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Faecal contamination of rural drinking water in a commercial farming area in Zimbabwe

A HEINANEN,** S K CHANDIWANA,*
O MAKURA, M CHIMBARI, M BRADLEY

SUMMARY

The bacterial quality of drinking water from various sources of supply was monitored in February, March and April 1987 and in household containers in March 1987 in farming communities in the Burma Valley area of Zimbabwe. Faecal coliform (FC) counts were used as an indicator of faecal contamination. The range of FC counts was wide from 0 to >10000/100 ml of sample water. The bacterial quality of borehole water supplies was satisfactory (10 or less FC/100 ml) and significantly better (t-test, $p<0.001$) than the quality of river water, piped river water and piped mountain stream water, which were of poor quality. Approximately 45 percent of the drinking water samples examined had satisfactory FC counts (0-10 FC/100 ml), but these supplies were only available to about one third of the population in the study area. The bacterial quality of drinking water sampled in household containers was markedly lower than that sampled at the source of supply suggesting that much contamination takes place during collection or in the households. Recommendations on how to improve the quality of drinking water in the farming communities are given.

Blair Research Laboratory,
P O Box 8105, Causeway,
Harare, Zimbabwe.

**Correspondence to S K Chandiwana*
***Presently at the Finnish Institute of Marine Research,*
P O Box 33, 00931 Helsinki,
Finland

INTRODUCTION

A good and adequate supply of drinking water is important to public health. The quality of drinking water is one of the major factors affecting the health pattern of rural communities in the tropics [1-4]. The greatest danger associated with drinking water is contamination by sewage or human excrement because of the possibility that they contain carriers of infectious diseases. As a consequence, drinking water can act as a means of transmission for a number of serious diseases such as dysentery, cholera and typhoid which cause diarrhoeal diseases. [5, 6]

The quality of drinking water is generally not a problem in urban areas of Zimbabwe where residents are served by pipe-borne and purified water supplies. But in rural areas where about 80 percent of the country's population lives, the quality of water supply and the availability of water can be a problem. The quality usually gets worse during the rainy season when faecal material are flushed into the water supply. [7-11]

The present study was carried out in Burma Valley, a commercial farming area in Zimbabwe. The quality of drinking water was monitored during part of the rainy and post rainy seasons to get baseline information which will be useful in planning and evaluating a strategy to improve the quality of water supplies in the area where community based health education and sanitation programmes are currently being implemented. Faecal coliform (FC) counts were used as an indicator of faecal contamination.

MATERIALS AND METHODS

Study area: Burma Valley is a large scale commercial farming area situated in eastern Zimbabwe lying next to the Zimbabwe-Mozambique border (19°15' — 19°20' lat. south and 32°44' — 32°54' lgt. east). The climate is tropical with mild and dry winters and vegetation is *Brachystegia* savanna woodland-type and soil is mostly sandy of granite origin. There are 20 commercial farms and the main crops are tobacco, coffee and bananas. All year farming is made possible by irrigation. According to a population census carried out in January 1987, the number of residents in the area is approximately 4 500.

Sanitary facilities in the compounds where the farmworkers live are poor and inadequate. [12] Living conditions in the farmhouses where the farmers live are better although piped water may be from the same water source as that used by the farmworkers. Drinking water is obtained from different sources, i.e. unprotected natural waters such as rivers and streams (piped or unpiped) and from boreholes. Unlike communal areas in Zimbabwe, wells are not a common water source in Burma Valley. Water is usually not filtered or treated.

Collection of samples: The drinking water samples for FC counts were collected from the 2 most important water sources of each farming community, 3 times during 1987: between the 4th and 11 th of February, between the 6th and 10th of March and between the 4th and 5th of April. In addition, samples were collected from a school clinic and a club house. Samples were collected between 0730 h and 1730 h. Total number of samples in February was 43, in March 42, (1 out of the piped water supplies was not yielding water) and in April 41 (1 pipe was broken and 1 farmhouse closed).

14 of the samples were piped river water and 6 samples were taken directly from rivers. 12 samples were obtained from piped mountain stream water. 9 samples were taken from borehole supplies, 1 sample was water piped from a dam and 1 sample was taken from an unprotected well. The major water sources in the area are represented in this sampling programme. 26 samples were water supplies for the compounds of the farmworkers, 14 were for the farmhouses and 3 samples were for other establishments in the area.

In March, 3 compounds were chosen for sampling drinking water for FCs from containers of as many households as possible. Household samples were selected as a cluster sample using a single water point. The intention was to find out if the quality of water obtained from a supply source of known bacterial quality remained the same after transferring the water into household containers. Samples were collected from 15, 12 and 17 households of the 3 compounds between 0900 h and 1300 h. As the containers were small (generally less than 50 l capacity) it was assumed that the water in them had been collected within the previous 24 hours.

