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Assessment of Baraton dam water quality by studying different Microbial levels and Physicochemical parameters

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Abstract

The current study was done to analyse different microbial levels and physicochemical parameters of Baraton dam water. Although waterborne diseases occur worldwide, they are commonly reported in the developing countries where sanitation is poor and safe drinking water is limited to a small proportion of the population. A total of 24 water samples were examined by standard bacteriological methods. Of these six, twelve and six were collected from dam, chlorinated pipeborne and waste water tap. Dam water samples had mean counts of $1.0\pm1.0x10^0$ CFU/ml at incubation temperatures of 22^0C, 37^0C and 44^0C. The bacterial counts at 44^0C is above permissible standard count of 0 CFU/100ml and therefore suggested faecal contamination. Chlorinated tap water and waste water samples at similar temperatures did not have faecal bacteria. There were no statistical significant differences between chlorinated tap water and waste water suggesting efficient treatment processing. Low *Salmonella typhi* counts of $1.0x10^0$CFU/100ml found in dam water is unacceptable by international standards. While the chlorinated tap water supply in UEAB area meets the required standard, it is only available to those in the University.

Key-Words: Dam, Microbial, physicochemical, Water

Introduction

Waterborne diseases occur throughout the world. In the last five years, over one billion people lack access to an adequate water supply; more than twice as many lack basic sanitation (WHO/UNICEF, 2006; Clasen, 2008). One thousand five hundred (1,500) million cases of waterborne infections and illnesses were reported globally (Burget and Esrey, 1995; Kolsky *and Blu*menthal, 1995; WHO, 1995a). Of the 1500 million cases, 680, 320 and 500 million cases are due to viruses, bacteria and parasites respectively. Further, five million hospitals in the world are occupied by patients suffering from waterborne illnesses annually. Half of the beds are in the developing countries and 90% of these beds are occupied by children (Kolsky, 1995; WHO, 1996a; Bartram et al., 2005; Bostoen et al., 2007). The mortality rate due to waterborne diseases is 33% (UN, 1992; WHO, 1995b; Prüss-Üstün et al., 2008) with children constituting 80% and the rest 20%.

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Environmental pollution with human faecal matter due to poor sanitation facilities in urban areas plays a major role in maintaining and spreading waterborne diseases in the developing countries (WHO, 1988; Gillespie, 1994; Mensa et al, 1995; WHO, 1995b). Overcrowding in the urban areas as a result of fast urban migration rates has confounded the spread and maintenance of waterborne illnesses (UN, 1996; UNESCO, 2006). The rural picture is similar. A high birth rate in a limited arable land in the rural areas of developing countries has lead to overcrowding. Moreover, undeveloped sanitation systems in addition to overcrowding have encouraged environmental pollution with human excreta (Menken, 1989; JMP, 2008). As rural populations increase, people live closer to each other and to their own wastes. Further, discriminate defaecation practices that contaminate drinking water supplies and environmental pathogenic organisms causing diarrhoea become common place in developing countries as Kenya (Forget, 1992; Thebaut, 2005).

The entire rural Kenyan population depends on rivers, wells, swamps and lakes for potable water (UNEP, 1987; WHO, 1995b). These water sources are unprotected and therefore subject to human faecal pollution from an environment that is already polluted (WHO, 1996a). Most Kenyans drink unsafe water as

only 15-20% of rural populations and 49% of the urban areas are supplied with piped water (World Bank, 1994; WHO, 1995a). It is, however, not known whether such supplies are adequately chlorinated in accordance with international standard guidelines for drinking water (WHO, 1984/85; WHO, 1987; Gillespie, 1994; WHO, 1996b).

Kenya has no standards of its own for drinking water and there is no systematic approach for bacteriological water quality tests nor are there any systematic and consistent drinking water monitoring services countrywide. As such it is difficult to ascertain bacteriological water quality even when such water is drawn from pipes in the rural areas or in the urban areas as the University of Eastern Africa, Baraton (UEAB). UEAB and Baraton centre has a population of 15,000 and is located in the highlands of Nandi. Urban problems experienced by other big towns in Kenya such as poor sanitation, high rate of urban migration, overcrowding and water supplies of unknown quality are also found in Baraton. This is particularly so in the slums where sanitation is extremely poor and the environment heavily polluted with human faecal material (WHO, 1995a).

