The effect of a water-hygiene educational programme on the microbiological quality of container-stored water in households

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Abstract

This study investigated whether a water-handling hygiene education programme could improve the health-related microbiological quality of container water stored and used in households in a dense urban settlement in the Free State Province. Previous studies in the area indicated that stored container water became contaminated during the process of fetching from communal standpipes and then storing and handling the water at home, which exposed the study population to a potential risk of microbiological infection. A water-hygiene education programme was implemented together with a health-related microbiological water quality assessment programme. Members of selected households participated in a series of domestic water-handling hygiene education training sessions over a period of eight months and the quality of their stored water monitored for improvement in tandem over the same period. The results were compared to those of similar tests done during previous studies in the same area. Turbidity, heterotrophic bacteria numbers and total coliform bacteria were used as indicators of general microbial water quality while *E. coli* bacteria were used to indicate faecal pollution. While the results generally reflected significant improvements for all the indicators from the previous studies, a potential risk of infection was still indicated for consumers. Based on education programme attendance profile, the study sample was divided into **frequent, intermittent** and **never** groups. No significant changes were found in water quality between the three groups, even though the **frequent** group attended most of the training sessions. This implies that the programme did not have a particular influence on any one group. Container-stored water was still being contaminated in the domestic environment despite the water-handling hygiene education programme. An improved hygiene-education programme appears to be needed to change deep-rooted inherent behaviours such as hand- washing prior to water handling as well as proper protection of container-stored water from environmental contamination.

Keywords: Water-hygiene education, container-stored water quality, turbidity, heterotrophic bacteria, total coliforms, *E. coli*, infection risk

Introduction

In many developing areas of South Africa, microbiologically safe water is supplied to communities at communal taps. Studies have shown that collecting water from these taps, as well as storing it in, and handling it from containers at home cause quality deterioration to such an extent that the water poses potential risks of infection to consumers (Jagals et al., 1999; Medical Research Council, 1999). During storage and handling at home, people contaminate water with pathogenic micro-organisms (Pinfold, 1990). To ensure that consumers get maximum health benefit from water supply improvement programmes, domestic water-storage and -handling practices must therefore be addressed (Cartwright, 1998).

One way to improve water-handling practices is by promoting water-handling hygiene (Coulson, 2000). A strong pillar of hygiene promotion is hygiene education (International Water and Sanitation Centre, 2001). Hygiene education aims to change people's behaviour into positive hygiene practices which, in the context of domestic water hygiene, includes regular hand-washing and proper collection, storage and handling of water (Kaltenthaler and Drasar, 1996; Coulson, 2000). In other words, where people have to collect water from communal taps, sound hygiene practices should be taught and maintained to ensure that the way people store and use water at home, does not endanger their health (Mintz et al., 1995). The aim of this study was therefore to determine whether teaching people proper domestic stored-water handling as well as general container hygiene would significantly improve poor health-related quality of their household water.

During this study, members of a community were involved in an intense short-term education programme on domestic water hygiene practices, and their container-stored water quality assessed to determine whether the programme would bring about positive changes in the water quality. These members were selected on the strength of earlier participation in related studies done in the same area on general domestic hygiene (Theron, 2000) as well as the microbiological quality of stored water assessed by Bokako (2000).

Methodology

The study consisted of two components, that is, a water-hygiene education programme and a health-related microbiological water quality assessment programme. The education programme involved the selected group of household members in learning-actions to improve their domestic water-handling practices. The water-quality programme measured the effect of the educational hygiene programme had on the quality of stored water in the participant households.

The study was conducted in a residential suburb of Botshabelo in the Free State Province, South Africa. The area had approximately 3 100 households (Theron, 2000). People access the mu-

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Received 29 October 2002; accepted in revised form 26 February 2003.

