Technical note

Evaluation of the impact of household treatment procedures on the quality of groundwater supplies in the rural community of the Victoria district, Eastern Cape

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Abstract

The rural community in the Victoria district, Eastern Cape, uses groundwater from boreholes for drinking and other domestic purposes. The brackish taste of the water has been the major complaint from this community. In this study, the physicochemical and microbiological quality of the groundwater supplied to the community as well as the household treatment procedures which can be easily used to improve water quality standards were evaluated. For the physicochemical quality, salinity was the sole parameter of concern. The indicator bacteria were analysed using the membrane filtration technique. The bacteria detected were heterotrophic, total coliform, faecal coliform, and faecal streptococci. Total coliform counts were high in general and faecal coliforms were often detected and confirmed to be *Escherichia coli* by the indole test. The overall microbiological quality of the water was either poor or unacceptable according to South African standards. Both boiling and household bleaching succeeded in achieving the microbiological drinking water quality standards without much improvement on salinity or total hardness. Five minutes boiling could be recommended compared to household bleaching since, in addition to significantly improving the microbiological quality, it also slightly changed the salinity and total hardness by the precipitation of calcium carbonate.

Introduction

Many developing regions suffer from either chronic shortages of freshwater or the readily accessible water resources are heavily polluted. According to the World Health Organisation (WHO), a large portion of the population in developing countries live in rural and suburban areas where conventionally treated drinking water is generally unavailable (WHO, 1993). South Africa, like most developing countries, is experiencing rapid population growth. Accelerated population growth coupled with impoverished socio-economic development with limited water resources and poor sanitation, leads to an increase in diseases associated with poor living conditions among which water-related and water-borne diseases play a major role.

In the Eastern Cape, especially in the Victoria district, the majority of the rural community get their drinking water supply from groundwater sources. The water is drawn from the boreholes and distributed to the community without any prior treatment. People from this rural community often complain that the water tastes brackish which is normally an indication of poor quality, especially of high salinity.

Background

Groundwater

Groundwater supplies have some advantages over surface water. Groundwater is generally of a more uniform character and relatively free from harmful bacteria. Moreover, a groundwater supply can be easily developed at a small capital cost (Raghunath, 1982). Groundwater can, however, be contaminated as a result of poor solid, liquid and sanitary waste practices. Defective well construction and failure to seal abandoned wells as well as poor groundwater production management are also responsible for pollution. Contaminated groundwater can still appear clear and yet contain pathogenic organisms; visual evaluation should therefore be avoided. Bacteria in the liquid effluents from the septic tanks and cesspools, to name a few, are likely to contaminate shallow groundwater aquifers if poorly constructed or located with respect to the production borehole. Furthermore, the presence of a shallow or perched aquifer increases the risk of contamination (Pontius, 1990).

Physical chemistry

There are many physicochemical parameters of interest for water quality assessment. Some of the easily determined ones include temperature, pH, turbidity, salinity, hardness, nitrates, phosphates and certain trace elements. Temperature has a marked influence on the chemical and biochemical reactions that occur in the water body. High temperature, for instance, increases the toxicity of many substances such as heavy metals and pesticides. It also increases the sensitivity of living organisms to toxic substances (Dojlido and Best, 1993). Hydrogen ion concentration (pH) in water has an important influence on living organisms and the surrounding environment of the water. Low pH, for example, accelerates the corrosion of metals as indicated by the corrosion index. The permissible pH range varies between 6.5 and 8.5 for the WHO and between 6 and 9 for South Africa. Turbidity in water is caused by the presence of suspended matter which scatters and absorbs the incoming light. The variety of sources, character and size of suspended solids means that the measurement of turbidity gives only an indication of the extent of pollution. The WHO and

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South African maximum permissible level for turbidity is 5 mg/ℓ as SiO_2. The normal concentrations of sodium salts in potable water are usually less than 200 mg/ℓ. No health-based guideline value has been proposed in this regard. However, concentrations in excess of 200 mg/ℓ may give rise to unacceptable taste. Hardness in water is caused by dissolved calcium and, to a lesser extent, by magnesium. Acceptable hardness ranges between 100 and 200 mg $CaCO_3$/ℓ. Hardness of above 200 mg/ℓ can result in scale deposition, particularly on heating. Soft waters with a hardness of less than 100 mg/ℓ have a low buffering capacity. It has been suggested that the intake of very soft waters may have an adverse effect on mineral balance (Dojlido and Best, 1993; WHO, 1993; DWAF, 1996).

