Bacterial and chemical quality of water supply in the Dertig village settlement

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Abstract

Water contaminated with microbiological and chemical constituents can cause a variety of diseases. Water intended for human consumption should be safe, palatable and aesthetically pleasing. Water sources have different qualities influenced by natural or anthropological pollution. In South Africa, the availability of safe and clean water is a serious problem, especially in rural areas. Most people in such areas use water directly from available sources without any treatment and therefore are exposed to a variety of water-related diseases. The objective of this study was to determine the chemical and microbiological quality of drinking water supply to a rural community in order to estimate the health implications thereof. Water samples were collected weekly from five water sources, that is, Lefatlheng Well, Tlhaloganyo groundwater, Tlhaloganyo rain water, Matlaisane groundwater and Tshwane River in the Dertig/Lefatlheng village settlement which is in Hammanskraal, about 55 km north of Pretoria. To provide an indication of the microbiological quality of the water resources, indicator organisms including heterotrophic bacteria , faecal coliform, total coliform, *Salmonella* and coliphages were used. In order to support the results, bacterial isolates were identified using both the 20E and 20NE API systems to confirm their isolation. For the chemical quality analyses, different chemical quality variables including temperature, pH, dissolved oxygen (DO), aluminium (Al), iron (Fe), manganese (Mn), fluoride (F), nitrate (NO_3), nitrite (NO_2) and colour were determined. The chemical quality of all the water sources analysed was acceptable. In contrast, however, the microbiological quality of all the water sources exceeded the standard for potable water and the sources pose a serious health risk to consumers.

Introduction

No source of water that is intended for human consumption can be assumed to be free from pollution (*The Microbiology of Water*, 1994). Water sources have different qualities influenced by natural or anthropological pollution. Polluted water is an important vehicle for the spread of disease. It has been estimated that 50 000 people die daily world-wide as a result of water-related disease (Schalekamp, 1990). A large number of people in developing countries lack access to adequate water supply. In South Africa it has been estimated that more than 12 m. people do not have access to an adequate supply of potable water (DWAF, 1994). The availability of safe and clean water seems not to be a problem in towns and cities, where consumers generally receive a constant supply of water of high quality. In contrast, however, the inaccessibility of water which is fit for use is a serious problem in rural areas. Most people in these areas use water directly from available and often contaminated sources without any treatment and therefore are exposed to many water-related diseases.

The government has launched projects to ensure the provision of improved water supplies to communities in rural areas, but due to financial and human resource constraints, it is unlikely that the high-quality water will be provided to the majority of such people in the immediate future. Another limiting factor is that in other areas where such water supplies have been provided, the supplies are not always reliable or sufficient, and residents may often have to revert to traditional unprotected sources until the supply is restored (WRC, 1993). These water sources should therefore be examined for indicators of pollution and when the inspection shows that they are subjected to contamination, remedial action should then be taken. This will result in the decline in infectious and other communicable diseases, and ultimately improve the health standards of rural communities.

In South Africa, few data on quality of water sources and associated health problems are available, since limited surveys have been conducted. The risk of population exposure to water-related diseases is often underestimated because most studies normally approach this problem on a macro-scale, which all too often excludes most rural communities.

This study was aimed at examining the quality of drinking water supply to a rural community in order to estimate how the water supply may influence infection and disease (health implications) in the community. This was done by determining the chemical and microbiological quality of the water supply in relation to the South African guidelines for domestic water (DWAF, 1996). The study was planned to provide information that could assist in working out a model for water supply management in rural communities.

Materials and methods

Study site

The experimental site was Dertig/Lefatlheng Village, which is situated in Hammanskraal, about 55 km north of Pretoria. The following water sources commonly used in this area were identified and included in the survey: Tlhaloganyo groundwater (pumped from a borehole by a diesel motor and a pump and collected in a tank fitted with a tap), Tlhaloganyo rain water (collected from an impervious roof through a gutter to a tank

