THE EFFECT OF TYPE OF WATER SUPPLY ON WATER QUALITY IN A DEVELOPING COMMUNITY IN SOUTH AFRICA

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ABSTRACT

Efforts to provide water to developing communities in South Africa have resulted in various types of water supplies being used. This study examined the relationship between the type of water supply and the quality of water used. Source (communal taps, private outdoor and indoor taps) and point-of-use water samples were examined for heterotrophic plate counts (HPC), total and faecal coliforms, *E. coli*, and coliphages. Ten percent of samples were also analysed for enteric viruses, *Giardia* and *Cryptosporidium*. Approximately 320 households were included in a case-control study. In addition, a cross-sectional study was conducted. Both studies examined the relationship between different types of water facilities and diarrhoea among pre-school children. The source water was of good microbial quality, but water quality was found to have deteriorated significantly after handling and storage in both case and control households, exceeding drinking water quality guideline values by 1-6 orders of magnitude. Coliphage counts were low for all water samples tested. Enteric viruses and *Cryptosporidium* oocysts were not detected. *Giardia* cysts were detected on one occasion in case and control in-house samples. Comparisons of whether in-house water, after handling and storage, complied with water quality guideline values demonstrated households using communal taps to have significantly poorer quality than households using private outdoor or indoor taps for HPC and *E. coli* ($\chi^2 = 14.9, P = 0.001; \chi^2 = 6.6, P = 0.04$ respectively). A similar trend (although not statistically significant) was observed for the other microbial indicators. The cross-sectional study demonstrated an apparent decrease in health risk associated with private outdoor taps in comparison to communal taps. This study suggests that a private outdoor tap is the minimum level of water supply in order to ensure the supply of safe water to developing communities. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Water quality; water supply; epidemiology; health effects; bacteria; developing communities.

INTRODUCTION

It is estimated that more than 12 million people in South Africa do not have access to an adequate supply of potable water. This has resulted in the government setting a goal to ensure that all South Africans have access to an essential basic water supply. Basic water supply is defined as 25L/person/day within 200m of their dwelling (DWA&F, 1994). Efforts to provide water to developing communities include various types of water supplies, namely, communal taps, private outdoor taps and private indoor taps. "Serviced sites" are

often supplied in developing communities, which comprise either an outdoor private or communal tap. As an increasing number of such sites are being developed it is essential that the impact of these services on health be accurately assessed. It is often believed that by simply providing clean water, a positive impact on health will be realised. However, information on the relationship between the quality of water supplied to the community and the actual quality of water used in the household and possible associated health effects, is scarce. This study examined the effect of the type of water supply on water quality and its associated impact on health by means of a case-control and cross-sectional study. The case-control methodology is recommended as the epidemiological tool for measuring the health impacts of water supply (Baltazar *et al.*, 1988; Briscoe *et al.*, 1985; Cairncross, 1987). The cross-sectional methodology provides a general description of the incidence of disease associated with different levels of water supply.

MATERIALS AND METHODS

Study site - the study site comprised a peri-urban developing community in South Africa with an estimated population of 350,000 of which approximately 20% are less than five years of age. The study site is provided with a number of different levels of water services, namely, no formal water supply (7%), communal taps (17%), outdoor private taps (60%) and in-house taps (16%). The study was designed to include both wet and dry seasons. The case-control study included 316 cases and controls. Diarrhoea was used as an indicator of health. Cases were defined as pre-school children with severe diarrhoea attending the local clinics/hospitals for medical treatment. The definition of severe diarrhoea of three or more loose stools a day was used (WHO, 1993). Children of similar age from the immediate neighbourhood of the cases, coming from a household with the same type of water supply, and who did not have diarrhoea in the preceding 14days, were selected as controls.

Sampling and analysis - water samples were collected from both case and control source supplies and points-of-use. Source water samples were collected from either communal or private outdoor taps, private indoor taps, or whatever water supply an individual collected their water from, if no formal water supply was provided. Point-of-use water samples were collected from within a household from storage containers, where no indoor tap was available. Water samples were analysed for heterotrophic plate counts (HPC), total and faecal coliforms, *E. coli*, and coliphages according to Standard Methods (APHA, 1989). In addition, ten percent of samples were analysed for enteric viruses (Nupen *et al.*, 1981), *Giardia* and *Cryptosporidium* cysts and oocysts (Kfir *et al.*, 1993). For the cross-sectional study data was collected over two one-week periods during both the wet and dry seasons. The parents or caretakers of all children presenting to the health facility with diarrhoea were interviewed and information on the child and type of water supply was recorded by means of a short questionnaire. Statistical analyses of microbiological data were performed using Statgraphics (STSC, version 6) and SAS. Analysis of variance (ANOVA) of log transformed microbiological data and a nonparametric comparison of two samples were used to compare the water quality of cases and controls. Chi square tests were used to measure the statistical associations between water quality and type of water supply.