Naturally occurring nitrates in groundwater vary generally from zero to a few milligrams per litre. An increase of nitrates in groundwater is often associated with farming or poor sanitary activities. Neither nitrates nor nitrites act directly as a carcinogen in mammals. The WHO guideline value for nitrate in drinking water (i.e. 50 mg NO_3/ℓ) is established solely to prevent methaemoglobinaemia which is lethal in babies and whichdepends on the conversion of nitrate to nitrite. Phosphates, in the concentrations that occur in natural waters, are not harmful to health. The main concern is the growth of algae, the blue-green algae in particular, which can produce toxins as a by-product of photosynthesis in water supply reservoirs (Dojlido and Best, 1993; WHO, 1993). The trace elements of interest in drinking water of non-industrial areas are cadmium and lead. Levels of cadmium in drinking water are usually less than one microgram per litre. When consumed, cadmium accumulates primarily in the kidneys and has a biological half-life in humans of 10 to 35 years. A WHO guideline value for cadmium of 0.003 mg/ℓ is established on the allocation of 10% of the provisional tolerable weekly intake of drinking water. Lead, when consumed, accumulates in the skeleton. Infants, children of up to six years of age, and pregnant women are the most susceptible to its adverse health effects. Lead is toxic to both the central and peripheral nervous system, including subencephalopathic, neurological and behavioural effects (WHO, 1993).

Bacteriological background

Micro-organisms' threat to the safety of drinking water is a growing peril even in industrialised nations that have long regarded themselves as immune to widespread water-borne illnesses so common in developing countries (Young, 1996). The most common and widespread health risk associated with drinking water is contamination by human or animal faeces. Routinely, it is impossible to test the water supply for all pathogens related to waterborne diseases because of the complexity of the testing, the time and cost related to it. It is therefore preferable to use indicator systems, which are able to index the presence of pathogens and related health risks in water. At present, there is no absolute indicator which complies with all the criteria. Traditional indicators of drinking-water quality include the coliform group and the heterotrophic plate count. The microbiological drinking water guidelines aim at ensuring both the protection of human health and the evaluation of the treatment efficacy. This is why more than one indicator organism is often needed (LeChevalier and McFeters, 1985; Genthe and Seager, 1996). Coliforms are allochthonous to the water environment. They become easily injured due to exposure to stresses. Injury is reversible under proper conditions of temperature and nutrients. Sources of injury include disinfectants, ultraviolet radiation, environmental factors (e.g. heat, freezing and sunlight) and biological interactions (LeChevalier and McFeters, 1985).

The quality of drinking water is a complex issue. Although drinking-water quality standards may vary from country to country, the main objective remains the prevention of any harmful health impact on the consumers. Due to the scarcity of freshwater, tap water may be erroneously regarded by many rural people to be a panacea and concerns regarding its safety as less pressing or even irrelevant. It is, however, important to note that there are many potential sources of water contamination in the rural areas due to limited environmental awareness. A rural community should be empowered with alternative means to treat drinking water in order to meet the challenges of providing safe water for every home. Although there are many household water treatment methods known to date, there is a need to evaluate, redefine and simplify these procedures according to the realities of each community.

Objectives of the study

The purpose of this study was twofold. Firstly, to examine the physicochemical and microbiological quality of the groundwater supplied to the rural community in the Victoria district, Eastern Cape, South Africa. Secondly, to select one of the groundwater sources to evaluate and redefine two household treatment procedures which can be used easily as well as cost-effectively by the rural community to achieve water safety standards.

