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Studies on microbial quality of filtered water in households of a university community in Nigeria

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SUMMARY

Water samples from home filters in nine residential areas of a Nigerian university community were studied. The membrane filter technique was used to determine the total coliform and faecal coliform counts/100 ml of water. Most of the 100 samples studied were grossly contaminated with total coliform counts/100 ml ranging from 0–442, faecal coliform counts/100 ml, 0–216 and the total aerobic plate count per millilitre ranged from $3{\cdot}0 \times 10^3$ to $1{\cdot}9 \times 10^9$ c.f.u. The source (dams) of water, fitness of filter candles, frequency of cleaning candles and pH of water did not significantly ($P > 0{\cdot}05$; χ^2) affect the microbial quality of either filtered boiled or unboiled tap water.

Escherichia coli type I was isolated from 17·9% of the faecal coliforms tested but from only 2·3% of total coliforms. *Enterobacter aerogenes* was most predominant (38·5%) amongst faecal coliforms isolated while *Enterobacter cloacae* was the most frequent (37·2%) of the total coliform isolates.

The gross contamination of filtered water from all households sampled calls for an enlightenment of residents on the proper use of home water filters.

INTRODUCTION

The microbial quality of pipeborne and well water supplies to some Nigerian communities have been reported to be poor with coliform counts far exceeding the level recommended by the World Health Organisation (Rand, Greenberg & Taras, 1975; Bako, 1978; Adesiyun *et al.* 1983; Onuorah, 1984). These reports suggest that poor water quality could have an adverse effect on the health of the majority of the Nigerian population. To date, information is not available on the microbial quality of water consumed in households regardless of the initial source – pipeborne, well or stream. Such information is needed because when water supply gets to a household from any source, practices such as boiling, filteration, or alum treatment and basic sanitation may affect the microbial quality of water consumed.

The situation in most Nigerian university staff houses is unique in the sense that most households are routinely provided with water filters (predominantly the double-candle type) for their use. This then affords an opportunity to directly assess the health risk associated with water consumption in households. In view

of the evident poor knowledge on the proper use of home water filters, even in university communities, this study was conducted to determine the microbial quality of water from home filters and to assess the effects of some practices in households on water quality.

MATERIALS AND METHODS

Sampling areas

Nine residential areas for staff of Ahmadu Bello University, Zaria were studied. The number of residential units per area were identified and approximately 10% of the units (households) randomly selected in each area served as sampling units. Five of the residential areas studied had their water supply from the University dam while the other four were supplied by the Zaria dam.

Sample collection

For each household sampled, using a prepared questionnaire, the following information was obtained: (i) number of people in the household; (ii) type of water filtration technique; (iii) type of water filtered; (iv) frequency of cleaning candle of filter; (v) possession and use of a candle diameter gauge.

Approximately 200 ml of water was directly drawn from filters or containers where stored (for households practising no filtration) into sterile 300 ml bottles and taken to the laboratory within 1 h. Any sample that could not be processed immediately was refrigerated for a maximum of 12 h.

Bacterial isolation, identification and enumeration

Total aerobic plate count

Serial dilutions of water samples were made in saline and plated in duplicate plates of nutrient agar. Plates were incubated at 37 °C for 24–48 h and the counts per ml of water sample was determined using a colony counter.

Coliform detection

The membrane filter (MF) technique described by Lechevallier, Cameron & McFetter (1983) was used with some modification. For each sample, 50 ml and 100 ml portions were filtered through 0·45 μm membrane filters in a unit connected to a vacuum pump. Filters were aseptically removed using a sterile pair of forceps and with the grid side up, the plates were placed on M-endo agar (Difco, U.S.A.) and Fc-agar (Difco, U.S.A.) in 47 mm plastic Petri dishes for total coliform and faecal coliform detection, respectively. To prepare both media, 1·5% agar was incorporated into the broth concentration.

The inoculated M-endo plates were incubated upside down at 37 °C for 24 h while the Fc-agar plates were incubated at an elevated temperature of 44·5°C in a water bath for 24 h. Colonies with green or gold metallic sheen on M-endo agar were regarded as total coliforms while light blue to dark-green colonies on Fc-medium were regarded as faecal coliforms as earlier suggested (Wolf, 1972). They were enumerated and expressed per 100 ml of water.

