The quality of water from protected springs in Katwe and Kisenyi parishes, Kampala city, Uganda

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ABSTRACT

Background: In the sub-urban areas of Kampala city, springs are a major source of water for domestic use. Though spring water is considered to be aesthetically acceptable for domestic use, presence of poorly designed pit latrines, poor solid waste management as well as poor and inadequate spring protection, may lead to contamination of spring water with pathogenic bacteria.

Objectives: The objectives of the study were to examine the bacteriological quality of water from ten springs in Katwe and Kisenyi parishes of Kampala, and to identify and quantify risks for spring water contamination with faecal bacteria.

Methods: A cross-sectional sanitary risk assessment using a standardised format was carried out in ten randomly selected springs in the parishes of Katwe and Kisenyi parishes in Kampala. A total of 80 samples of water from these springs were collected from December 2001 to March 2002. The samples were analysed for indicators of faecal contamination: total coliforms, faecal coliforms and faecal streptococci. Physico-chemical parameters were measured.

Results: Aggregate qualitative sanitary risk scores ranged from medium to high. The total coliform counts in 90% of the samples exceeded the WHO guideline for drinking water. All the samples had faecal coliform counts above the WHO guideline. A strong correlation (r2= 887) was observed between the median faecal coliform counts and the sanitary risk score. Sixty percent of the samples had nitrate levels above the WHO recommended limit. There was no correlation between the levels of chlorides and nitrates and levels of indicators of faecal bacterial contamination.

Conclusions: The sanitary risk assessment score is a reliable tool for predicting the likely levels of bacterial contamination of spring water. Water from the ten protected springs studied is unsuitable for drinking without treatment.

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INTRODUCTION

In Uganda, like other developing countries, sanitation and water supply are often inadequate. As a result, many low-income communities in these countries rely on untreated groundwater for drinking and other domestic use[1]. In Kampala City, only 55% of the population is supplied with piped water, out of which only 9% is connected to the sewerage system[2].

In the sub-urban areas of Kampala City, springs are a major source of water for domestic use. This is because of the availability of springs in these areas, and also due to the lack of piped water. Though spring water is considered to be aesthetically acceptable for domestic use, presence of poorly designed pit latrines, poor wastewater management, poor solid waste management as well as poor and inadequate spring protection, may lead to contamination of water from the springs with pathogenic bacteria. In addition, drinking water may be contaminated with nitrates. The health effects of presence of nitrates in water are linked to methemohemoglobinemia[3]. Children between the ages of 12 to 14 years drinking water containing greater than 105 mg/l of nitrate have been reported to exhibit delayed reactions to light and sound stimuli[3].

Previous studies conducted in and around Kampala City examined largely the bacterial load of spring water without attempting to identify and quantify the potential risk factors contributing to the contamination. In the case of the parishes of Katwe and Kisenyi, the risk factors for spring water contamination were largely unknown. The objectives of the present study therefore were, firstly, to examine the bacteriological quality of water from selected springs in these parishes, and secondly, to

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identify and quantify risks for spring water contamination with bacteria indicator organisms.

MATERIALS AND METHODS

Study area

The study was conducted in Katwe and Kisenyi parishes. These parishes are suburbs of Kampala City, and are located about 2 km southwest of the city. They are informal low-lying settlements with a high population density. They have inadequate infrastructure and poor services including water supply. The water table in these parishes is high.

Selection of study springs

A list of all the springs with a good yield throughout the year in the two parishes was obtained from the local area authorities. Ten springs were then randomly selected for the study; 4 from Katwe parish and 6 from Kisenyi parish. In Katwe parish, the selected springs were Nakatanza, Kazungu, Musoke and Kasule, while those in Kisenyi parish were Luzige, Kiteeso, Maama Betty, Kakajo, Bwanika I, and Bwanika II.