Water supply in these areas is mainly by unprotected wells or boreholes or ponds and dams that are found in each compound. UEAB has clean water point known as "*Water Kiosk"* at Baraton centre but it is not popular because the water is perceived to be expensive for the residents who are poor. River Kimondi and UEAB dam is the reliable sources of water. Baraton Dam is the preferred source of water for the university. UEAB dam, situated within the university adjacent to the nature preserve, sources its water from surrounding springs. Human activities are prevalent in the vicinity with agricultural activities being the major ones. The water treatment plant of the University releases its waste back to the dam. These human activities could be having some impacts on the quality of the dam water. Water quality of this dam is unknown.

There has not been systematic testing of water supplies in UEAB, in accordance with international standards. Waste water discharge from the treatment plant flowing on the land surface over 600 meters may contain pathogenic organisms and faecal indicator organisms in levels unacceptable by widely used water Standards. These activity suggests that the people may be at risk of getting waterborne infections. Although the dilution factor can counter this threat in the rainy season (UNEP, 1987; UNEP, 1989), this may not be the case in the dry spell suggesting that the communities in Baraton may be at the greatest risk.

Since there is neither systematic bacteriological testing of potable water nor bacteriological water monitoring in UEAB, it is important that its water supplies be evaluated against accepted bacteriological standards and the water treatment plants and waste water discharge from the treatment plant be tested for dangerous bacteria for the sake of *Baraton* communities.

Material and Methods

Study Area

UEAB is in Nandi Country, Rift Valley region. Nandi North District, a highland region, exhibit large forest cover of highland equatorial type covering slightly over 30% of the area and the rest being plantations, grasslands and swamps. The districts terrain varies greatly with latitude ranging between 1900 metres above sea level (m.a.s.l) in the west to 1500 m.a.s.l. in the East. With its undulating ridges, the only two main rivers and large swamp have their origin from the district's forest cover, draining westwards to join river Yala eventually to Lake Victoria.

Water for domestic and agricultural uses in UEAB and peri-urban areas is obtained from UEAB dam (Fig.1). This water is treated at UEAB water treatment plant. Areas having no access to adequate chlorinated pipeborne water rely on shallow wells.

Sample collection and Processing

Water samples were collected fortnightly from taps and dam in UEAB over a period of three months beginning August to October 2013. Water was collected in 250ml sterile bottles. According to Collee *et al.,* (1989), the bottles were provided with ground glass stopper and its neck protected by aluminium foil paper then sterilized. All water samples were taken between 0900 and 1100 hours, stoppered and transported in a cool box to the microbiology laboratory of the Biological Sciences Department and analyzed within six hours of sampling.

Six water samples collected from the dam were tested in duplicate and enumerated for viable bacterial count (VBC) (Table 1). Water was collected with the aid of a 250 ml lead-weighted sampling bottle fitted with a rope. The bottle cap was asceptically removed and lowered into the dam to a depth of 50 centimeters. When no air bubbles rose to the surface, the bottle was raised and the cap replaced carefully. The bottle was accurately labelled.

Twelve chlorinated water samples from the main supply and six water samples from unchlorinated treatment plant for waste water were collected fortnightly from the taps respectively. Each tap was sampled six times and tested in duplicate. Tap water samples were collected from Baraton centre water kiosk, storage tank and waste water treatment faucet

within UEAB (Table 2). Chlorine in tap water was neutralized by the addition of 0.1 ml/L of a 3% solution of Sodium Thiosulphate (Chesbrough, 1984 and KBS, 1985).

Bacteriological Analyses

All glass ware, 10 ml and 1 ml straight-sided delivery pipettes wrapped in aluminum foil paper, Petri dishes (100 mm diameter and 15 mm depth) were rinsed in distilled water and sterilized. Sterile distilled water was used in media preparation. Two incubators set at 22°C and 37°C respectively were used. Thermometers were provided in each incubator for use in maintaining the daily temperature records. Wire loops with an internal diameter of 3 mm and inoculating needle from a 0.80 mm nichrome wire were both sterilized by flaming in a Bunsen burner.

Aquarter-strength Ringer solution (RS) (OXOID BR52, Hamshire, England) was prepared by dissolving 1 RS tablet in 500 ml of distilled water and then it was autoclaved at 121°C for 15 minutes. With a straight-sided pipette fitted with syringe-like lever operated pump, 1 ml sample was delivered asceptically into 9 ml RS (the first dilution blank) tube just above the level of diluent. The liquid was gently rolled between the palms to mix. With a fresh pipette, l ml was removed from the mixture and transferred to the next dilution blank and the process was continued up to (10-5 for river and dam, and 10-4 for chlorinated pipeborne water) as follows (Table 1a):

Single strength (SS) MacConkey Broth (MB) (BITEC. Cat 3/146, Suffolk, United Kingdom) was prepared by dissolving 40 grams into 1000 ml of distilled water. The media was distributed in 5 ml quantities into culture tubes (150mm x 15mm) and sterilized as described above. Double strength (DS) MB was prepared the same way as the SS MB, using double the quantities of the ingredients (except water). Media was distributed in 10 ml quantities into fermentation tubes and sterilized as above.