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TABLE 1
MICROBIOLOGICAL ANALYSIS OF WATER SAMPLES

Variable	Technique	Medium	Incubation temperature	Incubation time
Heterotrophic bacteria	Spread plate	Nutrient agar (Biolab)	37°C	48h
Total coliforms	Spread plate	Chromocult coliform agar (Merck)	37°C	24h
Faecal coliforms	Spread plate	Chromocult coliform agar (Merck)	44.5°C	24h
Salmonella	Spread plate	Rambach agar (Merck)	37°C	24h
Coliphages	Double-agar-layer plaque assay (Grabow *et al.*, 1984) using *E. coli* strains **WG4** and **K12** as hosts.	Phage agar (Grabow et al., 1984)	37°C	18h

fitted with a tap), Matlaisane groundwater (pumped from a borehole by a diesel motor and a pump and collected in a tank fitted with a tap), Lefatlheng Well and Tshwane River water.

Sample collection

Water samples were collected weekly from the five water sources for a period of 13 weeks. For the microbiological quality analyses, sampling was done aseptically into sterile glass bottles. For chemical quality analyses, thoroughly cleaned non-sterile bottles were used.

Microbiological water quality analyses

Microbiological analyses were conducted within 6h after the samples were collected.

Bacterial counts

For total coliform, faecal coliform and *Salmonella* counts, the membrane filtration technique was considered but the method proved to be too sensitive for the analyses of the raw water samples. Chromocult coliform agar is a selective culture medium used for the isolation of coliforms whereas Rambach agar is a differential culture medium for isolating *Salmonella*, coliforms and other *Enterobacteriaceae*.

Identification of bacterial isolates

After bacterial colonies had been counted, plates were selected for the identication of different bacterial isolates. Bacterial colonies differing in size, shape and colour were randomly selected from the different plates and further isolated on nutrient agar (Biolab) by the streak plate technique and incubated at 37°C for 24h. These were further purified by the same method at least three times before Gram staining was done. Oxidase tests were then done on those colonies which were gram-negative. For those isolates that were found to be oxidase-positive, the 20NE API kit was used and the strips were incubated at 30°C for 24h. The 20E API kit was used for the oxidase-negative colonies and the strips were incubated at 37°C for 24h. The strips were then read and the final identification was done using computer software at Separation Scientific Laboratories, Johannesburg, South Africa.

Physical and chemical water quality analyses

Except for temperature (°C) and DO (mg/ℓ and % saturation), which were determined *in situ* at each sampling point by means of a WTW OXI 320 oxygen meter, all other water quality variables were analysed within 6 h after sample collection. pH was measured using a Beckman pH meter and the temperatures at which the pH measurements were done, were also reported. Colour was measured using the SQ 118 Photometer (Merck) in Hazen units. All the other inorganic water quality variables including NO_3, NO_2, Fe, Mn, Al, and F were measured in mg/ℓ using the SQ 118 Photometer and the relevant test kits (Merck).

Results

Microbiological water quality analyses

Bacterial counts

See Table 2 for the bacterial quality of the water samples analysed.

Heterotrophic bacteria

Heterotrophic bacteria counts ranged between 7.75×10^3 and 4.56×10^4 cfu/mℓ for Tshwane River water, between 2.91×10^3 and 5.08×10^4 cfu/mℓ for Lefatlhleng Well, between 7.0×10^2 and 1.08×10^6 cfu/mℓ for Matlaisane groundwater, between 1.0×10^1 and 1.63×10^4 cfu/mℓ for Tlhaloganyo rain water (with an avarage count of 3.27×10^3 cfu/mℓ) and counts for Tlhaloganyo groundwater were between 0 and 1.15×10^4 cfu/mℓ, with an avarage count of 4.69×10^3 (Table 2). Heterotrophic bacteria counts for all five water sources were generally above 1.0×10^2 cfu/mℓ, which is the maximum recommended limit for no risk (DWAF, 1996). The general microbiological quality of the water sources was therefore above the allowed limit.