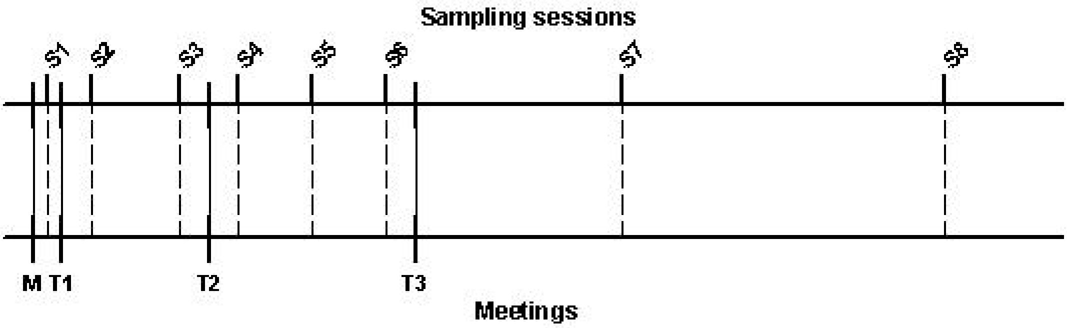

Figure 1
Meeting- and sampling-frequencies

nicipal supply of treated water at communal standpipes on average 80 m (range 10 to 300) from their houses (Jagals et al., 1997). Of 300 households that had constantly returned the poorest microbiological water quality results, as well as being observed practicing poor domestic stored-water hygiene during the previous studies, 80 were non-randomly selected to participate. Because female members are predominantly concerned about health matters of households (Theron, 2000), at least one senior female member of each of the selected households was invited to participate.

Hygiene education

The selected household members were invited to participate in the hygiene programme that consisted of one informative meeting (M1) followed by three training sessions (T1-3). The training sessions were conducted in an interactive manner according to guidelines of the Participatory Hygiene and Sanitation Transformation (PHAST) methodology proposed by World Health Organisation (WHO, 1998).

Meeting M1 focused on feed-back from outcomes reported in the previous studies by Bokako (2000) and Theron (2000). During T1, the study-group identified positive and negative water-hygiene practices from their respective households. These were translated into including practical sessions on container hygiene. T2 focused on preventative measures to control the negative practices and ways of implementing measures of improvement, which included advanced practical sessions on container hygiene. During T3 group discussions evaluated the whole programme - in particular focusing on which practices were easy to change within the short time of the programme, as well as those practices that were difficult to adjust on such a short time scale.

An attendance list monitored participants' involvement during each education (training) session. It quickly became apparent that not all selected households in the study sample were continually represented. This phenomenon alluded to the research aim and raised the question on whether water quality in containers of the households that frequently attended would show significant improvement over that of the group that never attended. The potential participants were therefore grouped into three namely *frequent*, *never* and *intermittent.* The *frequent* group consisted of household members that attended the first informative meeting as well as at least two training sessions. Members of the *intermittent group* attended one to two sessions while none of the *never* group attended any session.

Stored-water quality assessment

The water quality-assessment programme consisted of eight sampling sessions (S1-8) and was implemented in tandem with the training sessions (Fig. 1).

Ideally the sampling sessions should have been done on a more regular basis (e.g. once a month) with two sampling sessions fitted in between each training session (intended to be conducted every two months). Such a symmetrical programme design was prevented by circumstances such as the social events on the community calendar as well as availability and accessibility of meeting venues. Instead, the sampling sessions and meeting / training sessions were fitted in whenever the majority of the selected members indicated that they were ready – something that did not happen within even periods.

Container-stored water samples were collected (from each of the 80 households initially listed as participating, whether attending or not) at intervals indicated in Fig. 1. To reflect realistic container-contaminant loads, a brushing technique, reported by Bokako (2000), was used to dislodge biofilm, assumedly with entrapped micro-organisms, from the inner sidewalls of containers and suspending it in the container water. Samples of the suspension were taken in sterile Whirl Packs® and analysed within 6 h.

Infection-risk limits from the *Assessment Guide Volume 1: Quality of Domestic Water Supplies* (Water Research Commission (WRC), 1998) as well as from the *South African Water Quality Guidelines for Domestic Use* (DWAF, 1996), were the guidelines used for water quality assessment.

Indicators of general microbial quality

A combination of turbidity measurements, heterotrophic bacteria numbers as well as total coliform numbers measured the level of particulate and microbiological contamination caused by the suspended material in the container-stored water.