Typical colonies from M-endo and Fc-media from all water samples were randomly selected and stored on nutrient agar slants at 4 °C till needed.

Table 1. *Classification of microbial quality of candle-filtered water used in this study*

Organism tested	Category		
	Fair	Poor	Very poor
Total coliforms/100 ml*	0–10	11–100	Over 100
Faecal coliforms/100 ml†	0–5	6–20	Over 20
Total aerobic plate count/ml‡	$0–9{\cdot}9 \times 10^3$	$1{\cdot}0 \times 10^4–9{\cdot}9 \times 10^6$	$1{\cdot}0 \times 10^7$ and over

* For all water samples, the range obtained for total coliforms/100 ml was 0–442.
† For all water samples, the range obtained for faecal coliforms/100 ml was 0–216.
‡ The range of total aerobic plate count/ml obtained for all water samples was $3{\cdot}0 \times 10^3–1{\cdot}9 \times 10^9$.

A total of 125 isolates from Fc-agar (39) and M-endo agar (86) were further identified according to *Bergey's Manual of Determinative Bacteriology* (Buchanan & Gibbons, 1974).

Chemical analysis

An atomic absorption spectrophotometer (Unicam SP 1900) was used to determine the lead, cadmium, calcium and arsenic contents of water samples.

Statistical analysis

For all bacterial counts (total coliform, faecal coliform and total aerobic plate) a non-parametric approach with the chi-square test was used (Colton, 1974). With most of the total coliform counts far exceeding the recommended 2·2/100 ml (Rand, Greenbert & Taras, 1975), three categories (fair, poor and very poor) with appropriate ranges were drawn up (Table 1) and the observations for total coliform, faecal coliform and total aerobic plate counts were noted. With the aid of a computer program using cross-tabulations by dam, fitness of gauge, frequency of cleaning candles and pH for total coliform, faecal coliforms and total aerobic plate counts, the proportions of observations in the categories were compared using a χ^2 (chi-square) test.

RESULTS

Table 1 shows the classification of microbial quality of candle-filtered water employed in the study. For the 100 water samples, the total coliform counts ranged from 0–442/100 ml, 0–216/100 ml for faecal coliforms and the total aerobic plate count ranged from $3{\cdot}0 \times 10^3$ to $1{\cdot}9 \times 10^9$ c.f.u./millilitre of water.

The distribution of residents in various households over nine residential areas and mean pH values of water samples are shown in Table 2. Amongst the 100 households sampled, the mean number of people per household ranged from $4{\cdot}6 \pm 3{\cdot}1$ to $7{\cdot}3 \pm 1{\cdot}4$ with an overall mean of $6{\cdot}3 \pm 2{\cdot}5$. The mean pH was $7{\cdot}6 \pm 0{\cdot}8$ while the mean ranged from $6{\cdot}8 \pm 0{\cdot}3$ to $8{\cdot}6 \pm 0{\cdot}4$. The differences in pH values of water samples between the nine residential areas were not statistically significant ($P > 0{\cdot}05$; t-test).

A comparison of microbial quality of candle-filtered water from Zaria and

Table 2. *Distribution of residents in areas and pH values of water sampled.*

Residential area	No. of housing units sampled	Mean no. of people/household*	Mean pH of water in households*
I	7	7·0 ± 2·5	7·2 ± 0·3
II	9	7·0 ± 3·8	7·3 ± 0·1
III	8	7·3 ± 1·4	8·1 ± 0·4
IV	14	6·0 ± 2·0	6·8 ± 0·3
V	14	4·6 ± 3·1	6·9 ± 0·5
VI	22	6·4 ± 2·6	8·5 ± 0·5
VII	6	5·8 ± 2·6	8·6 ± 0·4
VIII	16	6·9 ± 1·7	7·5 ± 0·5
IX	4	5·5 ± 1·0	8·4 ± 0·4
Total	100	6·3 ± 2·5	7·6 ± 0·8

* Mean ± S.E.

University dams is shown in Table 3. For the 70 households that filtered boiled tap water, the difference in microbial quality of water from both dams was not statistically significant ($P > 0{\cdot}05$; χ^2). Similarly, for the 30 households using unboiled tap water, the source did not significantly ($P > 0{\cdot}05$; χ^2) affect microbial quality. Generally, a higher proportion of samples from filters with boiled water were in the 'fair' category than those filtering unboiled water.