Total coliforms

Total coliform counts ranged between 1.2×10^4 and 6.4×10^4 cfu/mℓ for Tshwane River water, between 1.18×10^3 and 4.9×10^4 cfu/mℓ for Lefatlheng Well water, between 4.7×10^2 and 1.0×10^3 cfu/mℓ for Tlhaloganyo rain water, and between 1.1×10^2 and 2.1×10^3 cfu/mℓ for Tlhaloganyo groundwater (Table 2). The counts were above 5 cfu/100 mℓ, which is the maximum recommended limit for no risk (DWAF, 1996). The results suggest that

TABLE 2
BACTERIAL QUALITY OF THE WATER SAMPLES ANALYSED

Limit for no risk*	Variable		A	B	C	D	E
0-100 cfu/mℓ	Heterotrophic bacteria (cfu/mℓ)	Minimum	0.00	1.0×10^{1}	7.0×10^{2}	2.91×10^{3}	7.75×10^{3}
		X	4.69×10^{3}	3.27×10^{3}	1.19×10^{5}	1.55×10^{4}	2.71×10^{4}
		SD	3.39×10^{3}	5.69×10^{3}	3.38×10^{5}	1.39×10^{4}	1.26×10^{4}
		Maximum	1.15×10^{4}	1.63×10^{4}	1.08×10^{6}	5.08×10^{4}	4.56×10^{4}
0-5 cfu/100 mℓ	Total coliforms (cfu/mℓ)	Minimum	1.1×10^{2}	4.7×10^{2}	ND	1.18×10^{3}	1.2×10^{4}
		X	2.0×10^{2}	6.9×10^{2}	ND	1.8×10^{3}	2.9×10^{4}
		SD	9.0×10^{1}	2.8×10^{2}	ND	2.7×10^{4}	3.0×10^{4}
		Maximum	2.9×10^{2}	1.0×10^{3}	ND	4.9×10^{4}	6.4×10^{4}
0 cfu/100 mℓ	Faecal coliforms (cfu/mℓ)	Minimum	1.0×10^{1}	9.0×10^{1}	ND	2.6×10^{2}	5.9×10^{3}
		X	4.0×10^{2}	1.6×10^{2}	ND	3.4×10^{3}	1.3×10^{4}
		SD	3.6×10^{2}	8.9×10^{1}	ND	3.4×10^{3}	9.1×10^{3}
		Maximum	7.0×10^{2}	2.6×10^{2}	ND	7.0×10^{3}	2.3×10^{4}
0 cfu/100 mℓ	*Salmonella* (cfu/mℓ)	Minimum	2.0×10^{1}	1.9×10^{1}	ND	5.0×10^{1}	7.0×10^{3}
		X	1.7×10^{2}	8.0×10^{1}	ND	4.6×10^{2}	2.1×10^{4}
		SD	1.3×10^{2}	1.0×10^{2}	ND	3.9×10^{2}	2.1×10^{4}
		Maximum	2.5×10^{2}	2.0×10^{2}	ND	8.25×10^{2}	4.6×10^{4}

A: Tlhaloganyo groundwater **B**: Tlhaloganyo rainwater **C**: Matlaisane groundwater **D**: Lefatlheng Well water **E**: Tshwane River water **X**: Mean **SD**: Standard deviation ***** DWAF, 1996 **ND**: Not determined

the general sanitary qualities of the water sources, as indicated by total coliform counts, were unacceptable.

Faecal coliforms

Faecal coliform counts ranged between 5.9×10^{3} and 2.3×10^{4} cfu/mℓ for Tshwane River water, between 2.6×10^{2} and 7.0×10^{3} cfu/mℓ for Lefatlheng Well water, between 9.0×10^{1} and 2.6×10^{2} cfu/mℓ for Tlhaloganyo rain water, and between 1.0×10^{1} and 7.0×10^{2} for Tlhaloganyo groundwater (Table 2). These counts were far above 0 cfu/100 mℓ, which is the maximum recommended limit for no risk (DWAF, 1996). These results suggest faecal pollution of the water sources, and implies that these water sources pose a serious health risk to consumers. When faecal coliform counts are greater than 20 per 100 mℓ, as observed from all the water sources examined in this study, there is a significant and increasing risk of infectious disease transmission (DWAF, 1996).

Salmonella

Rambach agar plate counts ranged between 7.0×10^{3} and 4.6×10^{4} cfu/mℓ Tshwane River water, between 5.0×10^{1} and 8.25×10^{2} cfu/mℓ for Lefatlheng Well water, between 1.9×10^{1} and 2.0×10^{2} cfu/mℓ for Tlhaloganyo rainwater, and between 2.0×10^{1} and 2.5×10^{2}. Rambach agar is a differential culture medium for identifying not only *Salmonella*, but also coliforms and other *Enterobacteriaceae*. No *Salmonella* was identified from any of the samples analysed, from all the water sources examined, and most colonies resembled coliforms. The counts were above 5 cfu/100 mℓ, which is the maximum limit for no risk of coliforms (DWAF, 1996). The quality of the water sources, as indicated by this water quality variable, was unacceptable.

