The effects of supplied water quality on human health in an urban development with limited basic subsistence facilities

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Abstract

Domestic unavailability of water supply in South Africa often leads to improper use of supplied or other unsafe sources of water. The relationship between water quality, water availability, water accessibility, water use and incidence of diarrhoea due to these factors, was investigated in this study. The study was conducted in a large low socio-economic developing urban settlement. Reported diarrhoea cases were followed up to establish the water usage pattern of consumers in these particular households. Water was generally obtained from supply at public standpipes and stored in various forms of containers in households. Microbiological indicators were used to assess possible contamination of the water supply. Tests indicated limited instances of faecal and other forms of microbiological contamination in sections of the water-supply network. Indications were also found that the network in this area could intermittently be subjected to pollution from unknown sources although incidences were limited and not prolonged. Tests on the bulk water supply from the utility to the consumer water network indicated no faecal contamination in the bulk supply. In general the supply quality tested indicated no risk to consumers. However, the insanitary condition of containers as well as the manner of storing and handling of the containerised water led to contamination of water supplies. By implication, the system of water supply through public standpipes was conducive to conditions that could lead to contamination of stored water supply in households within the target consumer group.

Introduction

Water is generally accepted to be a vehicle for disease transmission under certain circumstances and must be properly controlled from a public health point of view (Chanlett, 1992). Public health control over water supplies in developing countries is often not sufficient to protect communities against disease (UNEP, 1991).

In South Africa, water infrastructure is well developed in many regions, providing treated water to a substantial portion of the population. However, large parts of the population often do not have ready access to such treated water (Von Schirnding et al., 1993). This domestic unavailability of water supply often leads to improper use of supplied and other unsafe sources of water which can be related to health and disease (Feachem and Blum, 1983). Even when a community in a low socio-economic environment is supplied with treated piped water, it does not necessarily mean that water-related health hazards will be totally eliminated. Factors such as treated piped water being contaminated due to low pipe pressure and breakdown in the network system may contribute to diarrhoeal infections (Hebert, 1983). Water hauled from the supply point should be protected from contamination during haulage, storage and handling by consumers as it can also contribute to diarrhoea (Pinfold, 1990). Supplied water quality, water haulage, storage and handling must, therefore, be taken into consideration in any water supply system to ensure that the consumer is provided with safe drinking water (Forsyth, 1993).

Diarrhoea is an enteric disease often related to the ingestion of contaminated water (Levine et al., 1993). In areas with less adequate water supply, diarrhoea can also be the indicator for the breakdown of any number of social habits. It may also be the indicator for some unknown aetiological agent produced from environments such as food and water as well as personal hygiene patterns (Von Schirnding et al., 1993; Pinfold, 1990; Levine et al., 1993). It is not clear to what extent the handling and storage of water obtained from a controlled remote supply influence the sanitary quality of such volumes of water. Furthermore the influence of such sanitary quality on the health of the consumer is not certain.

Therefore, this study was aimed to assess the health impact of:

- limited availability of water due to underdeveloped reticulation
- consumer-use patterns and quality of supplied water during haulage and storage.

The study was conducted in a section of a large, low socio-economic urban development with limited sanitary facilities and drinking water provision. Information obtained from a community health diagnosis project (Keil and Figaruoa, 1994) indicated that diarrhoeal infections were the disorders responsible for the largest percentage incidence of disease causing a high infant mortality rate in the area. However,the aetiological agents for such enteric infections were not generally known nor investigated due to the lack of information, lack of community participation and the absence of general health diagnoses in the area.

Potential faecal contamination in the supply was tested by using total and faecal coliform bacteria as indicators. Total bacterial presence in the water was assessed through heterotrophic plate counts. Enteric virus contamination was assessed using somatic coliphages as model virus indicators (Grabow et al., 1993). *Clostridium perfringens* was used to indicate the possible presence of spore- and cyst-forming pathogens.