Materials and methods

Study sites

The study was carried out in three different villages in the Victoria district of the Eastern Cape, namely Krwa-krwa, Ngqele and Khayamnandi. All the above villages use groundwater for drinking. At Krwa-krwa, the borehole is located within the residential area whereas at Ngqele and Khayamnandi, they are on the outskirts of the residential area. In general, the water is drawn from the borehole using electric power and pumped into a storage tank made of cements or bricks situated on a hill. The storage tank in Khayamnandi was regularly left open and the residents often drew water directly from the top of the tank. In Krwa-krwa and Ngqele, the storage tanks, although sealed, were found to be covered by some greenish film layer indicating a poor maintenance of this valuable resource. In all the three villages, the water from the storage tank goes into the distribution system without any prior treatment or quality monitoring.

Collection of water samples for physicochemical and microbiological analyses

The water samples were collected fortnightly in each village using sterilised 1ℓ bottles. The samples were collected from the boreholes, storage tanks and stand-pipes. The samples were transported to the laboratory in cooling boxes to prevent high temperature shifts. The microbiological analysis was carried out immediately after arrival in the laboratory (within about 4 h including collection and transport to the laboratory).

Physicochemical analytical techniques

The physicochemical parameters examined were temperature, turbidity, pH, salinity, total hardness, nitrates, phosphates, cadmium, and lead. The temperature was measured on the sampling site using a thermometer. The turbidity was determined using a Hach 2100 P turbidimeter. The pH was determined using a micro pH 2000 pH-meter from Crison while salinity was assessed by the conductivity method. The conductivity was measured using WTW LF18 conductivity meter (WTW 82362 Weilheim, Germany). The conductivity readings in µS/cm were converted to salinity (mg NaCl/ℓ) using the following formula:

$$\text{Salinity (mg NaCl/ℓ)} = f_1 \, x\chi$$

Where χ is the specific conductivity in µS/cm and f_1 is the conversion factor (0.52 for concentration range of 0 to 100 mg NaCl/ℓ and 0.55 for range greater than 100 mg NaCl/ℓ) (Dojlido and Best, 1993).

Hardness, nitrates and phosphates were determined using the Nova 60 water analyser (Merck NT Laboratory supplies) while cadmium and lead were determined by atomic absorption spectrometry (Unicam analytical system 939/959 AA system). The standard solutions for atomic absorption determination of cadmium and lead were prepared using cadmium chloride and lead nitrate respectively. The cadmium chloride stock solution (1 mg/mℓ) was prepared by dissolving 0.204 g of cadmium chloride in 50 mℓ of hydrochloric acid and the volume made up to 100 mℓ with distilled water. From the above stock solution, 0.01, 0.03, 0.05 and 0.07 mg/ℓ standard solutions were prepared.

For lead determination, lead nitrate stock solution (1 mg/mℓ) was prepared by dissolving 0.16 g lead nitrate in 50 mℓ of nitric acid and the volume made up to 100 mℓ with distilled water. The stock solution was diluted to obtain the same standard concentrations as above.

Microbiological analytical techniques

The heterotrophic bacteria, total coliform, faecal coliform, faecal streptococci and injured coliform counts were performed using the membrane filtration technique. R2A, m-Endo Les, mFC, KF-streptococcus and mT7 agars were used for heterotrophic bacteria, total coliform, faecal coliform, and faecal streptococci counts respectively. All the media were from Difco laboratories (Detroit, Michigan, USA). The 100 mℓ water sample was filtered using 0.45 µm pore size, 47 mm diameter filter membrane. All the plates were incubated at 35°C for 24 h except mFC agar plates which were incubated at 44.5°C for 24 h. The indole test was performed on faecal coliform colonies to confirm the presence of *Escherichia coli* strains.

Evaluation of household treatment procedures for the achievement of water safety standards

Two water treatment procedures, namely, boiling and bleaching were evaluated. The water samples for this experiment were collected from Khayamnandi stand-pipe. Water from Khayamnandi was used in this study because of the three villages under consideration, it had the poorest quality. Water samples here were collected in sterile 20 ℓ plastic containers while sterile 2 ℓ glass flasks were used for the treatment systems.

Water treatment by boiling

Three different boiling times were tested (i.e. 1, 5 and 10 min) and 2 ℓ of water contained in 2 ℓ glass flasks were boiled for a determined time and allowed to cool down to room temperature. The supernatant was transferred into a sterile flask and the precipitate discarded. Microbiological and physicochemical analyses were done on the supernatant as described above immediately after cooling as well as 24 h after storage.