- *Turbidity* (Turb): This test measures the concentration of suspended matter in water. Changes in the turbidity levels in the container water were assumed to be changes brought about by dislodged particulate matter, and therefore reflected increases or decreases in biofilm formation. In the context of this study, increased biofilm was an indicator of contaminant build-up in containers and therefore an indication of hygiene efficiency. A HACH 2100 turbidity-meter was used to measure turbidity levels in nephelometric turbidity units (NTUs).
- *Heterotrophic bacteria:* The numbers of these were expressed as heterotrophic plate counts (HPC), which indicated the general microbial quality of the container-stored water. The quality was assumed to be influenced by the level of contamination caused by container biofilm as well as other bacteria introduced from the domestic environment during water-handling. The pour-plate HPC-technique enumerated the heterotrophic bacteria numbers (*Standard Methods*, 1998). Petri-plates, containing HPC agar (*Standard Methods*, 1998) and 0.3 ml aliquots of sample (diluted in series) were inverted and incubated aerobically at 35°C for 48 h. All visible colonies on each plate were counted and expressed in number of micro-organisms per 1 ml.

TABLE 1
Before and after turbidity levels (in NTUs) as well as indicator bacteria numbers ($\log_{10}$) detected in container water used by the study population

	Statistical variables	Turbidity >1 NTU = Secondary health effects possible (WRC, 1998)	Heterotrophic bacteria >1 000/1 mℓ = indicative of after-growth in distribution systems (DWAF, 1996)	Total coliforms >10 / 100 mℓ = clinical infections in sensitive groups expected (WRC, 1996)	*Escherichia coli* 0 detectable in 100 mℓ (WHO, 1997)
Before education intervention	n	145	132	124	151
	Median	1.88	6.06	2.49	<1(Log -1)
	25th Percentile	1.14	2.65	1.41	<1(Log -1)
	75th Percentile	3.27	6.91	3.59	<1(Log -1)
	At the 95th percentile	Exceeded guideline	Exceeded guideline	Exceeded guideline	Exceeded guideline
After education intervention	n	640	640	640	640
	Median	0.17	4.91	1.39	<1(Log -1)
	25th Percentile	0.13	3.46	0.38	<1(Log -1)
	75th Percentile	0.22	6.75	2.66	<1(0)
	At the 95th percentile	Exceeded guideline	Exceeded guideline	Exceeded guideline	Exceeded guideline
Comparing before and after data **Mann-Whitney Rank Sum Test**		Significant difference ($P < 0.001$)	Significant difference ($P < 0.001$)	Significant difference ($P < 0.001$)	Significant difference ($P < 0.001$)

* All results that recorded zero as well as log-negative values are indicated as <1

- *Total coliforms (TC):* For this study, TCs indicated the hygienic quality of water (*Standard Methods*, 1998; Grabow, 1996) and therefore provided useful information on environmental contamination of water stored in household containers (Jagals et al., 1997). TCs were cultured using the membrane filtration technique and the defined substrate medium Chromocult® Coliform Agar. This particular selective medium is used for simultaneous detection of TC and *E. coli* in the same water samples (Jagals et al., 2001; Merck, 1996). Counts of red to salmon-coloured colonies were expressed as TC colony-forming units (CFU) per 100 mℓ (WRC, 1998).

Indicator of hazardous microbiological pollution

Escherichia coli (E. coli) specifically measured the extent of faecal pollution that might contribute to poor health-related microbiological water quality (WHO, 1997; Grabow, 1996). *E. coli* (EC) indicate whether micro-organisms introduced from the domestic ambit were of faecal origin, e.g. people handling water with unwashed hands after visiting the toilet (Jagals et al., 1999). The membrane filtration technique and Chromocult® Coliform Agar was used to culture EC. Numbers of dark-blue to violet colonies were expressed as *E. coli* CFU per 100 mℓ.

Results and discussion

Table 1 compare the general health-related water quality before (Bokako, 2000) and after (this study) intervention. The information in Table 1 implies that the educational intervention had been effective in encouraging people towards keeping their containers in such a sanitary state, as well as handling domestically-stored water in such a way, that health risks posed by consuming the water are eventually kept at a minimum.

The significant difference in the turbidity levels suggests lower levels of suspended particulate matter, which reflected less dislodged biofilm from container walls during scrubbing, thereby indicating increased cleaning and rinsing of containers since the time Bokako had done her study. The significantly lower numbers of heterotrophic bacteria and total coliforms support this. Nevertheless, the general water quality, still exceeded the various risk limits in guidelines at the 95th percentile (suggested by DWAF, 1996), even for *E. coli*, where these organisms were often not cultured.