The parameters to measure environmental health risk were the *South African Water Quality Guidelines for Domestic Water* (Vol. 1) (Department of Water Affairs and Forestry, 1993) and *Proposed Water Quality Criteria in South Africa*, of the

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Department of National Health (Aucamp and Vivier, 1990).

Reported incidences of diarrhoea were investigated to assess any possible relationship between the above-mentioned factors and the occurrence of such diarrhoea.

Materials and methods

Demography of the study site

The project was conducted in one of the poorer and lesser-developed sections of the settlement. This section has a population of approximately 10 360 inhabitants. Housing structures, in general, do not have in-house running water. Sanitation was provided through individual pit latrines (Zollner, 1993). Water for the people in this section is supplied mainly by public street taps (73 in total) and some 27 yard taps. The person:water-tap ratio averaged 140 people per street tap and 6 people per yard tap.

Water collection

Water, obtained from this supply, is generally then hauled in containers over distances of up to 300 m. The average distance was calculated at approximately 80 m per household.

This gathered water supply is stored in various forms of containers in households. These containers vary in volume (10 to 25 ℓ), material (galvanised metal to plastic) and mechanism/method for closing (open bucket to screw tops).

Study period and support programme

The study period of 7 months spanned summer, autumn and up to late-winter. The study section is provided with medical services by an international aid organisation, *Medicines du Monde (MDM)* (Doctors for the World). Part of the medical/clinical service programme includes an experiential community health diagnosis programme which is a questionnaire-based health data collection programme.

Case studies

During the study period up to 179 cases of diarrhoea were reported at the MDM clinic. These reported cases were followed up to be interviewed by questionnaire to establish the water-use pattern of consumers in these particular households. Unfortunately only 74 cases could be interviewed due to circumstances such as no person at home on the date of the visit. Further drawbacks were movement and time restrictions imposed on the researcher due to certain social circumstances in the area at the time of the study. This relatively small sample size limited the statistical value of the study to a deterministic profile of the sample population.

Control studies

Of the 2 592 houses in the area, 10% were randomly selected as a control group. Of this 10%, 35 households with a similar demographic profile to the diarrhoea group, but which had not reported any enteric disease patterns for at least 12 months, were selected. These households were subjected to a similar water-sampling analyses and interview routine as the diarrhoea-affected group. Only 26 households could be interviewed due to circumstances similar to those of the case study group.

Sampling

A total of 129 water samples from the supply network were analysed. Of these, 29 samples were taken from taps randomly selected from the water supply network in the section and 100 samples of water from the storage containers were analysed. These comprised 74 samples from affected (case) and 26 samples from non-affected (control) households.

The hygiene status of the inner surfaces of the containers was analysed. Swabs were also taken from the inside-wall surfaces of each container with a sterile cotton swab according to the dry-swab method (Jay, 1992). A dry surface area of 1 cm^2 just inside each water container was swabbed above the water line.

Microbiological analyses

Microbiological analyses were done on water from the supply network as well as stored household water. The bulk water supply from the Water Utility to the local authority water network is tested regularly by the Utility. The results are summarised in Table 1.

Total coliforms (TC), faecal coliforms (FC), *Clostridium perfringens* (CP), heterotrophic plate counts (HPC) and somatic coliphages (SC) were used as microbiological indicators of the water supply and stored water quality. Total bacteria counts were done from the swabs taken from the inner surface of stored water containers.

All water samples were cooled to approximately 4°C during transportation from the study area to the laboratory and analysed within 6 h of sampling. Samples were analysed for TC, FC and CP, using membrane filters placed on selective growth media. The plates were incubated aerobically at 35°C (TC) and 44.5°C (FC) for 24 h (*Standard Methods*, 1992). *C. perfringens* were anaerobically incubated at 37°C for 48 h (Grabow et al., 1984). Heterotrophic bacteria were enumerated from the samples by spreading 0.3 mℓ sample dilutions onto a non-selective medium and incubating aerobically at 37°C for 48 h (*Standard Methods*, 1992). Somatic coliphage levels were also assessed using double layer plaque assays with *Escherichia coli* strain (ATCC 13706) as host. The plates were incubated at 37°C for 24 h (Grabow et al., 1993). The surface swabs were transported to the laboratory at approximately 4°C in a sterile tube container. The swabs were rolled onto the surface (Jay, 1992) of the non-selective growth HPC medium and incubated aerobically at 37°C for 48 h (*Standard Methods*, 1992).