Water treatment by using household bleach

Household bleach, i.e. non-scented Jik (Reckitt & Colman South Africa (Pty) Ltd, Elandsfontein) was used in this experiment. A stock solution was prepared by diluting 3 mℓ of Jik in a sufficient volume of distilled water to make one litre. This gave a concentration of 105 mg/ℓ chlorine. From this stock solution, four different concentrations were prepared. The first 2 ℓ bottle was filled with 7.6 mℓ of the stock solution and made up to the mark to make a final concentration of 0.4 mg/ℓ. The second, third and fourth bottles were filled with 11.4 mℓ, 15.2 mℓ and 19.1 mℓ to make up final concentrations of 0.6 mg/ℓ, 0.8 mg/ℓ and 1.0 mg/ℓ respectively. The mixture was allowed to stand for 2 h after a thorough mixing. An untreated water sample from the same source was used as control. All the experiments on the evaluation of household treatment procedures were carried out in duplicate.

Results and discussion

Physicochemical results

The physicochemical parameters and the microbiological quality indicators of the groundwater samples from Krwa-krwa, Ngqele and Khayamnandi for two consecutive months (October and November 1998) are summarised in Tables 1 and 2 respectively. Water sampling and analysis were done on 21 October and 6 November 1998 respectively for both Krwa-krwa and Ngqele while for Khayamnandi, they were sampled on 31 October and analysed on 13 November 1998. The borehole in Ngqele was inaccessible, therefore not sampled but the water in the distribution system was sampled.

At Krwa-krwa, the turbidity was high compared to the standard, especially from the water sample collected on 21 October 1998. The fact that the water level in the storage tank was very low and the taps were dry could explain this high turbidity.

For both Krwa-krwa and Ngqele, the sodium chloride content estimated from electrical conductivity was approximately twice the standard value for potable water (WHO, 1993). The high salt content could account for the complaints by the residents of these areas that the water had a brackish taste. Groundwater samples from the above villages had a total hardness <100 and can better be described as soft waters. All the other parameters remained within the standard guidelines of both the WHO and South Africa.

At Khayamnandi, the sodium chloride content estimated from electrical conductivity of the groundwater was approximately threefold the WHO standard value. Contrary to the other two villages, the total hardness here was within the recommended range of 100 to150 mg/ℓ. This difference in the salinity as well as total hardness between Khayamnandi and the other two villages could be due to the differences in the geological environment in these areas (Raghunath, 1982). Krwa-krwa and Ngqele share probably the same geology since they are much closer to each other compared to Khayamnandi.

Cadmium and lead concentrations in all the water samples were relatively low compared to both the WHO and South African standards. This could be expected since there is no industrial activity going on around these areas.

With regard to the physicochemical parameters under consideration, groundwater from Krwa-krwa, Ngqele and Khayamnandi could be described in South African water classification terms as being of ideal water quality (Class blue) except for salinity, Cd and Pb. According to the latter, the water quality would be considered as poor (Class red). In Krwa-krwa and Ngqele, in addition to higher

TABLE 1
TEMPERATURE (°C), TURBIDITY (NTU), pH, SALINITY (mg NaCl/ℓ), TOTAL HARDNESS (mg Ca/ℓ), NITRATES (mg/ℓ), PHOSPHATES (mg/ℓ), CADMIUM (mg/ℓ), AND LEAD (mg/ℓ) LEVELS IN GROUNDWATER SAMPLES FROM KRWA-KRWA (1), NGQELE (2), AND KHAYAMNANDI (3) COMMUNITIES, EASTERN CAPE, SOUTH AFRICA

