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Bacteriological quality of potable water sources supplying Morogoro municipality and its outskirts: a case study in Tanzania.

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SUMMARY

Bacteriological quality of potable water supplying Morogoro municipality and its outskirts (population 135000 people) was assessed by the determination of the most probable number (MPN) of faecal coliforms, *Escherichia coli*, faecal streptococci and *Clostridium perfringens* for a period of 6 months. River water and chlorinated pipeborne water were found contaminated with microorganisms in the order of $3{\cdot}8 \times 10^1$ to $4{\cdot}95 \times 10^3$; $3{\cdot}2 \times 10^1$ to $4{\cdot}5 \times 10^3$; 10^1 to $6{\cdot}4 \times 10^1$ and $1{\cdot}2 \times 10^1$ to $2{\cdot}5 \times 10^2$/100 ml of water respectively. Injured coliforms in treated water averaged 87%. Pollution of river water by organic matter was much above acceptable standard. These findings indicate that there is a need for further treatment of water before consumption in order to avoid potential health hazards.

INTRODUCTION

Microbial contamination of drinking water had been reported in various communities in the developing world [1–8]. Non-treatment or insufficient treatment of drinking water to acceptable international standards has been noted in such countries [6]. Contaminated food and water are often regarded as important vehicles of diarrhoeal transmission [9]. Despite the government's efforts to provide safe and adequate potable water to the majority of the population, waterborne disease outbreaks are still reported. Waterborne diseases contributed about 8·7–10·0% of all diseases reported in Tanzania during 1984–5 [10] and diarrhoeal diseases and all forms of gastroenteritis mortality rate averaged 10·2% in Morogoro region in the past few years [11].

The purpose of this study was to examine the bacteriological quality of water supplied to the municipality of Morogoro and adjacent communities in the outskirts which have a current population of around 135000 people. Water samples were screened for concentrations of indicator organisms like coliforms, faecal coliforms, *Escherichia coli*, faecal streptococci and *Clostridium perfringens* as relevant indices. Furthermore the presence of organic matter was investigated in these water samples.

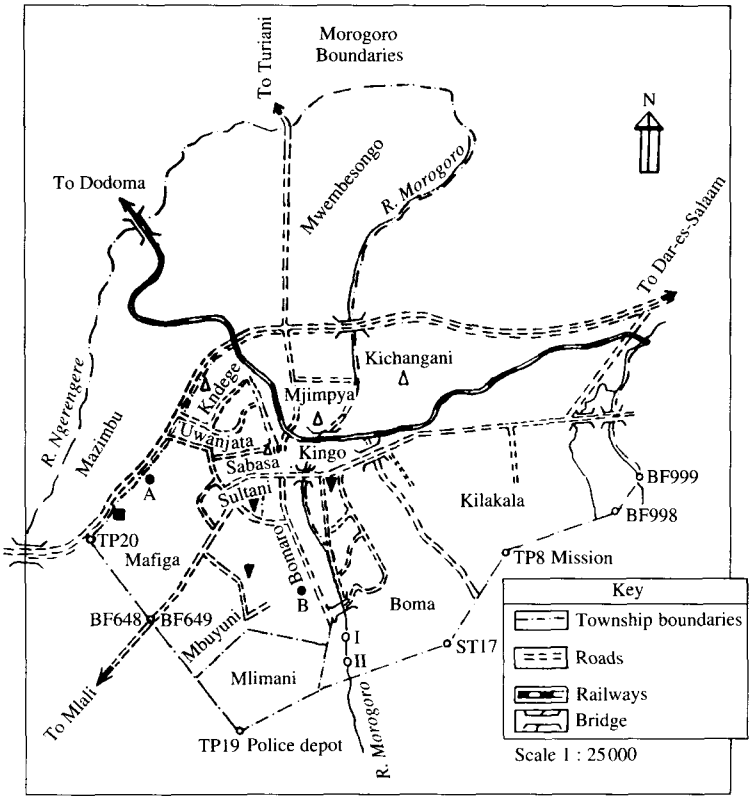

Fig. 1. Map of Morogoro municipality showing sampling points (courtesy of Morogoro Municipal Council). Legend: ○, river sampling points; □, Mindu dam; ●, storage tanks: A, Mafiga; B, Boma Road tank; △, sampling point of Mafiga distribution system; ▼, sampling point on Mambogo (Boma road) distribution system.

MATERIALS AND METHODS

Water sources and sampling procedure

Water for domestic purpose in Morogoro municipality is obtained from two different sources and distributed separately. Water is collected from Morogoro river and Ngerengere river and treated at Mambogo and Mafiga water stations respectively. Water from the former source is stored in a tank along Boma Road and the latter is collected from Mindu dam and then pumped to Mafiga before distribution (Fig. 1). Some communities in the outskirts having no access to piped water obtain it from rivers traversing these areas.