Results

Supplied water quality (Table 1 and Fig 1)

Total and faecal coliform counts in water sampled from the bulk supply and also from the network water supply used by affected and non-affected families tested geometric mean values below maximum low risk limits proposed in *South African Water Quality Guidelines* (Department of Water Affairs and Forestry, 1993) as well as the *Proposed Water Quality Criteria for South Africa* from the Department of National Health (Aucamp and Vivier, 1990).

Total coliforms up to 66 organisms/100 mℓ were tested with geometric mean values of not higher than 9 organisms/100 mℓ in the supplies of the affected group. In the same supplies faecal coliforms were tested with geometric mean values not exceeding 2 organisms per 100 mℓ with range peaks of up to 27 organisms/100 mℓ.

In all the water supply categories heterotrophic bacteria levels showed geometric mean values of less than 10 000 organisms/1 mℓ. This was below the maximum low-risk limits proposed by the *Proposed Water Quality Criteria in South Africa* from the Department of National Health (Aucamp and Vivier, 1990). However in water supplies used by affected families, peaks of up to 40 000 organisms/1 mℓ were tested. Water supplies used by non-affected families which were tested, showed peaks marginally exceeding the 10 000 organisms/1 mℓ level.

TABLE 1 GEOMETRIC MEAN LEVELS OF INDICATOR ORGANISM TESTS IN SUPPLIED MUNICIPAL WATER						
Municipal water supply	**Samples: = n**	**Total coliforms /100 mℓ (100/100 mℓ)****	**Faecal coliforms /100 mℓ (10/100 mℓ)***	**Heterotrophic plate count /1 mℓ (10 000/1 mℓ)****	***C. perfringens* /100 mℓ (10/100 mℓ)****	**Somatic coliphages /1 mℓ (100/100 mℓ)***
Bulk supply	n = **8**	**3**	**<1**	**3 100**	**<1**	**<1**
Water supply	n = **29**	**4** (0 - 11)	**<1** (0 - 3)	**3 776** (0 - 25 000)	**<1** (0 - 3)	**<1**
Affected group	n = **74**	**9** (0 - 66)	**2** (0 - 27)	**6 608** (0 - 40 000)	**1** (0 - 7)	**<1**
Non-affected group	n = **26**	**4** (0 - 54)	**1** (0 - 18)	**1 065** (0 - 10 167)	**1** (0 - 3)	**<1**

* Maximum low-risk indicator organism limits proposed by *South African Water Quality Guidelines* (DWAF, 1993).
** Maximum low-risk indicator organism limits proposed by *Water Quality Criteria in South Africa* of the Department of National Health (Aucamp and Vivier, 1990).
Counts: Geometric means of organism levels = *upper line*. Ranges of organism levels = *lower line*.