Date	Parameter	Borehole			Storage tank			Stand-pipe		
		1	2	3	1	2	3	1	2	3
21-10-98/ 31-10-98	Temperature	20	ND	20	22	22	22	22	22	22
	Turbidity	12.3	ND	0.46	1.21	2.23	0.36	0.81	1.55	0.83
	pH	7.71	ND	7.47	7.88	7.87	7.83	7.85	7.95	7.95
	Salinity	495	ND	770	495	495	770	495	495	770
	Total hardness	52	ND	100.5	34	65.5	97	37	62.5	84.5
	Nitrates	8.1	ND	5.4	7.8	<0.5	5	2.9	<0.5	5.2
	Phosphates	0.07	ND	0.01	0.04	0.01	0.035	0.03	0.02	0.005
	Cadmium	$7x10^{-4}$	ND	$1.5x10^{-4}$	$7x10^{-4}$	$9x10^{-4}$	$2.2x10^{-4}$	$8x10^{-4}$	$9.7x10^{-4}$	$1.5x10^{-4}$
	Lead	$4x10^{-3}$	ND	$4.9x10^{-3}$	$4.3x10^{-3}$	$5.7x10^{-3}$	$3.4x10^{-3}$	$5x10^{-3}$	$5x10^{-3}$	$9x10^{-3}$
06-11-98/ 13-11-98	Temperature	20	ND	20	20	20	20	ND	21	21.5
	Turbidity	1.18	ND	0.62	7.96	1.32	0.76	ND	0.64	0.3
	pH	7.82	ND	7.51	7.89	7.68	7.67	ND	7.85	7.60
	Salinity	495	ND	825	495	495	770	ND	495	770
	Total hardness	58.5	ND	106	61	63.5	99	ND	55.5	97
	Nitrates	20.8	ND	5.6	19	7.2	5.7	ND	7.2	5.6
	Phosphates	0.01	ND	5.88	0.08	0.005	0.44	ND	0.025	0.34
	Cadmium	$4x10^{-5}$	ND	$8x10^{-5}$	$4x10^{-5}$	$1.5x10^{-4}$	$4.2x10^{-4}$	ND	$<10^{-5}$	$3.8x10^{-4}$
	Lead	$1.3x10^{-3}$	ND	$3.4x10^{-3}$	$1.3x10^{-3}$	$1.3x10^{-3}$	$1.9x10^{-3}$	ND	$1.5x10^{-3}$	$2.3x10^{-3}$

Legend: ND means not determined.

TABLE 2
HETEROTROPHIC (HPC), TOTAL COLIFORM (TC), FAECAL COLIFORM (FC) AND INJURED COLIFORM COUNTS PER 100 mℓ OF BOREHOLE, STORAGE TANK AND STAND-PIPE GROUNDWATER SAMPLES FROM KRWA-KRWA (1), NGQELE (2), AND KHAYAMNANDI (3) COMMUNITIES, EASTERN CAPE, SOUTH AFRICA

Period	Indicator organism (colony per 100 mℓ)	Borehole			Storage tank			Stand-pipe		
		1	2	3	1	2	3	1	2	3
21-10-98	HPC	421	ND	302	1797	1735	774	1666	1216	522
	TC	0	ND	178	196	272	184	18	24	218
	FC	0	ND	0	0	14	308	2	4	206
	FS	0	ND	0	0	0	ND	ND	0	0
	IT	NA	ND	ND	NA	+	+		+	+
06-11-98	HPC	423	ND	293	562	1839	1899	ND	1100	1221
	TC	584	ND	0	708	226	588	ND	476	714
	FC	0	ND	0	0	0	16	ND	0	4
	FS	0	ND	0	0	0	14	ND	0	6
	IT	NA	ND	NA	NA	ND	+	ND	NA	+

Legend: NA means not applicable, ND not determined, and + presence of *Escherichia coli* as confirmed by the indole test.

salt content, the quality with regard to total hardness was also poor (WRC, 1998). The turbidity increased when the water level in the storage tank was low suggesting that sampling could have brought all the precipitates again into suspension.