Sample Enumeration

All water samples were enumerated using standard bacterialogical methods. Viable bacteria count (VBC) was enumerated using Yeast Extract Agar (YEA) (OXOID CM 19, Hamshire, England) while most probable number (MPN) of coliform bacteria and E.coli were enumerated using MB. Bacterial pathogens were enumerated and characterized using Desoxycholate Citrate Agar (DCA) (DIFCO 0274-01-8, Detroit, Michigan), Triple Sugar Iron (TSI) (DIFCO 0256-01-9, Detroit, Michigan) and Motility Indole Urea (MIU) Cheesbrough (1989).

A desired volume of water sample was diluted as above (e – General directions in sample processing) and enumerated for VBC as described by Collins et al. (1995). Using MPN method as described by Collee et al. (1989), water samples were enumerated for TTC and E.coli. By reference to the probability tables, the MPN of TTC in the 100 ml water sample was estimated. Known bacterial water pathogens were enumerated according to the procedure of Collins et al. (1995).

Results and Discussion

At 22^0C, the mean viable bacteria count (VBC) range for the dam was between $1.0 \pm 1.0 \times 10^0$ CFU/ml (Table 2). VBC had no influence on either Thermotolerant coliform bacteria (TTC) or *E. coli* levels (Table 3). However, a high TTC resulted in a high *E. coli* isolations. This relationship is supported by ANOVA and regression analysis results (Table 3) which is statistically significant ($F=16.2$, $P= 2.8 \times 10^{-2}$) implying that feacal material could have been present.

At 37°C, the mean VBC range for the Dam was also $1.0 \pm 1.0 \times 10^0$ CFU/ml (Table 3). Similarly, VBC levels did not show influence on either TTC or *E. coli* levels. Similarly, TTC and *E. coli* relationship was statistically significant (Table 4).

At 22°C, the mean VBC range shown by all the taps was $0.0 \pm 0.1 \times 10^0$ CFU/ml. (Table 2). At both incubation temperatures (22 and 37°C), VBC had no influence on either TTC or *E.coli* (Table 3). TTC levels were low and had no reciprocal *E.coli* isolations.

***Salmonella* and *Shigella* sp. Levels in Dam water**

Low levels of Salmonella typhi in the dam was a mean of 1.0×10^0 CFU/ml. High levels of S. Typhi were obtained in September and lowest levels in October (Fig. 2).

Physical parameters

The mean pH values of drinking water samples should range from 6.3 to 7.7 and should also be within WHO optimum limits of between 6.5 and 8.5 (Nkansah, et al., 2010). Storage tank and Baraton kiosk had acceptable pH values of the range 7.2 to 8.2. Dam water with pH value of 6.1 is lower than 6.5 and therefore considered too acidic for human consumption and can cause health problems such as acidosis. Waste water with the pH value of 9.2 is greater than recommended standard of 8.5 and is considered to be too alkaline for human consumption.

Annual mean temperature was calculated from monthly water samples and then tested for significant correlation to time. The lowest monthly water temperature observed was 20°C which occurred in August 2013 at Waste water tap. Temperature maxima occurred in August and September with the highest

monthly water temperature (24°C) occurring at the Dam. Water temperature fluctuations at monitoring sites in sampling sites may have been influenced by a number of factors including season, time of day, cloud cover, and the flow and depth of the surrounding water body, especially for the Dam.

Examination of monthly mean turbidity values (NTU) revealed considerable variability at sampling sites. There was no indication of a distinct seasonal trend nor of major differences in average turbidity conditions between storage tank and Baraton kiosk . However, variability appeared to be greater at the Dam and waste water sites, and may be due to fluctuations in the amount of detritus being washed from the extensive marsh, upland sites that surround it and washed residues from the treatment plant. Turbidity is affected by detrital and sediment runoff. This tendency is illustrated by high values of turbidity at Dam and waste water sites which was confirmed by spectral analysis (Table 5).