Sampling in duplicates from randomly selected sites (Table 1) was carried out fortnightly over a period of 6 months from January to June, 1989. The sampling points were Kiwanja cha Ndege, Sabasaba, Mji mpya and Kichangani public taps (Mafiga tank supply); Morogoro regional hospital, Sultan area, Sokoine University main campus (Boma Road supply). Two points, i.e. I and II, were chosen along Morogoro river in the vicinity of two communities. Point I was further downstream compared with point II. Water was collected in sterile bottles according to a

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Table 1. *Water samples collected* as per indicated source from Morogoro municipality*

Source no.	Site	Number of samples	Type of sample
1.	Morogoro river site I	24	Raw water (non treated)
2.	Morogoro river site II	24	Raw water
3.	Sultan area public tap	24	Pipeborne drinking water (treated)
4.	Morogoro hospital tap	24	Pipeborne drinking water (treated)
5.	University campus cafeteria tap	24	Pipeborne water (treated)
6.	Sabasaba area public tap	24	Pipeborne drinking water (treated)
7.	Kiwanja cha Ndege public tap	24	Pipeborne drinking water (treated)
8.	Mjimpya public tap	24	Pipeborne drinking water (treated)
9.	Kichangani area public tap	24	Pipeborne drinking water (treated)

* Duplicate samples were collected fortnightly from each site over a 6-month period between 1 January to 30 June 1989.

recommended procedure [12] and, in case of tap water sodium thiosulphate was added in the sampling bottles to dechlorinate it. Samples were transported to the laboratory in a coolbox and tested within 2 h of sampling.

Bacteriological analyses

Samples were analysed for the presence of injured coliforms, faecal coliforms, *Escherichia coli*, faecal streptococci, *Clostridium perfringens* and organic matter by determination of the biochemical oxygen demand.

Recovery of injured coliforms

Pipeborne water was analysed for the presence of injured coliforms according to the procedure described by McFeters and colleagues [13] using tryptic soy agar without dextrose but supplemented with 1% lactose and 0·3% yeast extract (TLY) and TLY agar containing 0·1% desoxycholate and incubated at 37 °C for 48 h. Typical colonies were streaked on eosin methylene blue (EMB) – lactose agar and incubated for 24 h.

Faecal coliforms and Escherichia coli

The enumeration of faecal coliforms by MPN technique was carried out in the EC broth incubated at $44{\cdot}5 \pm 0{\cdot}2$ °C for 24 h according to the procedure reported by Thatcher and Clark [14]. *E. coli* was identified according to the IMViC reactions [15, 16].

Faecal streptococci

The most probable number (MPN) of faecal streptococci was determined by the multiple tube method as above using Bacto-Azide Dextrose Broth (Difco, Detroit)

Table 2. *Counts of index microorganisms per 100 ml of Morogoro municipal water**†

Source no.	Faecal coliforms (FC)	E. Coli	Faecal streptococci (FS)	*C. Perfringens*
1.	$4{\cdot}9 \pm 0{\cdot}63 \times 10^3$	$4{\cdot}4 \pm 0{\cdot}60 \times 10^3$	$6{\cdot}4 \pm 0{\cdot}72 \times 10^1$	$2{\cdot}5 \pm 0{\cdot}48 \times 10^2$
2.	$3{\cdot}3 \pm 0{\cdot}51 \times 10^3$	$2{\cdot}9 \pm 0{\cdot}49 \times 10^3$	$5{\cdot}0 \pm 0{\cdot}63 \times 10^1$	$1{\cdot}2 \pm 0{\cdot}32 \times 10^2$
3.	$1{\cdot}1 \pm 0{\cdot}30 \times 10^2$	$1{\cdot}0 \pm 0{\cdot}29 \times 10^2$	$2{\cdot}2 \pm 0{\cdot}42 \times 10^1$	$1{\cdot}7 \pm 0{\cdot}37 \times 10^1$
4.	$1{\cdot}1 \pm 0{\cdot}29 \times 10^2$	$9{\cdot}8 \pm 0{\cdot}88 \times 10^1$	$2{\cdot}0 \pm 0{\cdot}40 \times 10^1$	$1{\cdot}9 \pm 0{\cdot}39 \times 10^1$
5.	$1{\cdot}0 \pm 0{\cdot}28 \times 10^2$	$9{\cdot}1 \pm 0{\cdot}85 \times 10^1$	$2{\cdot}6 \pm 0{\cdot}46 \times 10^1$	$2{\cdot}3 \pm 0{\cdot}43 \times 10^1$
6.	$8{\cdot}8 \pm 0{\cdot}84 \times 10^1$	$8{\cdot}0 \pm 0{\cdot}80 \times 10^1$	$1{\cdot}0 \pm 0{\cdot}28 \times 10^1$	$1{\cdot}2 \pm 0{\cdot}31 \times 10^1$
7.	$5{\cdot}6 \pm 0{\cdot}67 \times 10^1$	$4{\cdot}2 \pm 0{\cdot}58 \times 10^1$	$1{\cdot}3 \pm 0{\cdot}32 \times 10^1$	$1{\cdot}2 \pm 0{\cdot}31 \times 10^1$
8.	$4{\cdot}2 \pm 0{\cdot}58 \times 10^1$	$3{\cdot}7 \pm 0{\cdot}54 \times 10^1$	$1{\cdot}0 \pm 0{\cdot}28 \pm 10^1$	$1{\cdot}8 \pm 0{\cdot}38 \times 10^1$
9.	$3{\cdot}8 \pm 0{\cdot}55 \times 10^1$	$3{\cdot}2 \pm 0{\cdot}51 \times 10^1$	$1{\cdot}3 \pm 0{\cdot}32 \times 10^1$	$2{\cdot}2 \pm 0{\cdot}42 \times 10^1$

* This represents a summary of the results of 24 samples from each site over 6-month period.
† Means and standard deviation of MPN counts.