Identification of bacterial isolates

According to the API system, oxidase test and Gram staining, organisms which are opportunistic human pathogens were identified from all the water sources analysed. These organisms include species of *Aeromonas, Pseudomonas, Alcaligenes, Klebsiella, Citrobacter, Enterobacter* and *E. coli* (Tshwane River water); species of *Aeromonas, Enterobacter* and *E. coli* (Lefatlheng Well water); species of *Pseudomonas* and *Aeromonas* (Matlaisane groundwater); species of *Aeromonas* and *Alcaligenes* (Tlhaloganyo rainwater) as well as species of *Aeromonas* and *Pseudomonas* (Tlhaloganyo groundwater). There was also a possibility of *Vibrio* species, which are enteric pathogens of humans, in all five water sources. The results therefore suggest that all these water sources pose a health risk to consumers (Table 3).

Coliphage counts

For Tshwane River water, coliphage counts ranged between 9.3 and 54 pfu/mℓ where *E. coli* strain WG4 was used, and between 4.5 and 16.5 pfu/mℓ where strain K12 was used (Table 4). These counts were above 1 pfu/100 mℓ, which is the maximum recommended limit for no risk (DWAF, 1996). These results suggest the possible viral contamination of the water source and thus, a serious health risk to consumers. The results also indicated that *E. coli* strain WG4 yielded more coliphage counts than K12. For Lefatlheng Well water, Matlaisane groundwater, Tlhaloganyo rain water and Tlhaloganyo groundwater, no coliphages were isolated from any of the samples analysed (Table 5). The viral quality of these water sources, as indicated by coliphage counts, was acceptable. None of these four water sources posed any health risk to consumers in terms of this water quality variable.

TABLE 3
BACTERIAL ISOLATES IDENTIFIED FROM THE WATER SAMPLES ANALYSED

Source of water	Bacterial isolates identified
Tlhaloganyo groundwater	*Pseudomonas fluorescens, Aeromonas hydrophila, Aeromonas caviae, Tatumella ptyseos* and possibility of *Vibrio fluvialis*
Tlhaloganyo rain water	*Aeromonas hydrophila, Aeromonas caviae, Bordetella species, Alcaligenes* species and possibility of *Vibrio fluvialis*
Matlaisane groundwater	*Aeromonas hydrophila, Aeromonas caviae, Pseudomonas fluorescens* and possibility of *Vibrio fluvialis*
Tshwane River water	*Aeromonas hydrophila, Aeromonas caviae, Pseudomonas chlororaphis, Klebsiella pneumoniae Enterobacter cloacae, Escherichia coli 1, Bordetella* species, *Alcaligenes* species, *Aeromonas sobria, Citrobacter amalonaticus, Citrobacter diversus, Citrobacter freundii* and *Pseudomonas pseudomallei*, and possibility of *Klebsiella terrigena/planticola* and *Vibrio fluvialis*
Lefatlheng Well water	*Aeromonas hydrophila, Aeromonas caviae, Vibrio parahaemolyticus, Sphingo multivorum, Escherichia coli 1, Enterobacter agglomerans, Escherichia fergusonii, Enterobacter cloacae, Rahnella aquatilis, Pasteurella multocida* and possibility of *Vibrio fluvialis*

TABLE 4
COLIPHAGE QUALITY OF THE WATER SAMPLES ANALYSED

Limit for no risk*	*E. coli* strain		A	B	C	D	E
0 -1 pfu/100 mℓ	WG4 (pfu/mℓ)	Minimum	0	0	0	0	9.3
		X	0	0	0	0	32.0
		SD	0	0	0	0	17.9
		Maximum	0	0	0	0	54
0-1 pfu/100 mℓ	K12 (pfu/mℓ)	Minimum	0	0	0	0	4.5
		X	0	0	0	0	10.5
		SD	0	0	0	0	6
		Maximum	0	0	0	0	16.5