RESULTS

Summary statistics of the microbial variables for case and control, source and point-of-use water samples are given in Table 1. Water supplied to the community by means of reticulation was generally of good microbiological quality, complying with South African drinking water quality specifications (SABS, 1984). However, water quality deteriorated significantly, after handling and storage, with guideline values exceeded by 1-6 orders of magnitude for all parameters. The 95th percentile for control source water HPCs was below the recommended 100/mL, whereas case source water HPCs were slightly above this value (Table 1). The 95th percentiles of HPCs of case point-of-use water samples were 3-4 orders of magnitude higher than source water samples. No total and faecal coliforms and *E. coli* were detected in >95% of source water samples, whereas between 8% and 25% of point-of-use water samples contained these organisms. Maximum total and faecal coliform values detected in point-of-use water samples were as high as 10^9 and 10^8/100mL, respectively (Table 1).

Analysis of variance (ANOVA) indicated statistically significant deterioration of water quality after collection and storage for both cases and controls, with the exception of control *E. coli* counts, whereas no significant differences were observed between case and control water quality. Samples that exceeded guideline values for all microbial parameters tested were significantly higher for point-of-use water samples than source water samples. Coliphage counts were low for all water samples tested with 98-100% of samples having <1/10mL PFU's. Enteric viruses and *Cryptosporidium* oocysts were not detected in any of the water samples. *Giardia* cysts were detected on one occasion in both case and control point-of-use samples.

Table 1. Summary statistics

	Case - point of use (n = 161)	Case - source (n = 155)	Control - point of use (n = 162)	Control - source (n = 155)
Heterotrophic plate counts (cfu/mL)				
Geometric mean	40	2	21	2
Range	$0 - 8.3 \times 10^7$	$0 - 7.2 \times 10^3$	$0 - 8.9 \times 10^6$	$0 - 1.8 \times 10^4$
95th percentile	1.0×10^6	1.62×10^2	2.7×10^5	8.9×10^1
% >100/mL	30	6	21	4
No statistically significant difference between case and control water samples				
Statistically significant difference between source and point-of-use water samples $P = 0.0000$				
Total coliforms (cfu/100mL)				
Geometric mean	3	<1	3	<1
Range	$0 - 4.4 \times 10^9$	$0 - 1.05 \times 10^2$	$0 - 4.6 \times 10^7$	$0 - 1.9 \times 10^4$
95th percentile	3.0×10^5	0	1.2×10^5	0
% >0/100mL	25	4	22	3
No statistically significant difference between case and control water samples				
Statistically significant differences between source and point-of-use water samples $P = 0.000$				
Faecal coliforms (cfu/100mL)				
Geometric mean	2	<1	2	<1
Range	$0 - 3.8 \times 10^8$	$0 - 81$	$0 - 4.0 \times 10^7$	$0 - 1.3 \times 10^4$
95th percentile	1.5×10^4	0	2.7×10^4	0
% >0/100mL	15	3	17	4
No statistically significant difference between case and control water samples				
Statistically significant differences between source and point-of-use water samples $P = 0.002$ and $P = 0.0006$ for cases and controls respectively				
E coli (cfu/100mL)				
Geometric mean	<1	<1	<1	<1
Range	$0 - 3.4 \times 10^4$	$0 - 5.6 \times 10^1$	$0 - 1.8 \times 10^6$	$0 - 6.5 \times 10^2$
95th percentile	1.0×10^1	0	1.6×10^1	0
% >0/100mL	10	2	8	3
No statistically significant difference between case and control water samples				
No significant difference between control source and point-of-use water samples $P = 0.1$				
Statistically significant difference between case source and point-of-use water samples $P = 0.008$				

Figure 1 illustrates the comparison of whether water at point-of-use complied to guideline values, according to type of water supply. The proportion of water samples that exceeded guideline values at point-of-use was far more frequent where communal taps were used than both private outdoor or indoor taps. This is clearly indicated for HPCs where 32% of in-house waters from communal taps exceeded water quality guideline values in comparison to 14% and 12% where private outdoor and private indoor taps are used, respectively. In addition, point-of-use water collected from private outdoor taps exceeded guideline values more

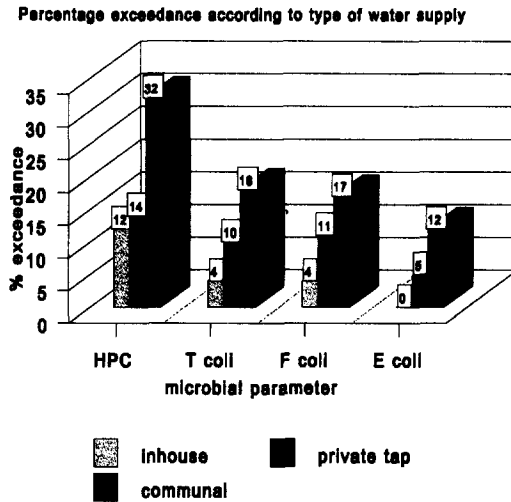frequently than water used from indoor taps. These differences were statistically significant for HPC and *E. coli.*

Percentage exceedance according to type of water supply

Figure 1. Comparison of exceedance of guideline values at point-of-use according to type of water supply.
[HPC χ^2 = 14.9 P = 0.01; Total coliform χ^2 = 5.3 P = 0.07; Faecal coliform χ^2 = 4.1 P = 0.13; *E. coli* χ^2 = 6.6 P = 0.04].