Sanitary inspection

A cross-sectional sanitary assessment was carried out in each of the selected springs to identify the risks for contamination with faecal bacterial organisms. The assessment followed a standardised procedure described by Howard[4]. The procedure involved completing a ten-point standardised data form with a series of questions with a yes and no options for designated risks. A score of one point was awarded for each "yes" answer (risk observed) and zero point for each "no" answer (no risk observed). By summing all "yes" scores, a final risk score was obtained, which provided the overall assessment of the risk profile of each spring. The total sanitary risk score was converted to a percentage. The aggregate risk score was graded as very high (81 to 100%), high (51 to 80%), medium (31 to 50%), low (1 to 30%) and nil (0%).

Collection of water samples

A total of 80 water samples were collected from December 2001 to March 2002. This was a dry season, though occasional rains were experienced. The sampling interval was two weeks, giving a total of 8 samples per spring. The samples were taken from the commonly used outlet of the springs. A field data form was completed to record the name of spring, location, date, and weather conditions.

On-site measurement of water temperature, pH and electrical conductivity

The water temperature and pH were measured using a WTWÒ microprocessor pH/temperature meter. The meter was calibrated with pH 4 and 7 using standard buffer solutions according to manufacturer's instructions (WTW, Vienna, Austria). The electrode was rinsed with distilled water between samples. Electrical conductivity was measured using a WTWÒ microprocessor conductivity meter calibrated at 25^0C.

Laboratory analyses

The laboratory analyses were carried out in the Public Health and Environmental Engineering Laboratory of the Department of Civil Engineering, Faculty of Technology, Makerere University. The bacteriological parameters analysed were total coliforms, faecal coliforms and faecal streptococci, while the physico-chemical parameters measured were turbidity, nitrate and chloride levels.

Enumeration of total coliforms

Total coliforms were isolated and enumerated using the membrane filtration technique and growth on membrane lauryl sulphate broth (MLSB). The sample was filtered and the membrane was then placed on an absorbent pad soaked in MLSB. The plates were then incubated for one hour at room temperature, to aid resuscitation, and incubated for a further 23 hrs at 37^0C. All yellow colonies extending on the membrane were counted with the aid of a magnifying lens and recorded as presumptive total coliforms. For confirmation, a representative number of characteristic yellow colonies were sub-cultured into tubes of Brilliant Green Bile (BGB) broth and incubated at 37^0C for 48 hours. Gas production in BGB broth confirmed the presence of coliforms. The results were then expressed as the number of colonies in 100 ml of original sample as described by APHA[5].

Enumeration of faecal coliforms

Faecal coliforms were also enumerated using the membrane filtration technique. The plates were incubated at 44^0C. Sub-cultures for confirmation were incubated at 44^0C for 24 hours. Yellow colonies of various sizes extending on the membrane were counted with the aid of a magnifying lens and taken to be thermotolerant coliforms (presumptive). Gas production in BGB broth confirmed the presence of thermotolerant coliforms.

Enumeration of faecal streptococci

Faecal streptococci were isolated and enumerated by the membrane filtration technique. The filters were placed on membrane Enterococcus agar (Slanetz and Bartley agar,

Oxoid Ltd), and plates were then inverted. The agar plates were pre-incubated at 37^0C for 4 hours to aid bacterial resuscitation. The plates were then incubated at 44^0C for a further 44 hours. After incubation all red, maroon and pink colonies that were smooth and convex were counted and recorded as faecal streptococci. The number of colonies in 100 ml of original sample was then computed.

Measurement of turbidity, nitrate and chloride levels

Turbidity was measured using the HACH DR/2010Ò Spectrophotometer. Twenty five millilitres of a well-mixed sample were measured into a clean sample cell. Another sample cell was filled with distilled water. The intensity of light scattered and absorbed by the sample was compared to that measured for standard Formazin suspensions and was read at a wavelength of 860 nm.