A: Tlhaloganyo groundwater **B**: Rainwater **C**: Matlaisane groundwater **D**: Lefatlheng Well water **E**: Tshwane River water **X**: Mean **SD**: Standard deviation ***** DWAF, 1996

Physical and chemical water quality analyses

For all five water sources that were examined, the [Fe] was below 0.1 mg/ℓ, [NO_3] and [NO_2] were below 6 mg/ℓ, [Al] was below 0.15 mg/ℓ, [F] was below 1.0 mg/ℓ, and [Mn] was below 0.05 mg/ℓ (Table 5). All these variables were in concentrations below the maximum recommended limits for no risk. Temperature and colour were below 25°C and 15 Pt-Co respectively, which are the maximum recommended limits for no risk. The pH was within the recommended limit for no risk (pH between 6 and 9). The results suggest that none of the water sources analysed pose any health risk to consumers in relation to these water quality variables, and also that the aesthetic quality was acceptable. Measuring DO provides an indication of pollution of natural water. DO decreases when water is polluted. DO (in % saturation), for all the water sources examined, was below the limit recommended for no risk (70%). These data confirms the results of the microbiological quality analyses suggesting that the water sources are polluted.

Discussion and conclusion

The purpose of this survey was to examine the chemical and microbiological quality of drinking water supply to a rural community in order to establish how and why the water supply may influence infection and disease in the community. The results indicated that the chemical quality of all the water sources analysed was acceptable. In contrast, however, the bacterial quality of all the water sources, as suggested by the indicator organisms used, exceeded the standard for potable water. Various pathogenic bacteria were also identified from the different water

TABLE 5
CHEMICAL AND PHYSICAL QUALITY OF THE WATER SAMPLES ANALYSED

Variable	Limit for no risk		A	B	C	D	E
# Nitrate (mg/ℓ)	0-6 mg/ℓ	X SD	5.93 2.74	2.40 2.16	1.34 0.88	1.94 1.68	4.45 2.80
# Nitrite (mg/ℓ)	NS	X SD	0.011 0.020	0.006 0.006	0.005 0.004	0.041 0.045	0.087 0.019
* Nitrate & nitrite (mg/ℓ)	0-6 mg/ℓ N	X SD	5.94 2.76	2.41 2.17	1.35 0.88	1.98 1.73	4.54 2.80
* Iron (mg/ℓ)	0-0.1 mg/ℓ	X SD	0.027 0.041	0.013 0.019	0.049 0.083	0.037 0.015	0.038 0.014
* Aluminium (mg/ℓ)	0-0.15 mg/ℓ	X SD	0.017 0.009	0.014 0.009	0.016 0.006	0.026 0.011	0.029 0.021
* Manganese (mg/ℓ)	0-0.05 mg/ℓ	X SD	0.031 0.050	0.019 0.013	0.018 0.019	0.043 0.013	0.054 0.026
* Fluoride (mg/ℓ)	0-1.0 mg/ℓ	X SD	0.0735 0.735	0.270 0.100	0.371 0.379	0.366 0.124	0.455 0.216
* Colour (Hazen)	15 Pt-Co	X SD	0.83 1.16	0.66 0.81	1.16 0.98	5.50 0.83	8.33 1.21
# DO (mg/ℓ)	NS	X SD	3.06 0.39	3.40 0.94	3.38 0.68	2.80 0.89	3.83 0.55
# DO (% saturation)	70 %	X SD	41.16 9.16	38.16 10.32	39.50 8.59	37.0 14.0	47.33 10.86
# Temperature (°C)	< 25°C	X SD	21.53 3.20	19.81 3.71	22.63 3.31	21.33 2.35	20.73 3.36
* pH	6.0 - 9.0	X SD	7.45 0.23	6.85 0.24	8.22 0.13	6.30 0.45	8.20 0.14
* Temperature for pH (°C)	NS	X SD	19.50 1.79	19.54 1.84	19.53 1.76	19.56 1.80	19.57 1.80

A: Tlhaloganyo groundwater **B:** Tlhaloganyo rain water **C:** Matlaisane groundwater **D:** Lefatlheng Well water
E: Tshwane River water **X:** Mean **SD:** Standard deviation ***** DWAF, 1996 # DWAF, 1993

sources. The viral quality of Tshwane River water, as indicated by coliphage counts, was also unacceptable; however, the viral quality of the other water sources (Lefathleng Well water, Tlhaloganyo groundwater, Tlhaloganyo rain water and Matlaisane groundwater) complied with the standard for potable water. In general, the results suggested that the microbiological quality of all the water sources examined was unacceptable, and these sources pose a serious health risk to consumers.