While it appears that households in the community have been maintaining their containers in an improved sanitary condition in more recent times, the question of whether the water quality of the frequent attendees (to the training programme) improved significantly over those who did not attend frequent, still remained as well as a further question whether it was indeed the educational programme that had caused the improvement in water quality. The water quality assessment results for the three study sample groupings were therefore compared. Figures 2 to 5 show that the results for all four indicators did NOT differ significantly.

General discussion

In general the results indicated that the container hygiene of the selected households improved. Less biofilm formed as indicated by reduced turbidity, heterotrophic bacteria as well as total coliforms numbers. This improvement could be interpreted as an increased awareness towards maintaining containers in a more hygienic state. This change appeared NOT to have been brought about entirely by

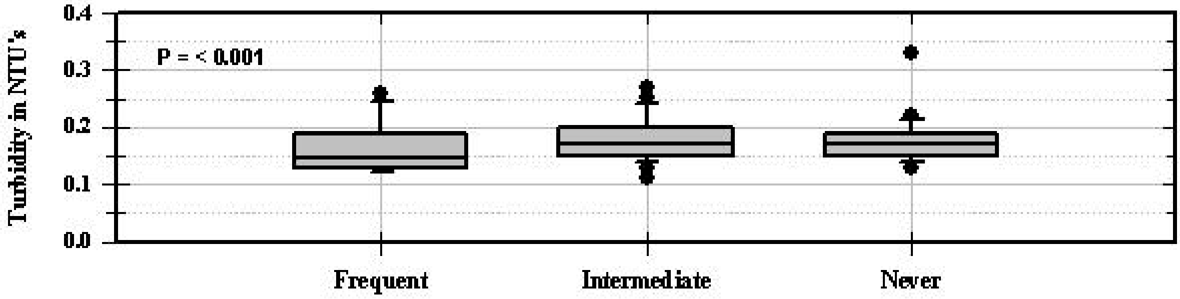

Figure 2
Comparing turbidity levels measured in the container-stored water of the study groups

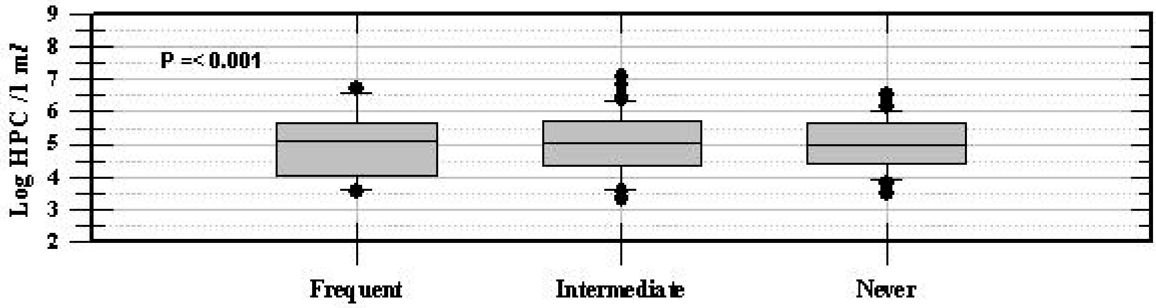

Figure 3
Comparing heterotrophic bacteria numbers detected in the container-stored water of the study groups

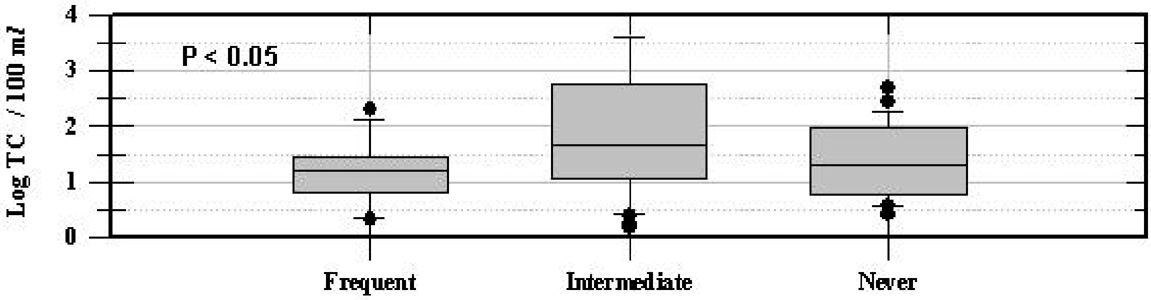

Figure 4
Comparing total coliform numbers detected in the container-stored water of the study groups