Results of the microbiological analysis

About the microbiological analysis, in general, water samples taken directly from the borehole showed lower bacterial contamination compared to the samples from the storage tanks and stand-

TABLE 3
Temperature (°C), Turbidity (NTU), pH, Salinity (mg NACl/ℓ), Total Hardness (mg Ca/ℓ), Nitrates (mg/ℓ), Phosphates (mg/ℓ), Cadmium (mg/ℓ), and lead (mg/ℓ) in Stand-pipe Groundwater Samples from Khayamnandi After Boiling and Household Bleaching

Parameter	Untreated water	Boiling			Household bleaching (mℓ/ℓ)			
		1 min	5 min	10 min	0.01	0.017	0.023	0.03
Temperature	20	20	20	20	20	20	20	20
Turbidity	0.25	0.65	0.7	0.73	0.22	0.33	0.22	0.31
pH	7.34	7.22	8.24	7.92	7.80	7.83	7.79	7.89
Salinity	770	660	605	605	715	715	715	715
Total hardness	105	94	93	90	97	89	93	92
Nitrates	5.5	5.3	5.1	5.0	5.4	5.2	5.3	5.4
Phosphates	$4.0x10^{-3}$	$3.9x10^{-3}$	$4.7x10^{-3}$	$5.0x10^{-3}$	$4.1x10^{-3}$	$3.5x10^{-3}$	$4.3x10^{-3}$	$4.2x10^{-3}$
Cadmium	$1.5x10^{-4}$	$1.6x10^{-4}$	$1.6x10^{-4}$	$1.4x10^{-4}$	$1.8x10^{-4}$	$1.7x10^{-4}$	$1.6x10^{-4}$	$1.6x10^{-4}$
Lead	$5.0x10^{-3}$	$3.9x10^{-3}$	$4.1x10^{-3}$	$4.3x10^{-3}$	$4.1x10^{-3}$	$4.0x10^{-3}$	$4.2x10^{-3}$	$4.5x10^{-3}$
Precipitate	-	+	+	+	-	-	-	-

Legend:+ refers to the presence of precipitate and - absence of precipitate.

TABLE 4
Heterotrophic (HPC), Total Coliform (TC), Faecal Coliform (FC), Injured Coliform (IC) and Faecal Streptococci (FS) counts per 100 mℓ of Stand-pipe Groundwater Sample from Khayamnandi After Boiling and Household Bleach Treatment

Indicator bacteria (colony/ 100 mℓ)	Untreated water	Boiling						Household bleaching (Jik mℓ/ℓ)			
		1 min		5 min		10 min		0.01	0.017	0.023	0.03
		A	B	A	B	A	B				
HPC	1195	200	274	2	14	0	0	76	22	16	0
TC	150	20	25	0	0	0	0	29	15	0	0
FC	0	0	0	0	0	0	0	0	0	0	0
IC	105	10	15	0	0	0	0	16	7	0	0
FS	16	2	5	0	0	0	0	4	1	0	0

Legend: A means immediately after cooling (about 4 h); B means after 24 h

pipes (Table 2). At Krwa-krwa, the total coliforms counts for the 6 November 1998 were above 100 counts per 100 mℓ. This is an indication of the poor hygienic quality of the water. Other indicator bacteria were within the limits of significant risk.

At Ngqele, during the sample collection on 21 October the water level in the storage tank was low. This suggests that the water had been in the storage tank for a much longer time. The longer the water stays in the system before being consumed, the more likely it is that the bacteriological quality will deteriorate (Clark et al., 1993; Hambsch and Werner, 1993). Total coliform counts were above 100 colonies per 100 mℓ. All the colonies for faecal coliforms were confirmed by the indole test to be *E. coli* strains.

At Khayamnandi, very high colony counts of total coliforms were recorded. The faecal coliform counts were also high, especially in the first sample. Low heterotrophic counts seemed to correspond with high faecal coliform counts and *vice versa*. This suggests that the high heterotrophic bacteria population may suppress the proliferation of faecal coliforms (LeChevalier and McFeters, 1985). A factor which could have probably contributed to the high bacterial counts in this water sample is the state of the storage tank that was left open. This could have facilitated the introduction of bacteria into drinking water by flying birds and insects, to name a few (Clark et al., 1993; Kryschi, 1998). According to South African standards, the overall quality of water both in the storage tank and at the point of use was unacceptably low and may lead to severe health effects, even with short-term use.