Samples were taken in sterile glass bottles and stored in a Kaylite box containing ice until processing them. Temperature and pH of each sample were measured immediately at the sampling site. PH was measured for the first 38 samples using phenol red as an indicator and for the rest of the samples using Whatman pH indicator paper.

Faecal coliform counts: Membrane filtration was carried out according to standard procedures and the medium used was membrane lauryl sulphate broth (Oxoid). Incubation for faecal coliform counts was carried out in the field using a portable MF-Millipore Incubator within 6 hours of sampling. [5] The samples were incubated at 44.5° for 18 hours. [14]

Data presentation and statistical methods: The data of population census of residents in different communities in Burma Valley were used to estimate the proportion of population supplied with drinking water of satisfactory bacterial quality. The significance of means was tested by Student's t-test after logarithmic transformation ($\log_{10} x+1$) of FC counts [15] to minimise variation and provide a better indication of the central tendency of FC distribution.

RESULTS

The amount of faecal contamination in different drinking water supplies varied considerably with a range from 0 to more than 10000 FC/100 ml. Detailed description of data is shown in Table 1. Although water supplies for the farmhouses gave lower FCs than those for the compounds, the difference was not significant ($p < 0.5$). The bacterial quality of borehole water samples was good except for one sample with 53 FC/100 ml. The water of this borehole supply was probably contaminated before sampling. The mean number of FC counts found in borehole water samples was lower than the mean number found in river water, piped river water and piped mountain stream water supplies ($p < 0.001$).

There were no significant differences between the

means of FC counts of piped river water and piped mountain water supplies when considered by month and when the data were pooled. The quality of these two piped water sources was poorer than that of borehole water, but the mean number of FC counts in the two water sources was lower than the mean number found in river water ($p < 0.001$). The bacterial quality of the different water sources did not vary significantly between the three sampling months considered (February, March and April (Table 1). The exception is piped mountain water which was better in March than in February ($p < 0.01$). The high means of FC counts for piped river water in February and April are attributed to 1 water source which had unusually high numbers of faecal coliform counts. The two most contaminated river water sources gave much higher counts in March and in April than in February: river 1, 422 and river 2, 1 600 FCs per 100 ml in February and river 1, 10 000 and river 2. 6 660 in March and river 1, > 10 000 and river 2, 3 100 in April.

Table 1 — *Faecal coliform counts per 100 ml, 95% confidence limits (D.H.SS. 1969) (in brackets) and mean of the samples collected in February, March and April 1987.*

borehole water	river water	piped river water	piped mountain water	piped dam water	well water
February					
0	422 (379 - 467)	81 (61 - 103)	448 (404 - 494)	18 (8 - 30)	142 (116 - 170)
0	39 (25 - 55)	77 (57 - 99)	639 (586 - 694)		
0	108 (85 - 133)	0	66 (48 - 86)		
0	561 (512 - 612)	7 5.7 - 9.7)	4 (1.2 - 10.2)		
0	1600 (1518 - 1684)	149 (23 - 177)	2 (0.4 - 7.1)		
0	14 (5 - 25)	33 (20 - 48)	113 (90 - 138)		
0		21 (9 - 34)	55 (38 - 74)		
0		2 (0.4 - 7.1)	53 (36 - 72)		
0		40 (25 - 57)	121 (97 - 147)		
		103 (81 - 127)	800 (741 - 861)		
		0	102 (80 - 126)		
		0	15 (5 - 27)		
		75 (56 - 96)			
		1600 (1518 - 1684)			

March

53	10000	60	110	50	20
(36 - 71)	(9798 - 10204)	(43 - 77)	(87 - 135)	(34 - 68)	(9 - 33)
0	412	24	0		
	(367 - 457)	(12 - 38)			
0	160	6	8		
	(133 - 189)	(2.2 - 13.0)	(3.5 - 15.7)		
0	520	0	0		
	(472 - 568)				
2	6660	10	0		
(0.4 - 7.1)	(6495 - 6827)	(4.8 - 18.4)			
0	4	4	30		
	(1.2 - 16.2)	(1.2 - 10.2)	(17 - 45)		
0		42	0		
		(27 - 59)			
1		0	12		
(.0.025 - 5.6)			(4 - 23)		
0		4	4		
		(1.2 - 10.2)	(1.2 - 10.2)		
		10	80		
		(4.8 - 18.4)	(75 - 102)		
		0	8		
			(3.5 - 15.7)		
		4			
		(1.2 - 10.2)			
		20			
		(9 - 33)			
		60			
		(43 - 77)			
n = 9	n = 6	n = 14	n = 11	n = 1	n = 1
mean 6	mean 2959	mean 17	mean 23		

6th — 10th of March 1987.