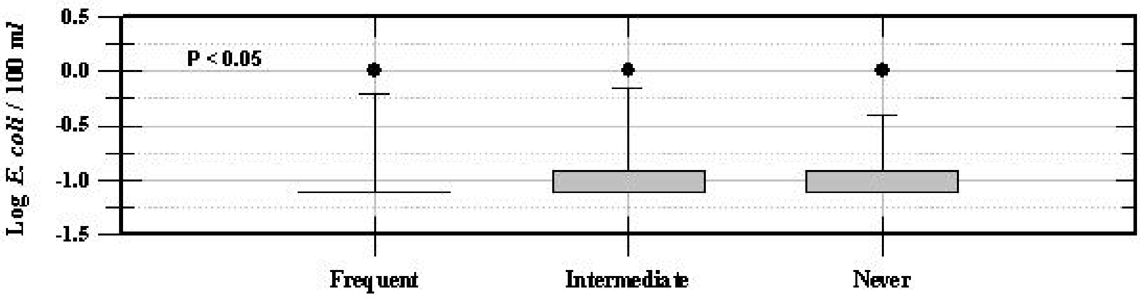

Figure 5
Comparing E. coli *numbers detected in the container-stored water of the study groups*

the training programme. Since the Bokako study (1998/99), several activities to increase community awareness have been implemented in the area, e.g. by Dywili and Jagals (1999).

Households appear to have adapted water handling routines to include more container-rinsing at the tap and more thorough washing of containers before refilling this resulted in less biofilm formation (indicated by the reduced turbidity levels). The biofilm that did form still remained an important source of heterotrophic bacteria (Bokaka et al., 2000), maintaining the heterotrophic numbers at excessive levels. Another important probability of the excessive heterotrophic bacteria levels was introduction into the containers from the domestic environment. High levels of heterotrophic bacteria in water can be caused by exposure of water to the atmosphere (Environmental Protection Agency, 2001). This implies that heterotrophic bacteria were still prominent because of biofilm formation as well as introduction into storage containers, probably during poor storage and handling practices. This was an indication that all three groups, despite maybe washing and rinsing their containers more frequently, still practiced poor hygienic handling of water from and in the containers during domestic chores.

A negative outcome of the study was that *E. coli* numbers were, at the 95th percentile, still higher than the WHO (1997) risk limit, even with the cleaner containers. While *E. coli* are sporadically found in distribution systems (container transported systems are also distribution systems), and also in low numbers in biofilm, even when water is adequately treated (Parent et al., 1996), the periodical faecal pollution of container-stored water can be associated with poor personal hygiene practices as well as unhygienic domestic environments (Mintz et al., 1995).

From similar studies conducted in other areas (WHO, 2001; Byers, 1996), it has been reported that behavioural changes are complex and that hygiene education alone may not be sufficient to change people's behaviour. This study had similar findings. The water-hygiene education (training) programme did not contribute significantly to behaviour change, which in turn, did not bring about expected improvement in the water quality.

Conclusion

It appeared as if the training programme and preceding activities were more successful in raising awareness (cleaner containers), than changing deep-seated behaviours or practices such as hand-washing with the limited quantities of water stored at home (leading to faecal contamination of container-stored water). Although container hygiene appeared to have improved, stored water still posed a potential risk of infection even after the educational programme.

The ideal objective should be that household members should store and use water in a hygienic manner, even in substandard dwelling structures where domestic environmental conditions are conducive to container-stored water contamination.

It is suggested that further projects of this nature could focus on:

- Raising awareness, thereby achieving more rapid results in terms of positive hygiene effects, e.g. cleaner containers, which is a readily achievable and sustainable target.
- Changing deep-seated behaviours in people, such as washing of hands after toilet visit (and before handling container-stored water), through sustained training (education) that could be extended from the home to schools and the workplace.
- Water-hygiene education programmes that are implemented concurrently in areas where water infrastructure improvements are being implemented, especially where the tap-to-glass sequence has intermediate elements such as fetching water in containers and storing and using it from these at home.

Acknowledgements

The authors wish to thank the National Research Foundation (NRF) for the support of this research project. The contributions of the Technikon Free State (facilities) as well as those by senior research students in the Unit for Water and Health (TFS) are gratefully acknowledged.

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