Nitrate levels were measured using the cadmium reduction method. Twenty-five millilitres of sample were transferred into a sample cell, and another sample cell was filled with an equal amount of distilled water. The contents of one Nitraver 5 Reagent Powder Pillow were added to each sample cell. The sample cells were stoppered and vigorously shaken for one minute. They were then left to stand for five minutes to allow development of the colour. The concentration in mg/l was measured against the blank (distilled water) at a wavelength of 500 nm using the HACH DR/2010Ò spectrophotometer.

Chloride levels were measured using the mercuric thiocyanate method. The sample cell was filled with 25 ml of sample and another with equal amount distilled water. Two millilitres of mercuric thiocyanate solution were added to each cell and swirled. One millilitre of ferric ion solution was pipetted into each sample cell and again swirled. After 2 minutes, chloride concentration of the sample in mg/l was measured against the blank and read at wavelength 455 nm using HACH DR/2010Ò spectrophotometer.

Data analysis

The data were entered in Microsoft ExcelÒ programme and descriptive statistics were computed. Statistical tests were performed using SPSS programme. The Pearson product-moment correlation coefficients for candidate chemical parameters with bacteriological quality parameters; the sanitary risk score and the median counts of total coliforms, faecal coliforms and faecal streptococci were computed. The bacteriological counts recorded were compared with the WHO guidelines for drinking water.

RESULTS

Sanitary risk assessment

Table 1 presents the risk assessment scores recorded. All the ten springs studied were at risk of contamination with bacterial faecal organisms. The qualitative aggregate risk score varied from medium to high. Seventy percent of the springs had a high risk score (51-80%), while 30% had a medium risk score (31-50%). No spring attained a risk score of either nil (0%) or very high (81 to 100%). The common risks identified were presence of pit latrines within a radius of 30 metres from the spring, presence of pollution sources such as solid wastes, inadequate sanitary protection measures such as lack fences around the spring, and absence of diversion ditches.

Table 1: **Risk assessment scores of springs in Katwe and Kisenyi parishes, Kampala city**

Parish	Name of spring	Risk observed	Percent risk score	Qualitative risk profile
Katwe	Nakatanza	2,3,5,6,7,8,9,10	80	High
	Kazungu	2,3,5,6,7,8,9,10	80	High
	Musoke	5,6,7,8,9,10	60	High
	Kasule	5,6,7,9,10	50	Medium
Kisenyi	Kakajo	2,5,6,7,8,9,10	70	High
	Maama Betty	5,6,7,9,10	50	Medium
	Kiteeso	3,5,6,7,9,10	60	High
	Luzige	3,4,5,6,7,8,9,10	80	High
	BwanikaI	2,5,6,9,10	50	Medium
	Bwanika II	3,4,5,6,8,10	60	High

Key to risks observed: 1= Spring unprotected; 2 = Masonry protecting spring faulty; 3 = Backfill area eroded; 4 = Spilt water floods collection area; 5 = Perimeter fence absent; 6 = Animals have access within radius 10 m of spring; 7 = Pit-latrine uphill and/or within 30 m of spring; 8 = Surface water collects upstream of spring; 9 = Diversion ditch above spring absent/non-functiona;l 10. Other pollution sources uphill of spring e.g., solid waste dumps, faeces, stagnant water, and drainage channels.

Physico-chemical parameters

Table 2 presents the levels of the physico-chemical parameters measured. The nitrate levels ranged from 21 to 145 mg/l. The highest mean nitrate levels of 140 mg/l was recorded at Kasule spring. Sixty percent (52 out of 80) of the samples had nitrate levels above the WHO maximum permissible level of 50 mg/l. The chloride levels ranged from 6 to 79 mg/l. The chloride levels in all samples were below the WHO maximum permissible level of 250 mg/l. The electrical conductivity ranged from 95 to 705 ìS/cm. All samples had turbidity levels within WHO permissible level of less than 5 FTU. The pH ranged from 4.4 to 6.7. Only 5% (4 out of 80) of the samples had a pH within the WHO recommended range of 6.5 to 8.5. There was little variation in temperature readings, with a range of 23.6 to 26.4^{0}C.