April

0	>10000	52	148	12	4
		(36 - 70)	(122 - 176)	(4 - 23)	(1.2 - 10.2)
1	30	4	72		
(0.025 - 5.6)	(17 - 45)	(1.2 - 10.2)	(53 - 93)		
0	270	16	2		
	(235 - 387)	(6 - 28)	(0.4 - 7.1)		
0	36	20	2		
	(22 - 52)	(9 - 33)	(0.4 - 7.1)		
0	3100	32	1070		
	(2987 - 3215)	(19 - 47)	(1003 - 1139)		
3	28	124	30		
(0.8 - 8.7)	(15 - 43)	(100 - 150)	(17 - 45)		
0		32	0		
		(19 - 47)			
0		196	28		
		(166 - 228)	(15 - 43)		
0		40	8		
		(25 - 57)	(3.5 - 15.7)		
		6	140		
		(2.2 - 13.0)	(114 - 168)		
		2	22		
		(0.4 - 7.1)	(11.35)		
		64			
		(46 - 84)			
		>10000			
n = 9	n = 6	n = 13	n = 11	n = 1	n = 1
mean 0.4	mean 2244	mean 814	mean 138		

4th — 5th of April 1987.

The range of measured pH values was from 5.0 to 8.0 (Table 2), which is favourable to faecal coliforms. The mean temperature of the samples did not vary much from February to April (Table 2). The lowest water temperature recorded for a sample was 21°C and the highest was 27°C. Faecal coliforms thrive within particular temperature ranges but the survival time of faecal coliforms in high water temperatures (> 15°) is shorter than in low water temperatures.[16] Therefore, the high water temperatures recorded for our samples (Table 2) could have shortened the survival time of the faecal coliforms resulting in underestimation of our counts.

Table 2: *The mean and range of temperature and pH measurements of the samples.*

	February	March	April
n	43	42	41
temp. (°C), mean	25.6	25.7	25.6
range	22 - 31	21 - 30	21 - 37
pH, mean	7.0	6.0	6.0
range	5.0 - 8.0	5.0 - 6.5	5.0 - 6.5

According to tentative guidelines for acceptable bacterial quality of drinking water (i.e. 0-10 FC/100 ml), which are based on research carried out in Zimbabwe,[10] 37 percent of the drinking water supplies in February, 59 percent in March and 42 percent in April in our study were satisfactory. The percentage of satisfactory samples from the most common water sources, piped river water, was lowest in April, 24 percent and highest in March, 64 percent (Table 1).

Table 3 shows the bacterial quality of samples from the original source of supply and after water had been transferred from these sources to household containers. Using the above named criteria, the quality of the original supply source was satisfactory (Table 3). After the water was transferred to the households 60 percent of the samples were satisfactory to the households 60 percent of the samples were satisfactory in the first compound, 17 percent in the second compound and 23 percent in the third compound (Table 3). The mean of FC counts in household containers of the first compound was 177/100 ml, in the second compound (302/100 ml) and in the third compound (83/100 ml). These means are not significantly different.

DISCUSSION

The present study forms one of the few studies carried out to assess the bacterial quality of drinking water in rural communities in Africa. The range of faecal coliform counts found is wide (0 - > 10000/100 ml) but is in accordance with those previously published for rural Africa: e.g. river samples from Uganda 500 - 800 FC/100 ml and river samples from Tanzania 100 - 1800 FC/100 ml,[1] zir (an earthenware, conical-bottomed vessel) water in Egypt 0-1000 *E. coli*/100 ml[17] and in Zimbabwe traditional wells 0 - 1800, bucket pumps 0 - 1600 and hand pumps 0 - 275 *E. coli*/100 ml.[18] In our study this variability was particularly found in the bacterial quality of different sources of mountain stream water and river water where faecal contamination of water tends to be focalized as people use discrete portions of natural bodies of water for a variety of contaminatory water contact activities (e.g. bathing). This would explain marked heterogeneity in the amounts of FC found in different parts of a water body. Such heterogeneity in contamination may have influenced results reported in the present study. For example, river 1 is a small stream running through one of the compounds and certain points in it were used for bathing and laundry downstream of which

Table 3 — *Faecal coliforms in 3 household water following collection from a supply source where the number of FCs are known.*

Household No.	Type of FC in supply source	FC in supply source	n	FC/100 ml in each category expressed as percentage of total 0 - 10	11 - 50	51 - 100	101 - 1000	>1000
I	borehole water	0	15	60	20	0	14	6
II	piped mountain water	0	12	17	50	17	8	8
III	piped river water	4	17	23	59	6	12	0

water was collected for drinking. This probably accounted for the high FC counts observed. Similarly, river 2 is a major watercourse and as it passes near most compounds in the area, there are increased chances of faecal contamination of the water. These observations suggest that spatial heterogeneity in contamination of natural water takes place but a better understanding of this situation requires further investigation.