In all three villages, higher bacterial counts were recorded in the storage tanks and at the point of use compared to the boreholes which had relatively lower bacterial counts. This observation confirms the fact that groundwater has relatively good bacterial quality (Raghunath, 1982). However, improper handling and storage time of water before use seem to play a role in the deterioration of bacteriological quality. This is evidenced by the high colony counts recorded at Khayamnandi as compared to Krwa-krwa and Ngqele where the storage tanks were properly sealed.

As far as the source of contamination is concerned in the case of Khayamnandi, living organisms are possibly the main source of pollution. These organisms are believed to be flying birds, insects and rats gaining access to the storage tank that was left open.

Results of the water treatment

In all the villages under consideration, the microbiological quality of the groundwater supplied to the communities was either poor or unacceptable according to South African classification (WRC, 1998). Water handling and limited environmental awareness could be the major reasons for quality deterioration. If people in these villages are going to meet the challenges of providing safe water to every home, alternative means of treating water at the household level should be considered.

Tables 3 and 4 display the results for the evaluation of the two household treatment procedures (boiling and bleaching) for the achievement of water quality standards. Stand-pipe water from Khayamnandi was used in this evaluation.

Concerning the evaluation of household treatment procedures for the achievement of water safety standards, relatively slight improvements were observed in the physicochemical quality of groundwater samples after boiling and household bleaching. Salinity and total hardness were the only parameters affected (Table 3). Boiling achieved 14% improvement in the reduction of the concentration of salinity after 1 min and 21.4% after both 5 min and 10 min while household bleaching achieved a reduction of 7.1 % regardless of the concentration of chlorine used. This difference could probably be associated with the precipitation of sodium carbonate. Boiling for 5 min was found to be the minimum time to obtain the slight improvement observed with regard to salinity. Total hardness was slightly reduced from 105 to about 90 mg Ca/ℓ regardless of the boiling time and the household bleach concentration used. Probably, boiling could have facilitated scale deposition since a large amount of precipitate was formed. Other parameters remained relatively unchanged before and after treatment by both methods. In general, both methods failed in achieving drinking-water quality standards with reference to physicochemical parameters.

Contrary to the shortcomings encountered with respect to physicochemical parameters, great success was achieved in reducing bacterial numbers. Variations in time taken to boil water proved to have a big effect on the microbiological quality of water. The shorter the time taken to boil the water, the more likely it is that the bacteria will regrow when the conditions become favourable. This is shown by the marked differences between the samples taken immediately after cooling of the boiled water and the 24 h samples. Boiling for 5 min was found to be the minimum boiling time to achieve drinking water quality standards in this case. The minimum time required to ensure complete destruction of all indicator bacteria was 10 min (Table 4). Similarly the concentration of household bleach played an important role in the microbiological quality of water after bleaching. The minimum concentration of bleach to achieve complete destruction of the indicator bacteria was 0.03 mℓ/ℓ. This concentration is approximately equivalent to one-eighth of a teaspoon (assuming that the teaspoon is 5 mℓ) in 20 ℓ of water. The minimum concentration of household bleach for achieving drinking-water quality standards was found to be 0.023 mℓ/ℓ which is approximately equivalent to one-tenth of a teaspoon in 20 ℓ of water. Below this value, there was only a reduction in the number of colonies.

In economic terms, household bleach is more cost-effective than boiling because it is cheap and only small volumes of the bleach need be used over large quantities of water. Boiling on the other hand may be relatively expensive for the rural community which still uses paraffin for heating.

Conclusion

Water coming directly from the boreholes had a lower level of bacteria, confirming the fact that groundwater has a relatively good microbiological quality. However, the quality deteriorated before it could reach the consumers. The deterioration was associated with the contamination in the storage tanks and the distribution system due to improper handling. The overall microbiological quality of the water in all the villages was either poor or unacceptable at the point of use.

Boiling and household bleaching of the groundwater helped achieve the microbiological water quality standards for domestic use. This was achieved by boiling water for 5 min or treatment with household bleach at 0.023 mℓ/ℓ. For economical reasons, household bleaching was the most affordable method for the rural communities in the Victoria district. Boiling could be a better option since it does also to some extent improve the salinity and total hardness in addition to microbiological quality.

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