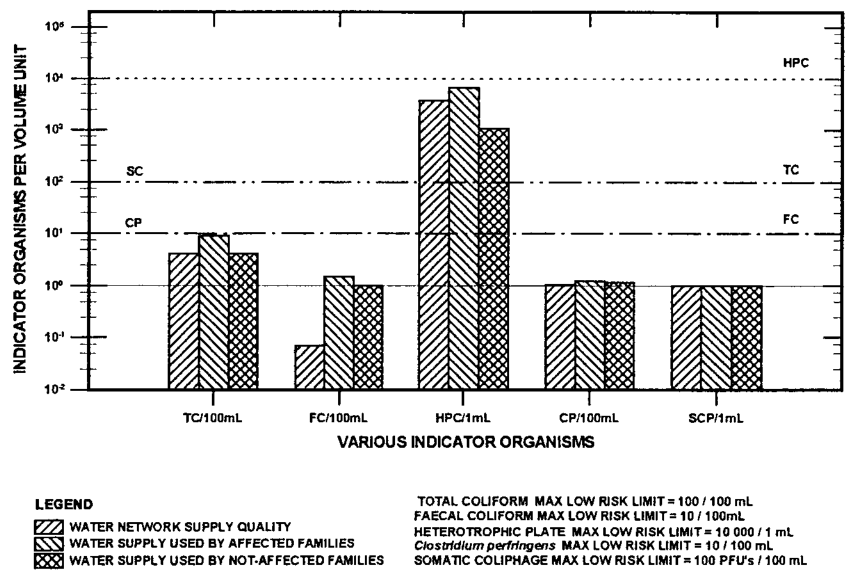

Figure 1
Indicator organisms levels tested in water supply

C. perfringens tests gave mean values of =1 organism/100 mℓ in all the water supply groups with the highest count of 7 organisms/ 100 mℓ in water by affected families. Somatic coliphages were not found in any of the samples.

Stored water quality (Table 2 and Fig 2)

Indicator organisms in the stored water supplies used by affected and non-affected families are shown in Table 2. In stored water used by both groups total coliform tests gave geometric mean values of 1 578 (affected) and 415 (non-affected) organisms/ 100 mℓ respectively. Peaks of up to 81 333 organisms per 100 mℓ were shown.

Faecal coliform tests showed peaks of 18 333 (affected) and 67 (non-affected) organisms/100 mℓ and mean values of 1207 organisms/100 mℓ for affected and 6 organisms/100 mℓ for non-affected families respectively.

Geometric mean values for heterotrophic bacteria were 85 288 organisms/1 mℓ in water stored in affected households and 25 047 organisms/1 mℓ in water stored in non-affected households. The highest range of peaks was found in stored water used by affected families. In stored water used by affected families, *C. perfringens* were found in all samples, ranging from less than 1 to 16 organisms/100 mℓ. Somatic coliphages were not found in any of the samples.

TABLE 2 GEOMETRIC MEAN LEVELS OF INDICATOR ORGANISM TESTS IN STORED WATER SUPPLIES						
Container water supply	**Samples: = n**	**Total coliforms /100 mℓ (100/100 mℓ)****	**Faecal coliforms /100 mℓ (10/100 mℓ)***	**Heterotrophic plate count /1 mℓ (10 000/1 mℓ)****	***C. perfringens* /100 mℓ (10/100 mℓ)****	**Somatic coliphages /1 mℓ (100/100 mℓ)***
Affected group	n = **74**	**1 578** (0 - 81 333)	**1 207** (0 - 18 333)	**85 288** (0 - 400 000)	**2** (0 - 16)	**<1**
Not affected group	n = **26**	**415** (0 - 10 000)	**6** (0 - 67)	**25 047** (0 - 150 000)	**1** (0 - 13)	**<1**

* Maximum low-risk indicator organism limits proposed by *South African Water Quality Guidelines* (DWAF, 1993).
** Maximum low-risk indicator organism limits proposed by *Water Quality Criteria in South Africa* (Aucamp and Vivier, 1990).
Counts: Geometric means of organism levels = *upper line.* Ranges of organism levels = *lower line.*