Figure 2 illustrates the statistical analyses (ANOVA) examining differences between type of water supply and bacterial counts at point-of-use. A significant difference for HPC (P = 0.0001) was observed. The same trend, although not statistically significant, was observed for the other indicator organisms.

95 % Confidence Intervals - means
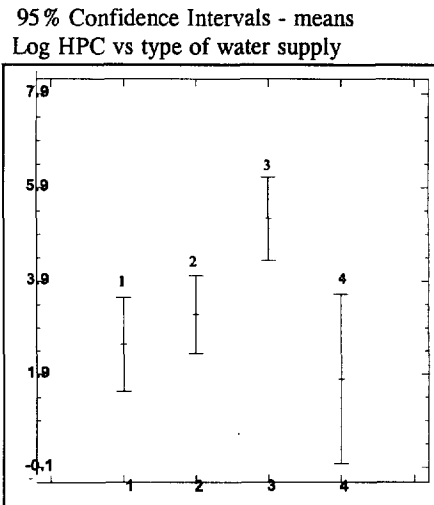**Log HPC vs type of water supply**

Figure 2. Comparison of water quality at point-of-use according to type of water supply (1 = in-house taps, 1 = private outdoor taps, 3 = communal taps, 4 = no formal services, P = 0.0001).

In total, 752 children with diarrhoea presented at health facilities during the two one-week study periods, with 65% recorded during the dry summer week of data collection. As illustrated in Figure 3, no notable

differences in the proportion of the cases and population frequencies in the formal and no-facility categories were observed. A smaller percentage of the cases than that of the overall population seem to use a private outdoor tap (39% *vs* 60%), and conversely; a larger percentage of the cases than the overall population make use of a communal tap (39% *vs* 17%). This illustrates a notable difference in the proportion of case frequencies and numbers of the population served by either an outdoor private tap or communal tap.
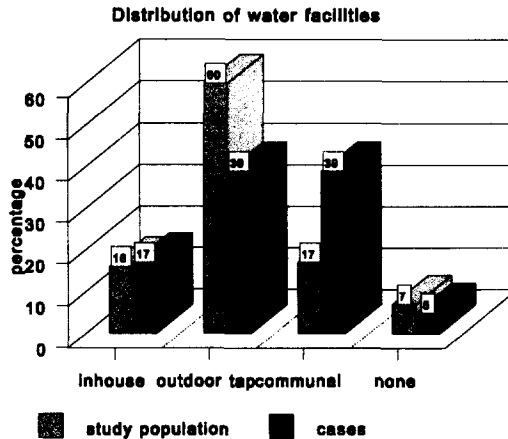

Figure 3. Comparison of distribution of water facilities of study population and cases: cross-sectional study.

DISCUSSION

Water quality was shown to deteriorate significantly after handling and storage with increasing levels of indicator organism levels, with the exception of coliphages. Studies conducted in other developing countries have found similar results, with varying faecal coliform concentrations between source and point-of-use water samples (Feachem *et al.*, 1978; Lindskog and Lindskog, 1988; Mertens *et al.*, 1990; Verweij *et al.*, 1991). These authors reported the type of water container to have an effect on stored water quality. Mintz *et al.* (1995) reported that using specially designed "safe" storage containers reduced diarrhoeal rates in pre-school children. In this study 97% of both cases and controls were found to make use of plastic storage containers and two thirds of these were open containers. The effect of different water storage practices could therefore not be assessed.

Findings illustrating a higher percentage of point-of-use water supplies exceeding guideline values and poorer water quality observed where communal taps are used, indicate that contamination is more frequent where many households make use of a common tap. This together with the increased incidence of diarrhoea associated with the use of communal taps in the cross-sectional study may suggest that contamination of in-house water from a source other than a family member poses a greater risk for diarrhoea, or the converse; contamination within the household does not pose the same risk for diarrhoea. These findings are in agreement with results from a study conducted in the Philippines (Van Derslice and Briscoe, 1995a) where it was found that "all coliforms are not created equal". They postulated that there are important differences between in-house contamination by 'internal' pathogens from family members and contamination of one's water source by 'external' pathogens. The present study supports Van Derslice and Briscoe's (1995b) proposed theory that by improving water quality alone, no impact on diarrhoea would be seen for infants living in highly contaminated neighbourhoods. Other factors in addition to water quality play an important role for improvements in health to occur, *i.e.*, improved hygiene and health-related knowledge and practices. It is recommended that this information be incorporated into policy guidelines for the provision of water in developing communities. It appears that the provision of private outdoor taps will afford greater protection against diarrhoea than communal taps shared by several families (up to more than 100 people).

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