Many studies suggest that rainwater and snow are the purest forms of water naturally available. If care is taken in collection and storage, rain water should contain low levels of micro-organisms (WRC, 1993). The poor microbiological quality of Tlhaloganyo rainwater might be due to the collection and storage methods employed. The water is collected from an impervious roof through a gutter into an unpainted metal tank. Water that washes over roofs and gutters invariably carries small quantities of organic matter such as leaves, insects and bird droppings, plus small amounts of dirt and dust. These form the essential nutrients for growth of bacteria (WRC, 1993). As the water is also stored for long periods of time in the tank, this could also lead to the growth of micro-organisms. For Tshwane River water, the poor microbiological quality might be due to direct contamination caused by human activities and indirect effects caused by climate change and other ecological disturbances (Ford and Colwell, 1996). It is a common practice for people in rural areas to discharge their domestic and/or agricultural wastes as well as

human body wastes into rivers. In addition to using a river as a source of drinking water, people in such areas also have a tendency to using the same source for bathing, washing (e.g. clothes), recreational purposes (e.g. swimming), etc. Since the Tshwane River is not fenced, wild and domestic animals seeking drinking water can also contaminate the water. Birds and some animals inhabiting the water can also contaminate the water through direct defecation and urination. Over-grazing and other poor farming practices, common in rural areas, may result in large quantities of topsoil ending up in the river after heavy rains, and thereby contributing to high turbidity. Turbidity indicates the presence of organic suspended material which promotes the growth of micro-organisms (WRC, 1993). Poor water sanitation practices (e.g. using unclean buckets to draw water from the well) might be the major contributor to contamination of Lefatlheng Well. Since the well is not protected, climate change and other ecological disturbances (as for Tshwane River) can also not be underestimated as possible sources of contamination. Contamination of the groundwater (Tlhalogango and Matlaisane) might be indirectly due to climate conditions. For example, heavy rains may transport organisms (derived from animals and birds) from the soil to the groundwater. Since pit latrine toilets are located not far from the two water sources, respectively, faecal contaminants from human excreta may also find their way to the water via this route. Since the groundwater is removed from the boreholes by diesel motors and pumps to tanks fitted with taps, contamination might also be as a result of some defects related to the plumbing of the water supply system.

Only a few surveys related to water quality and associated problems have been conducted in South Africa, since the benefits of this type of research are often underestimated. The majority of those studies approach the problem on a macro-scale, which all too often exclude most rural communities, and thus, the risk of population exposure to water-related diseases is often underestimated. The findings of this study, therefore, seem to be of great importance. This is also due to the fact that the information highlights the particular problems in the Dertig Village Settlement, which is probably representative of many such areas in South Africa. The information should therefore serve the purpose of highlighting (warning signal) the necessity to deal with water quality issues as a matter of urgency. We cannot afford to continue ignoring the public health and associated socio-economic impacts of water quality related problems of our rural areas. Immediate remedial action needs to be taken before the situation worsens. Low-technology options coupled with appropriate education can meet the immediate needs to prevent the transmission of water related diseases in rural communities (Ford and Colwell, 1996). These must be supplemented with an intensive heath care education programme aimed at improving resource management practices. Adequate long-term protection of South African's water sources is of vital importance for sustained economic growth and development (DWAF, 1993). Water is scarce in this country and further deterioration of the quality of the already limited sources should not be allowed to happen. Emphasis should be placed on the need to control microbial disease agents, develop sanitation and agricultural practices as well as other activities that can contribute to the degradation of water quality and cycle disease agents back to the human population (Ford and Colwell, 1996). In addition, the people should also be advised to maintain water free of contamination in the household. These might ultimately result in improvements in the health standard of our population.

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