Table 4 shows the effect of fitness of candles on the microbial quality of filtered water. No statistically significant ($P > 0{\cdot}05$; χ^2) difference was observed for the microbial quality of filtered boiled or unboiled tap water between households with fit and unfit candles. However, filtration of unboiled tap water resulted in samples with poorer microbial quality than those filtering boiled tap water with a predominance of the latter in the 'fair' category.

The effect of the frequency of cleaning candles on the microbial quality of candle-filtered water is shown in Table 5. Interestingly, the frequency of cleaning candles did not significantly ($P > 0{\cdot}05$; χ^2) affect the microbial quality of filtered water whether boiled or unboiled. Again, for each of the four frequencies of cleaning candles tested, the microbial quality of filtered unboiled water was relatively poorer than for boiled water.

Table 6 shows the frequency of isolation of members of the coliform group from isolates of total and faecal coliforms tested. *Escherichia coli* type I constituted only 17·9% (7 of 39) of the faecal coliforms and 2·3% (2 of 86) of the total coliforms tested. Amongst faecal coliforms, *Enterobacter aerogenes* was predominant, 38·9% (15 of 39) while *Enterobacter cloacae* was most frequently (37·3%) detected amongst total coliforms.

Chemical analysis of all samples tested showed that lead, arsenic, copper and cadmium contents were less than 0·05 p.p.m.

DISCUSSION

The finding that a majority of 100 water samples collected from households in all nine residential areas of a university community were grossly contaminated by coliforms (total and faecal) should be of health concern. Total coliform counts and faecal coliform counts ranging from 0–442/100 ml and 0–216/100 ml respectively

Table 3. *Effect of water source on microbial quality of candle-filtered water*

Source of water	No. of residential areas	No. of households sampled	Classification of water quality	No. of households: Boiled water[a] Total coliform count[c]	Boiled water[a] Faecal coliform count[d]	Boiled water[a] Total aerobic plate count[e]	Unboiled tap water[b] Total coliform count[f]	Unboiled tap water[b] Faecal coliform count[g]	Unboiled tap water[b] Total aerobic plate count[h]
University Dam	5	69	Fair	18 (25·7)	30 (42·9)	0 (0·0)	4 (13·3)	6 (20·0)	0 (0·0)
			Poor	25 (35·7)	13 (18·5)	28 (40·0)	8 (26·7)	3 (10·0)	14 (46·7)
			Very poor	4 (5·7)	4 (5·7)	19 (27·1)	10 (33·3)	13 (43·3)	8 (26·7)
Zaria Dam	4	21	Fair	14 (20·0)	16 (22·9)	1 (1·4)	2 (6·7)	4 (13·3)	0 (0·0)
			Poor	7 (10·0)	4 (5·7)	12 (17·1)	3 (10·0)	1 (3·3)	7 (23·3)
			Very poor	2 (2·9)	3 (4·3)	10 (14·3)	3 (10·0)	3 (10·0)	1 (3·3)

Figures in parentheses represent percentages.

[a] Per cent values expressed for total number of boiled water (70) samples.

[b] Per cent values expressed for total number of unboiled water (30) samples.

[c–h] Values were not significantly ($P > 0·05$; χ^2) different. The following levels of significance were obtained [c]($P = 0·1767$), [d]($P = 0·5871$), [e]($P = 0·3235$), [f]($P = 0·3235$), [g]($P = 0·4898$), and [h]($P = 0·4175$).

Table 4. *Effect of fitness of candle on microbial quality of candle-filtered[a] water*

Status of candle	No. of households sampled	Classification of water quality	No. of households: Boiled water[b] Total coliform count[d]	Boiled water[b] Faecal coliform count[e]	Boiled water[b] Total aerobic plate count[f]	Unboiled tap water[c] Total coliform count[g]	Unboiled tap water[c] Faecal coliform count[h]	Unboiled tap water[c] Total aerobic plate count[f]
Fit	77	Fair	26 (41·9)	39 (62·9)	1 (1·6)	6 (20·7)	9 (31·0)	0 (0·0)
		Poor	25 (40·3)	12 (19·4)	31 (50·0)	9 (31·0)	3 (10·3)	17 (58·6)
		Very poor	3 (4·8)	3 (4·8)	22 (35·5)	8 (27·6)	11 (37·9)	6 (20·7)
Unfit	14	Fair	3 (4·8)	4 (6·5)	0 (0·0)	0 (0·0)	1 (3·4)	0 (0·0)
		Poor	4 (6·5)	2 (3·2)	5 (8·1)	1 (3·4)	0 (0·0)	4 (13·8)
		Very poor	1 (1·6)	2 (3·2)	3 (4·8)	5 (17·2)	5 (17·2)	2 (6·9)

Figures in parentheses represent percentages.