Table 2: Physico-chemical quality of water from springs in Katwe and Kisenyi springs, Kampala City

Spring name	Nitrate levels (mg/l)	Chloride levels (mg/l)	Electrical conductivity (µS/cm)	PH	Turbidity (FTU)	Temperature (^{0}C)
Nakatanza	26±5[a]	12.4±4	102±24	4.6-5.6	<5	24.3±0.5
(n=8)	18-31[b]	7-19	95-119			23.6-25.2
Kazungu	21±5	10±3	120±37	4.4-6.7	<5	24.4±0.6
(n=8)	14-29	6-14	99-210			23.6-25.3
Musoke	33±7	20.5±5	167±21	4.9-6.4	<5	24.4±0.8
(n=8)	23-46	12-28	148-197			23.6-25.0
Kasule n=8	140±4	59.5±10	702±2	5.4-5.7	<5	24.9±0.7
	135-145	53-78	698-705			24.0-26.3
Kakajo	52±6	51±18	371±56	5.6-6.6	<5	25±0.5
(n=8)	44-60	23-66	242-409			24.2-25.5
Maama Betty	59±5	38±6	290±20	4.9-6.0	<5	25±0.8
(n=8)	50-66	26-45	259-315			24.3-26.4
Kiteeso	84±6	39±8	311±47	4.9-6.0	<5	24.6±0.3
(n=8)	73-95	24-50	256-368			24.1-25.0
Luzige	85±24	64±13	585±38	4.5-5.7	<5	24.6±0.4
(n=8)	32-108	40-79	532-620			24.2-25.3
Bwanika I	74±11	48±14	359±27	5.0-6.6	<5	24.4±0.3
(n=8)	60-86	23-61	316-389			24.0-24.7
Bwanika II	78±5	46±16	410±19	4.6-6.6	<5	24.6±0.2
(n=8)	74-88	23-68	388-435			
24.5-25.0						

[a] = mean±standard deviation; [b] = range

Bacteriological levels

Table 3 presents the levels of bacterial indicator organisms in water from the springs studied. All the springs were contaminated with faecal indicator bacteria. There was a wide variation in the microbial levels recorded in the springs. The total coliform counts ranged from 3 to 80,000 cfu/100 ml. The total coliform counts in 90% of the samples exceeded the WHO guideline for drinking water. The faecal coliform counts ranged from 1 to 60,080 cfu/100 ml. All the samples had faecal coliform counts above the WHO guideline for drinking water. The faecal streptococci levels ranged from 0 to 3,000 cfu/100 ml. Kakajo spring had the highest median levels for all bacterial indicator organisms of faecal contamination considered in the study. On the other, Kasule spring had the least median contamination levels. There was no significant difference (p=0.503) between the median total coliform counts of spring water from Katwe and Kisenyi parishes.

Table 3: Levels of indicators of faecal bacterial contamination of spring water in Katwe and Kisenyi parishes, Kampala City

Spring Name	Total coliforms (cfu/100 ml)		Feacal coliforms (cfu/100 ml)		Faecal streptococci (cfu/100ml)	
	Range	Median	Range	Median	Range	Median
Nakatanza (n=8)	10-6900	905	2-3800	601	0-750	45
Kazungu (n=8)	27-900	345	16-500	191	12-286	57
Musoke (n=8)	17-32000	75	10-7000	52	2-397	5
Kasule (n=8)	5-186	26	1-145	17	0-5	2
Kakajo (n=8)	1890-80000	7900	980-60800	4050	890-3000	1130
Maama Betty (n=8)	10-25000	22	5-3700	15	1-66	6
Kiteeso (n=8)	21-1700	89	13-1220	61	1-102	4
Luzige (n=8)	50-1028	640	27-870	383	4-101	20
Bwanika I (n=8)	4 – 319	49	1 - 251	27	0 - 89	6
Bwanika II (n=8)	3-398	87	1-186	46	1-23	9

Correlation of bacterial counts and the levels of chlorides and nitrates

The Pearson correlation coefficient of median total coliform counts with the nitrate levels was 0.293, and with the levels of chlorides was 0.193. The Pearson correlation coefficient of median faecal coliform counts with the levels of nitrates was 0.275, and with the levels of chlorides was 0.176. The Pearson correlation coefficient of median faecal streptococci counts with the levels of nitrates was 0.323, and with the levels of chlorides was 0.143.