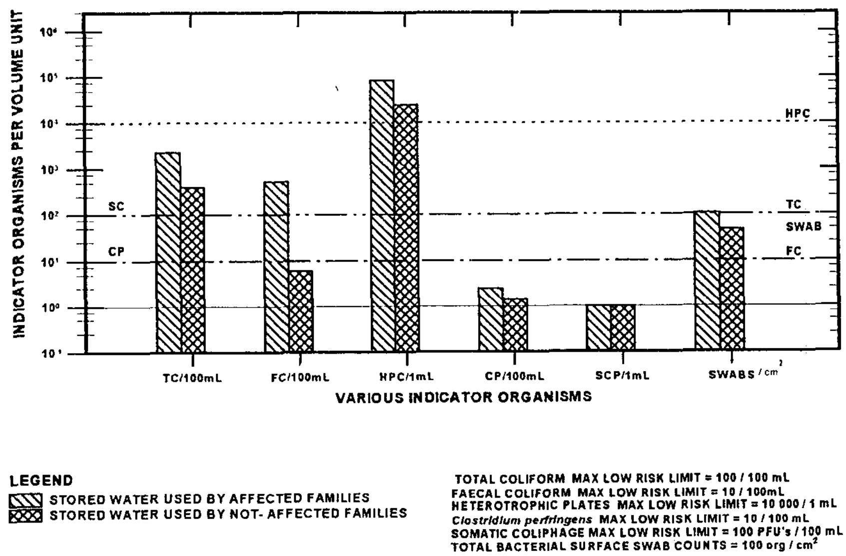

Figure 2
Indicator organism levels shown in stored water supplies used by the affected and non-affected families

Container hygiene (Table 3 and Table 4)

The results of swabs taken from the inner surfaces of the stored water containers used by affected families are shown in Table 3. The geometric mean counts of total bacteria were 107 organisms/cm^2 with peaks of up to 499 organisms/cm^2. Swabs taken from the inner surface of the stored water containers used by non-affected families gave mean values of 47 organisms/cm^2 and peaks of up to 120 organisms/cm^2.

Table 4 shows that 74% of affected households stored domestic water in open containers. This means that only 26% of these affected families stored water in closed screw-top containers. Of the non-affected families, 46% stored water in closed, and 54% in open containers.

TABLE 3 BACTERIAL COUNTS OF SURFACE SWABS TAKEN FROM INNER SURFACES OF STORAGE CONTAINERS (FIG. 2)		
	Affected group	**Non-affected group**
Swabs	n = **74** **107** (3 - 499)	n = **26** **47** (4 - 120)

Counts: Geometric means of organism levels = middle line. Ranges of organism levels = lower line.
n Values = Number of samples taken.

TABLE 4 CONTAINERS USED TO STORE DOMESTIC WATER SUPPLY				
	Affected group		Non-affected group	
Containers	Open-ended	Closeable screw top	Open-ended	Closeable screw top
Total	n = 51 (74 %)	n = 18 (26 %)	n = 14 (54 %)	n = 12 (46 %)

Discussion

Tests by the water utility on the bulk water supply delivered to the local authority consumer water network indicated no faecal contamination in the supply. Heterotrophic plate counts were at levels indicating low risk. Model viruses and organisms indicating spore- and cyst-forming pathogens were all at acceptable levels. This indicated that the microbiological quality of the bulk water supply was, although not ideal in terms of the heterotrophic plate counts, generally suitable for domestic use in the supply area.

Indicator organism counts tested in the general network water supply and water from samples taken at taps used by affected and non-affected families indicated a negligible risk due to microbiological quality. Tests did indicate limited instances of faecal and other forms of microbiological contamination in sections of the water network. These contaminations did not recur in follow-up tests. This indicated that the water network in the area could have been subjected to pollution from unknown sources at the time of sampling. According to the *South African Water Quality Guidelines* (Department of Water Affairs and Forestry, 1993) and *Proposed Water Quality Criteria in South Africa*, of the Department of National Health (Aucamp and Vivier, 1990), these counts indicated no possible negative effects on the health of the consumer unless long-term exposure to such water quality (should not occur for more than 12 d/yr) prevailed. In this study, long-term exposure did not occur.