[a] Ninety-one (91) households had candle-filters.

[b] Per cent values expressed for total number of boiled water (62) samples. Eight households using unfit candles and of these 4 had coliform counts $< 2{\cdot}2$ and total coliforms (0–290) and faecal coliforms (10–63).

[c] Per cent values expressed for total number of unboiled water (29) samples. Six households using unfit candles but none with coliform counts $> 2{\cdot}2$. Total coliform counts ranged from 70–442 and faecal coliforms, 24–380.

[d–f] Values were not significantly ($P = 0{\cdot}05$; χ^2) different. The levels of significance obtained were [d]($P = 0{\cdot}7011$), [e]($P = 0{\cdot}1516$), [f]($P = 0{\cdot}9060$), [g]($P = 0{\cdot}0924$), [h]($P = 0{\cdot}2771$) and [f]($P = 0{\cdot}8735$).

Table 5. *Effect of frequency of cleaning candle*[a] on microbial quality of candle-filtered water

Frequency of cleaning candle	No. of households sampled	Classification of water quality	No. of households: Boiled water[b] Total coliform count[d]	Boiled water[b] Faecal coliform count[e]	Boiled water[b] Total aerobic plate count[f]	Unboiled tap water[c] Total coliform count[g]	Unboiled tap water[c] Faecal coliform count[h]	Unboiled tap water[c] Total aerobic plate count[i]
Daily	9	Fair	2 (3·2)	3 (4·8)	0 (0·0)	1 (3·4)	1 (3·4)	0 (0·0)
		Poor	2 (3·2)	1 (1·6)	3 (4·8)	1 (3·4)	0 (0·0)	3 (10·3)
		Very poor	0 (0·0)	0 (0·0)	1 (1·6)	3 (10·3)	4 (13·8)	2 (6·9)
Twice weekly	27	Fair	8 (12·9)	12 (19·4)	0 (0·0)	1 (3·4)	2 (6·9)	0 (0·0)
		Poor	10 (16·1)	5 (8·1)	12 (19·4)	3 (10·3)	0 (0·0)	6 (20·7)
		Very poor	1 (1·6)	2 (3·2)	7 (11·3)	4 (13·8)	6 (20·7)	2 (6·9)
Weekly	30	Fair	11 (17·7)	15 (24·2)	1 (1·6)	3 (10·3)	4 (13·8)	0 (0·0)
		Poor	9 (14·5)	5 (8·1)	14 (22·6)	4 (13·8)	2 (6·9)	8 (27·6)
		Very poor	2 (3·2)	2 (3·2)	7 (11·3)	1 (3·4)	2 (6·9)	0 (0·0)
Fortnightly or longer	25	Fair	8 (12·9)	13 (21·0)	0 (0·0)	1 (3·4)	3 (10·3)	0 (0·0)
		Poor	8 (12·9)	3 (4·8)	7 (11·3)	2 (6·9)	1 (3·4)	4 (13·8)
		Very poor	1 (1·6)	1 (1·6)	10 (16·1)	5 (17·2)	4 (13·8)	4 (13·8)

Figures in parentheses represent percentages.

[a] Ninety-one (91) households had candle-filters.

[b] Per cent values expressed for total number of boiled water (62) samples.

[c] Per cent values expressed for total number of unboiled water (29) samples.

[d–i] Values were not significantly ($P > 0·05$; χ^2) different. The levels of significance obtained were: [d]($P = 0·9855$), [e]($P = 0·9789$), [f]($P = 0·5208$), [g]($P = 0·4897$), [h]($P = 0·3573$) and [i]($P = 0·1403$).