Correlation of bacterial counts and the sanitary risk score

The Pearson correlation coefficient of median total coliform counts with the sanitary risk score was 0.887, of median faecal coliform with sanitary score was also 0.887, and of median faecal streptococci with sanitary score was 0.795.

DISCUSSION

Surveillance of water quality to ensure microbiological and chemical safety is a vital public health function especially in developing countries[6]. The WHO recommended

guidelines for bacteriological quality of drinking water is less than 1 faecal coliform per 100 ml, and 10 total coliforms per 100 ml[7]. In this study, the bacteriological quality of water from protected springs in Katwe and Kisenyi parishes was poor. The median bacteria counts recorded in this study were quite comparable with earlier findings from other areas of Kampala City reported by Taylor and Howard[8] and Barret *et al*[9]. The presence of the indicator bacteria suggests sewage contamination of these sources. Humans drinking such water untreated are at a risk of waterborne diseases.

Although this study was conducted in the dry season, occasional rainstorms were encountered. This could explain the high bacteria counts recorded in some springs. This could probably have been as a result of sub-surface infiltration. In Uganda, sub-surface infiltration has been demonstrated to coincide with heavy rainfall[8,9].

The finding of no significant difference ($p= 0.503$) of the median total coliform levels of the springs in Katwe and Kisenyi parishes could be attributed to the similar characteristics of these parishes. Both parishes are densely populated, have a high water table and generally poor sanitation. Pit latrines are the major waste facility in use these areas[2,10,11]. The microbial load may also be attributed to sub-surface leaching from pit latrines as well as direct washing of faecal material in to the spring.

Sanitary inspection is an important tool in assessing risks of the bacterial contamination of spring water. It is used to identify causes of contamination and the risk of future contamination as well as an overall assessment of operation and maintenance of water supplies[4,12]. The strong correlation of median total coliform counts with the sanitary score showed that it is a reliable tool for preliminary risk assessment of spring water contamination with faecal bacterial organisms. Lloyd and Bartman[13] reported a similar correlation in a number of developing countries.

The presence of nitrates and chlorides in spring water is associated with faecal contamination derived from wastewater[14]. An increase of these parameters in drinking water indicates contamination with wastewater. The high levels of nitrates levels observed in this study could probably be attributed to poor sanitation, probably leaching of nitrates from the nearby pit latrines. Nitrate contamination of spring water from domestic sewage has been observed elsewhere in Africa. In Nigeria, for example, nitrate levels in shallow wells were demonstrated to correlate with high human population density[15,16].

In the present study, there was a weak correlation between nitrate levels and levels of bacterial indicator organisms of faecal contamination. In some springs, high nitrate levels were found even when low or no faecal coliform or faecal streptococci were found. Similar observations have been reported for groundwater sources in Iganga district in eastern Uganda[9]. This may be explained by the differences in hydro-geological regimes and likely contaminant entry point. Residence times in the shallow groundwater systems is likely to be short, and groundwater nitrate will be controlled by the degree of faecal loading and on mineralisation and nitrification of faecal nitrogen. The level of nitrates is controlled by rate of mineralisation of organic nitrogenous compounds and subsequent nitrification of ammonia, and possible localised denitrification[9]. The weak correlation observed could also be due to high dilution of faecal matter by rainwater and surface runoff or selective removal of nitrates and chlorides during transport in the soil[14].