Table 3. *Recovery of injured coliforms in drinking water supplied to the Morogoro municipality**

Source no.	C.f.u./ml on TSY†	C.f.u./ml on TSD‡	Percentage recovery
3.	$1{\cdot}53 \times 10^2$	$8{\cdot}0 \times 10^1$	73
4.	$2{\cdot}25 \times 10^2$	$1{\cdot}35 \times 10^2$	90
5.	$1{\cdot}40 \times 10^2$	$8{\cdot}0 \times 10^1$	60
6.	$1{\cdot}50 \times 10^2$	$8{\cdot}1 \times 10^1$	69
7.	$2{\cdot}75 \times 10^2$	$1{\cdot}90 \times 10^2$	85
8.	$1{\cdot}25 \times 10^2$	$3{\cdot}9 \times 10^1$	87
9.	$1{\cdot}05 \times 10^2$	$4{\cdot}8 \times 10^1$	57

* This represents a summary of results of 24 samples from each site over a 6-month period.
† TSY. Trypticase soy agar supplemented with lactose and yeast extract.
‡ TSY. Trypticase soy agar supplemented with sodium desoxycholate.
Cfu. Colony forming units.

incubated at 37 °C for 48 h. Confirmation of the presence of faecal streptococci was accomplished by inoculating positive tubes in ethyl violet azide broth at 37 °C for 24 h according to procedure described by Hamad and Dirar [17].

Clostridium perfringens

The most probable number of *C. perfringens* was determined by using reinforced clostridial medium, incubated anaerobically at 37 °C for 48 h and confirmed according to procedure reported by Harrigan and McCance [16].

Biochemical oxygen demand

The presence of organic matter in water was determined according to method 33·024 of the Association of Official Analytical Chemists [18]. The dissolved oxygen concentration was determined by the permanganate method 33·031.

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Table 4. *Relationship between biochemical oxygen demand (B.O.D.) and* log_{10} E. coli *counts in water samples screened from Morogoro municipality and suburban areas*

Source no.	B.O.D. (mg/1)	10 g_{10} *E. coli*/ 100 ml water
1.	6·50 ± 0·72	3·65 ± 0·54
2.	6·00 ± 0·24	3·47 ± 0·53
3.	0·70 ± 0·24	2·02 ± 0·40
4.	0·65 ± 0·23	1·99 ± 0·40
5.	0·65 ± 0·23	1·96 ± 0·40
6.	0·60 ± 0·22	1·90 ± 0·39
7.	0·55 ± 0·21	1·63 ± 0·36
8.	01·55 ± 0·21	1·57 ± 0·35
9.	0·55 ± 0·21	1·52 ± 0·35

* This represents a summary of the results of 24 samples from each site over a 6-month period: correlation coefficient (r) = −0·9766, level of significance $P < 0·01$.

RESULTS AND DISCUSSION

Sampling points of drinking water collected in Morogoro municipality and its suburbs fortnightly over a period of 6 months are shown in Table 1 and Fig. 1. All samples of raw water from the river and treated water points from the distribution system were found contaminated with coliforms, faecal coliforms, faecal streptococci and *C. perfringens* as summarised in Table 2. The heaviest microbial load was observed in raw river water used as potable water by communities living along Morogoro river. Site I downstream of this river was found to be more contaminated than site II upstream probably due to human and animal faecal contamination. The contamination of natural water sources by faecally derived organisms has been reported elsewhere [6, 19, 20]. Pipeborne treated water from comparatively older Mambogo distribution system had higher microbial counts than water from a dam on the relatively new Mafiga distribution system.

The higher incidence of bacteria in water could also result from surface runoff during the wet season of sampling [9, 21]. The IMVIC characterization of *E. coli* indicated the presence of *E. coli* biotype I. The recovery of injured coliforms (Table 3) further suggests possibility of heavier contamination of water than could be detected using selective media used for isolation. *C. perfringens* isolated from water and might also point to deficiencies in filtration process and other preliminary safeguards [22, 23] or resistance to chlorination. The possibility of treated water undergoing deterioration before reaching consumer tap has been reported [3].

River water contained a higher level of organic matter than pipeborne water (Table 4). A highly significant correlation was observed between the load of *E. coli* and organic matter (biochemical oxygen demand) suggesting the likelihood of an increase in organic matter with intestinal pathogens and parasites [24, 4].

According to the World Health Organization [25] standards the quality of water supplied to the municipality of Morogoro and its suburbs is poor and indicates potential health hazards. The current exercises suggests the need for additional

purification treatment efforts and more widespread and more often attempts at screening the water quality in this case and other similar areas in Tanzania.

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