-5 hours of collection. Samples were also taken on this visit from a transect of five piezometer tubewells in an approximately NW-SE transect across the catchment.

Results

Summary data on the physical attributes and measurements made for the wells sampled on all three visits are shown in Tables 1 and 2. During the November 1996 visit, indicators of bacteriological quality followed a similar pattern to that found in the earlier sampling period in May: 'good' wells remained clean (in bacteriological terms) and 'poor' wells continued to contain poor quality water. Overall, colony counts were consistently higher than the previous data set. The noticeable feature was that the bacteriological quality of the collector well had deteriorated markedly in the intervening six months of the dry season. Interestingly, it showed signs of improving with the onset of the rains in that the counts for the three samples taken on days 1, 3 and 5 gave diminishing colony counts.

During the April 1887 visit at the end of the rainy season, water levels in most wells were close to, or at ground level. There was a marked improvement in the bacteriological quality of all the well water, particularly in the collector well, which was 'clean'.

Discussion

When the bacterial counts for the beginning of the wet season are plotted against physical attributes of the wells, the following features emerge:

- The six lined wells had consistently better bacteriological quality than the partially lined or unlined wells. The well with the poorest quality within this subset (Well No. 22) was the only lined well which had no rim or sanitary apron. It was also the only well in this group which is not used as a potable source.
- The wells in the partially/unlined group but which do have a rim had better quality water than those without a rim. The exception was Well No. 16, of recent and good construction but which exhibited poor quality water: this well is also sited within a household complex, close (c20m) to huts and a latrine.
- The eight wells in the partially/unlined wells subset with high colony counts were also those which had cloudy or scummy waters.
- A plot of bacterial colony counts against $EpCO_2$ which can be interpreted as a measure of biological activity due to bacterial respiration but also may be indicative of a high degree of weathering of the bedrock, shows some correlation between low colony counts and high $EpCO_2$ values.

The immediate post-wet season data showed a marked improvement in the bacteriological quality of the well water, particularly in the collector well, which had become clear. This change in quality status could not be related on this occasion, however, to the presence or otherwise of a well lining and/or rim. This change in water quality, whereby contaminated wells become clean with the onset of the wet season and the resulting 'flushing' action of increased water throughput, is consistent with findings from contemporary investigations being carried out at the Blair Research Institute at a suburban site outside Harare (Chidavaenzi and Rukure, *personal communication*). Further support for this theory comes from the chemical analyses which show that alkalinity has generally gone down in the period November to April but $EpCO_2$ values have increased. It is suggested that alkalinity has dropped because of the flushing effect: at the start of the rainy season the water in the wells is relatively stagnant and has a high alkalinity compared with later in the season when more active groundwater flow is increasing volumes in the wells. The reason for higher $EpCO_2$ values is not so easy to explain. It may be related to degassing of groundwater or to greater decomposition of organic material in the waters. Any relationship with a diminution in bacterial count may be because of a longer residence time in the soil and therefore more opportunity for adsorption of the contaminant bacteria on to to soil particles and/or digestion by predators (Evans and Owens, 1972; Burton *et al.*, 1987).

Questioning of local users revealed that many of the wells previously of poor quality were not currently in use because there was plenty of water in wells closer to households and, being the 'wet' season, there was no

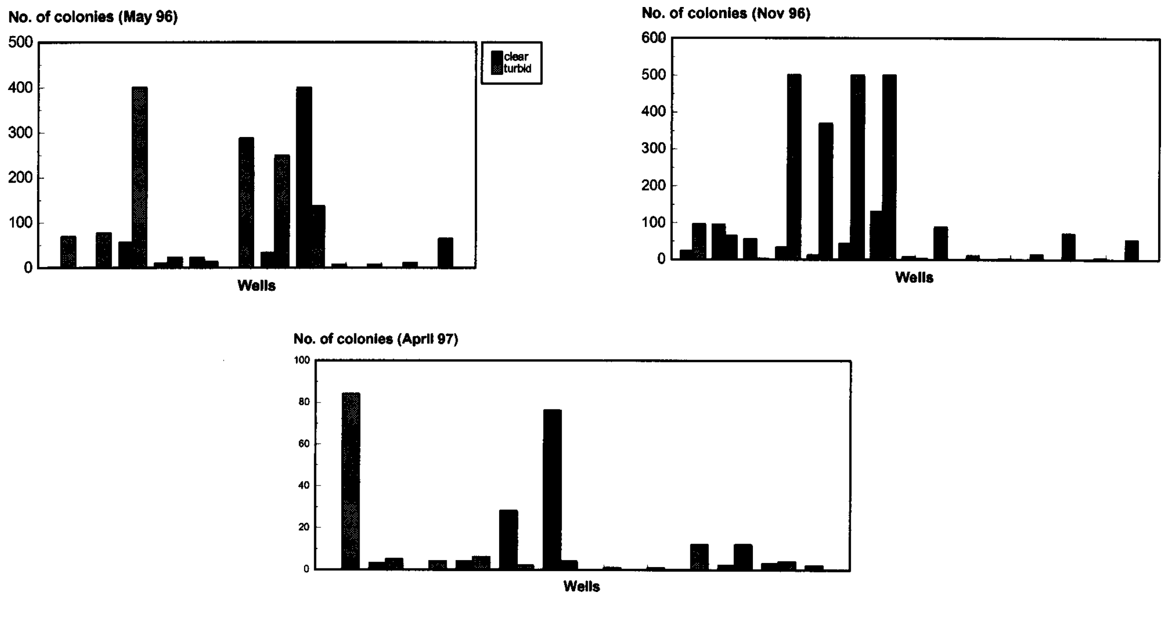

Figure 2. Water quality: relationship of turbidity to bacterial count

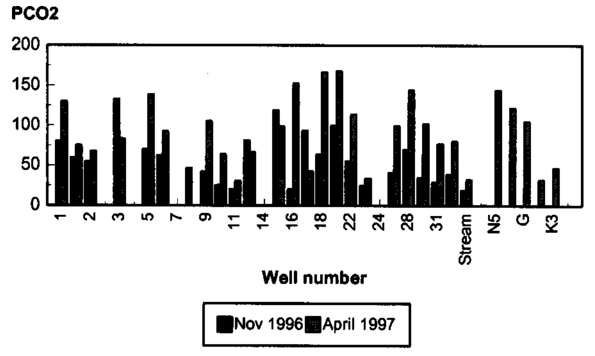

Figure 3. PCO2 concentration of well waters

demand for irrigation water. It thus appears that the hydrological behaviour of a rural catchment such as Romwe allows normal die-off mechanisms to operate very effectively. It also indicates that human contamination (particularly through poor hygiene) is the prime cause of the pollution encountered on previous visits, and not necessarily surface runoff contamination by animal slurry as had been suggested. However, one of the household wells with poor quality water on all occasions is still poor, as is the quality of the water from the nearest piezometer, perhaps indicating interception of groundwater from fissure(s) in close proximity to a neighbouring latrine situated some 20 metres distance from the well. Further investigations at this site are a high priority.

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