The low pH observed in some springs could have been as a consequence of carbon dioxide saturation in the groundwater[17]. Nshekanabo and Wozei[18] found the pH of spring water in Katanga, a suburb North of Kampala city, to be acidic.

We conclude that sanitary risk assessment score is a reliable tool for predicting the likely levels of bacterial contamination of spring water, and that water from the ten protected springs studied is unsuitable for drinking without treatment.

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REFERENCES

1. Howard AG, Bartman JK and Luyima P. Small water supplies in urban areas of developing countries. In: Cotruvo, JA, Craun, GF. and Hearne, N. (eds). Providing safe drinking water in small systems: Technology, operations and economics. Lewis Publishers, Washington DC, USA. 1999
2. NEMA. State of the Environment Report for Uganda, 1998. The National Environment and Management Authority, Kampala, Uganda. 1999.
3. Robillard PD, SharpeWE, and Wistock BR. Nitrates in drinking water. Pennsylvania State University, Agricultural and Biological Engineering. 2003.
4. Howard AG. Water supply surveillance: A reference manual. WEDC, Loughborough University, UK, 2002.

5. APHA. Standard methods for the examination of water and wastewaters. 19th Edition. American Public Health Association, Washington D.C. 1995.
6. Esrey SA, Potash JB, Roberts L and Shiff C. Effects of improved water supply on ascariasis, diarrhoea. dranculiasis, hookworm infection, schistosomiasis and trachoma. *Bulletin of the World Health Organisation* 1991; 69: 609-621.
7. WHO. Guidelines for Drinking Water Quality. Second Edition. Volume 1: Recommendations. WHO, Geneva. 1993.
8. Taylor RG and Howard AG. Groundwater quality in rural Uganda: Hydrochemical considerations for the development of aquifers within the basement complex of Africa. In: Groundwater Quality, McCall, JH (Ed.), 1995.
9. Barrett MH, Nalubega M, Howard AG, Taylor RG and Pedley S. The impact of on-site sanitation on urban groundwater quality in Uganda. In: Hydrogeology and Land Use Management. Fendecova and Fendek. (eds), IAH, 1999.
10. Mwesigwa D. Water and sanitation in peri-urban settlements. Sustainability of water and sanitation. Proceedings of the 21st WEDC Conference, Kampala, Uganda. 1995.
11. ARGOSS. Assessing risk to groundwater from on-site sanitation: Scientific Review and Case Studies. BGS commissioned Report, CR/02/079N. 2002.
12. WHO. Guidelines for drinking water quality. Second edition. Volume 3: Surveillance and control of community water supplies. WHO, Geneva, 1997.
13. Lloyd B and Bartman J. Surveillance solutions to microbiological problems in water quality control in developing countries. *Water, Science and Technology*, 1991; **24(2)**: 61-75.
14. Lewis WJ, Foster SSD, and Drasar BS. The risks of groundwater pollution by on-site sanitation in developing countries: A literature review. International Reference Centre for Waste Disposal Report Number 01/82. 1980.
15. Langennegger D. High nitrate concentrations in shallow aquifers in a rural area of central Nigeria. *Quality of groundwater, Studies in Environmental Science*, 1981; **17**: 135-140.
16. Malomo S, Okufarasin VA, Olorunniwo MA and Omode AA. Groundwater chemistry of weathered zone aquifers of an area underlain by basement complex rocks. *Journal of Africa Earth Sciences*, 1990; **11**: 357-371.
17. Byamukama D, Kansime F, Mach lR and Farnleitner A. Determination of Escherichia *coli* contamination with Chromocult coliform agar showed a high level of discrimination efficiency for differing pollution levels in tropical waters of Kampala, Uganda. *Applied and Environmental Microbiology*, 1999; 66**(2)**: 864-868.
18. Nshekanabo N and Wozei E. Spring water quality improvement in slums. Sanitation and water for all. Proceedings of 24th WEDC Conference, Islamabad, Pakistan. 1997.