Levels of indicator organisms were markedly higher in container water supplies (used by both groups) than in the network water supply. Total and faecal coliforms as well as heterotrophic bacteria levels in stored water used by the case study and control group in both instances exceeded maximum low risk limits proposed by the *SA Water Quality Guidelines* (Department of Water Affairs and Forestry, 1993) and *Proposed Water Quality Criteria in South Africa*, of the Department of National Health (Aucamp and Vivier, 1990). These guidelines provide criteria for the quality of domestic water used directly from a water supply network by consumers and are generally used to indicate hygienic water quality of the supply in the network itself. In this study, limits from the above-mentioned guidelines were used to indicate the hygiene status of water quality stored in containers at home. Total and certain species of the faecal coliforfn group, other than *E. coli*, may readily grow in water (Sjogren and Gibson, 1981). *E. coli* was not tested for in water samples in this study. It can therefore not be certain that the high levels of total and faecal coliforms in container water were indeed due to contamination of faecal origin.

It is evident that the quality of supplied water deteriorated rapidly in containers due to the circumstances surrounding haulage, storage and handling of such water from the water supply point until used by consumer. This was probably because water was generally hauled in open uncovered containers, and carried or pushed by wheelbarrow back to the houses. During collection, water was exposed to the environment or surrounding conditions, especially on the way home. The supplied water may have been contaminated by en-route environmental input such as dust. This water is also subjected to careless handling and haulage. At home the water containers were generally stored either on a table at a window or on the floor underneath the table. Open containers were generally left uncovered. Flies were often observed at the water line inside open containers.

The methods of extracting/obtaining water from a container also indicated possible contamination of such water. In most of the cases water is scooped with a mug kept uncovered somewhere in the vicinity of the container. Such a mug was generally exposed to unhygienic conditions, such as flies, dust and unwashed hands of consumers.

Lower indicator organism levels were found in stored water used by non-affected families than those used by affected families. This could be due to the difference in handling and storing supplied water between the two groups. The majority of non-affected families tended to store water in closeable screw-top containers, while a much larger majority of affected families stored water in open-ended uncovered containers. The water stored by affected households is more exposed to surrounding conditions, therefore posing a greater contamination potential.

Swabs taken from the inside wall surfaces of containers generally yielded higher total bacterial counts than the limits posed in Regulation R185. A maximum of 100 colony-forming units of bacteria/1 cm^2 is the hygiene limit imposed by Health Act (Act 63 of 1977) Regulation R185: *Regulations regarding the standards to which processing areas, facilities, apparatus and equipment where, or in which, or with which, food, intended for use by the final consumer, is processed, handled or prepared for purposes of sale to the public, shall conform* (Republic of South Africa, 1977). Although this Regulation R185 (Republic of South Africa, 1977) is generally used by environmental health practitioners to assess the status of hygiene of the preparation surfaces on food-handling premises, it was used, in this study, as a guideline to indicate the hygienic condition of the inside walls of containers.

In some of the cases the containers, after standing empty during the night, were rinsed only with water at the tap before filling. The containers were generally not cleaned and disinfected thoroughly. This could have contributed to the high swab counts. Swab counts from the containers used by affected households were generally higher than swabs from non-affected households. The difference in swab-counts may have been due to non-affected households using more closeable screw-top containers. This may have lowered exposure to the influence of the environment (dust, flies), on stored water quality. It may also indicate that members of the non-affected households handle their containers in a more hygienic manner than those from the affected households.

Conclusion

The relatively small sample size of the case study does not facilitate intensive statistical verification of the above results. However, indications are clear that water used from containers at home was not of the hygienic quality one would expect from a well-controlled source of in-house running water. Results indicated that methods of haulage and handling stored water, including unhygienic containers, were more likely to contribute to causes of diarrhoea in households subjected to this system, rather than water in the supply reticulation. Systems of water supply through public standpipes force haulage and storage of water in containers by households. By implication, this may be conducive to conditions that could lead to enteric disorders in consumer groups. Further research will be needed to investigate the health impacts of a broader spectrum of social habits and unknown aetiological agents produced from environments such as food and water, poor sanitation as well as personal hygiene patterns of populations in a low sosio-economic urban development.

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