Sampling was carried out during the rainy (December — February) and post-rainy (March — May) seasons when contamination of open waterbodies was considered most likely due to flushing of faeces from the soil into the water because of flooding. The findings of high FCs in river and mountain stream water (Table 1) may be attributed to this wash-in faeces from the land. Parts of the mountain areas are inhabited by people and who are likely to be responsible for the high FCs found in the water. These observations negates the commonly held view in the area that mountain stream water is good drinking water. However, throughout the sampling period, rainfall remained somewhat below "normal" levels. As there was only limited flooding the results represent those typical of quite dry weather conditions and flushing of faeces from the soil into the rivers, which are main sources of drinking water, might not have occurred as much as would have been the case in a normal rainy season. On the other hand, the less it rains, the more water is used for irrigation and this water may flush faeces into canals which lead into rivers whose water is piped into some of the compounds and farmhouses. Thus, irrigation may affect directly or indirectly the bacterial quality of drinking water an aspect which should be examined in more comprehensive epidemiological studies.

Eight borehole supplies, 1 piped river water supply and 1 piped mountain stream water supply gave satisfactory FC counts (0 - 10 FC/100 ml water) throughout the sampling period and were considered safe drinking water. Using this criteria for acceptable drinking water, it is estimated from available population figures of the various communities in Burma Valley and their drinking water sources that possibly up to two thirds of the population were drinking water of unacceptable quality during our sampling period. River water had higher FC counts than piped river water (Table 1) supporting the results of Moore *et al.* [7] that providing untreated piped water is better than using unpiped water.

In our study area, large portions of the pipes that conveyed water for drinking were often exposed to high temperatures from natural light for many hours. The lower FC counts in piped river water when compared to unpiped water (Table 1) may probably be explained by the fact that water temperatures in the pipes rose above levels which result in die-off of faecal coliforms. [16] There is need to investigate such hypothesis in well controlled experiments. The importance of such investigation can be seen from the fact that a single unprotected piped supply might be so contaminated as to produce diarrhoeal epidemics which would probably not arise if water were obtained from different parts of a river.

Borehole water is preferred as shown by the results of this study (Table 1) and others in Zimbabwe [10, 18] that indicate that borehole water is usually of acceptable quality. Nevertheless, in the short term, it is practically difficult to provide borehole water for all the residents in the study area due to costs of boreholes and sources such as shallow wells may provide good water to more people at the same cost. In addition, the bacterial quality of water can be improved by sand filtration and boiling of water. Efforts to improve the quality of drinking water must be accompanied by parallel efforts to keep such water clean as epidemiological evidence suggests that the transmission of endemic diarrhoeal disease in poor communities is more often water washed than water-borne (Cairncross, personal communication).

This is of particular significance if contamination of water occurs in storage tanks that serve whole communities as the contaminating pathogens will be transmitted throughout the community. On the other hand, contamination within the household tends to be focal and pathogens will be transmitted among members of that household alone.

Results of surveying the bacterial quality of household water supplies show that the water quality was much lower than that sampled at the borehole or piped river source (Table 3). The suggestion is that transferring water to the household containers results in marked contamination. The reasons for this could be use of contaminated household containers or contamination of the water by dirty hands during collection or in the households. These observations point to the need of health education campaigns to educate the target population to improve personal hygiene (e.g. hand washing with soap) as well as general hygiene standards (e.g. building and use of toilets).

Routine data on diarrhoeal cases recorded at a local

clinic in the study area should be analysed to determine the extent of the problem and how this may be related to faecal contamination of drinking water. Other studies showed that malnutrition was endemic in the study area and it was suggested that the malnutrition was exacerbated by the high prevalence of gastrintestinal helminths.[19] In addition, it is possible that poor water quality resulting in diarrhoeas may result in further deterioration of nutritional status in such communities. It is against this background that intervention measures to improve the quality of drinking water should be given high priority in order to improve the health status of the farming communities by reducing diarrhoea and other gastrointestinal diseases.

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