Table 6. *Relative frequency of occurrence of members of the family Enterobacteriaceae amongst isolated faecal and total coliforms*

Type of Organism	Faecal coliform*	Total coliform†
Escherichia coli type 1	7 (17·9)	2 (2·3)
Enterobacter aerogenes	15 (38·5)	21 (24·4)
Enterobacter cloacae	8 (20·5)	32 (37·2)
Klebsiella ozaenae	3 (7·7)	25 (29·1)
Serratia marcescens	3 (7·7)	6 (7·0)
Others (Invic)	3 (7·7)	0 (0·0)

* A total of 39 randomly selected isolates from all samples tested which gave positive reactions on Fc medium.

† A total of 86 randomly selected isolates from all samples that gave positive reactions on M-Endo medium.

are much higher than a standard of 2·2 coliforms/100 ml recommended for potable water (Rand, Greenberg & Taras, 1975; Freedman, 1977). In fact in the present study, only 31·0% of the samples may be considered fit for human consumption with 2·2 coliforms/100 ml or fewer. The health risk is further appreciated when it is realized that the water samples studied were assessed as consumed coupled with the fact that a mean of $6{\cdot}3 \pm 2{\cdot}5$ people per household were exposed to such poor quality water supply. Furthermore, the possible presence of other pathogens like *Vibrio cholerae*, *Shigella* spp., *Campylobacter* spp. and enteroviruses not specifically looked for, cannot be ruled out.

It was most surprising to observe that the fitness of candles as determined by gauges and frequency of cleaning them did not significantly affect the microbial quality of filtered water tested. Fit candles and frequent cleaning of such candles are expected to result in good quality filtered water. It was however interesting to note that supposedly good quality filtered water was not what came out of the lower half collector of most filtration units in households sampled. The practice of cleaning and rinsing filters with unboiled tap water as found in all households may have played a prominent role in the failure to observe a significant relationship between fitness of candle, and frequently cleaned candles and microbial quality. With pipeborne water in this environment earlier reported to be highly contaminated by coliforms (Onuorah, 1984), it therefore appears that filtered water is exposed to some left-over contaminated unboiled tap water in the lower collector of the filtering unit prior to reaching the consumer. This may serve as a source of coliforms for otherwise, filtered water.

It was also evident that households filtering unboiled tap water are exposed to poorer quality filtered water than those that used boiled tap water. Therefore, although samples eventually get contaminated in the collector, the degree of contamination is relative. Filtered water from households using unfit candles and unboiled tap water as expected were mostly contaminated as none of the samples from the six such households was considered potable (i.e. all had over 2·2 coliforms/100 ml) as the total coliform and faecal coliform counts/100 ml ranged from 70–442 and 24–380, respectively (Table 4). On the other hand, of 8 households with unfit candles but filtering boiled tap water, 4 were negative for total coliforms and faecal coliforms with a range of 0–290 and 0–63/100 ml of total coliforms and

faecal coliforms, respectively for the remaining 4 households. It is obvious therefore that despite the practice of cleaning candles with unboiled tap water of poor quality, boiling of water to be filtered has an effect of improving the quality of water that gets to the consumer.

The predominance of low-temperature (37 °C) coliforms (total coliforms) like *Enterobacter cloacae* (37·2 %), *Enterobacter aerogenes* (24·4 %) and *Klebsiella ozaenae* (29·1 %) is in agreement with the findings of Hammad & Dirar (1982) on Sudanese public water stands. That *E. aerogenes* constituted 38·5 % of the high temperature coliforms (faecal coliforms) in the present study also agrees with reports from Sudan and India (Hammad & Dirar, 1982; Raghavachari *et al.* 1939) although water from different sources were used. Aerogenes-like organisms have been shown to produce acid and gas at 44 °C (Boizot, 1941). The finding that only 17·9 % of the faecal coliforms were *E. coli* type I in this study is much lower than the 44·4 % reported by Hammand & Dirar (1982). *Escherichia coli* type I is known to be the most numerous type of coliform in faeces. This therefore suggests that the predominant coliform species *E. aerogenes*, *E. cloacae*, *Klebsiella ozaenae* and *Serrantia marcescens* do not necessarily indicate faecal contamination of filtered water. *Klebsiella ozaenae* may have been introduced by residents cleaning filtering units through insanitary practices like nose-picking.

In conclusion, it is advised that owners of home filters boil water regardless of source prior to filtration and cleaning of filtering units must be done under sanitary practices. Boiled tap water should be used in the final rinsing after cleaning. There is a need for further work to ascertain the presence or absence of some specific pathogens in home filtered water.

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