Types of Bacteria Isolated in Dam Water

In dam water, *Klebsiella, Enterobacter, Escherichia, Citrobacter* and *Proteus* were isolated including *Salmonella* (Fig. 3). In Fig. 3, some bacteria utilized thiosulphate, reducing it to ferrous sulphide forming a gas hydrogen sulphide which is visible as a black precipitate and others producing a yellow butt and slant on TSI. Possible bacteria are the enterobacter including *Klebsiella, Escherichia, Citrobacter* , *Proteus* and *Salmonella* that are gram negative bacilli. The further treatment with MIU showed motility indicative of *Salmonella*.

In the study area, the quality of tap water was found to be acceptable. This was due to absence of faecal contamination. Thermotolerant coliform bacteria were enumerated at zero CFU/100ml in tap water, and therefore acceptable in accordance with international standard guidelines for drinking water. The World Health Organization recommends a drinking water standard of 0 per 100 ml (WHO, 1996b). Although occasional numbers of heterotrophic bacteria cultured at 220C and 37°C were enumerated in tap water, they are not regarded as specific pointers of faecal contamination except as indicating the presence of large decomposing matter in water supply (Wilson and Miles, 1957; WHO,1984/85; Reasoner et al., 1989 and Maul et al., 1991) in agreement, reported that the presence of heterotrophic and thermotolerant coliform bacteria in tap water is occasioned by either occurrence and repair of burst pipes or growth either in the water or the pipe waters utilizing small concentrations of dissolved organic matter.

The dam had faecal contamination above any acceptable standards for portability, although all water samples from the dam showed good quality in color, temperature and pH. The quality of dam water was of great significance due to its low levels of faecal contamination. Levels of heterotrophic, thermotolerant coliform bacteria and Escherichia coli were observed. Ideally, there should be no coliform and E. coli in drinking waters according to the international standards. However, these standards have been considered to be possibly too stringent and also should not be applied absolutely (Wilson and Miles, 1957; Feachem, 1977). Although, different waters require specific and relevant established tolerance levels of its pathogens, the high levels of faecal contamination in this study area indicates that dam waters are a potential source of faecal infections and a reservoir of the agents of faecal-oral illnesses.

Main sources of dam water contamination by faecal pollutants include inappropriate location of latrines and polluted environments lacking both excreta and solid waste disposal facilities (Messou et al., 1995). Other possible sources are dust, flies, animal feaces and solid wastes.

The possible sources of pollution of the dam with human excreta may include surface run-offs not connected to sewers from UEAB. It was observed during the cause of the study that several surface run-off tended to originate from small residential units, farm, the road under construction, and waste water from treatment plant. These surface run-offs probably carried raw sewage which degrades the dam water quality.

The characterization of *Salmonella typhi,* and large numbers of *E.coli* in the dam clearly showed that raw sewage could be finding its way into the dam. Campbell (1983) argued that those microbes should not survive any reasonable treatment scheme except when raw sewage is discharged into a dam. Montgomery and James (1985), Brandes (1987) and Rose et al., (1991) have showed that these microbes persist for about 12 days in bath and laundry waters, 22 days in dam and about 7 days in both tap and river waters. Their persistence for some time despite the fact that surface run-offs was mildly biocidized to *E.coli,* (Campbell 1983) suggests pollution by faecal materials.

Water being one of the modes of transmission of faecal infections, lack of adequate safe water supplies and efficient water treatments to the whole community may negate the aim of chlorinated pipeborne water. The section of a community without access to treated water and efficient waste treatment will continue to harbour and perpetuate transmission to the rest of community

through poor personal hygiene and sanitation in domestic and public places such as residential quarters, catering institutions and other public utilities. Ways are therefore needed of ensuring that available water is safe for drinking and waste water safe to those especially in the community.

The best way to ensure safe water and adequate sanitation for the community would be to provide treated water and efficient waste water treatment plants. This may not be practical in the developing countries in the near future because of their economies. However, establishment of adequate water purification, efficient treatment plant, and suitable water quality standards can promote better health in a community such as the study area.

Conclusion

Water quality of dam is below the required standards. Chlorinated pipe borne water quality is acceptable and therefore potable. Thus proper treatment of dam water and health education especially to the community is recommended to improve sanitation and reduce waterborne diseases in the concerned populations and similar areas in Kenya. In view of this, the following recommendations are encouraged:

1. Local water standards be established to assist in surveillance and monitoring of all water supplies in UEAB, other institutions and other urban centres.
2. Further research be done on all raw water sources and results used in designing appropriate treatment plants.

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Fig. 1: Baraton Dam

Table 1: Dam and pipeborne sampling sites in UEAB and Baraton Centre Kiosk

Source label	Sites	Number of samples
Site 1	Dam (unprotected)	6
Site 2	Dam (unprotected)	6
Baraton Kiosk	Baraton Centre	6
Storage tank	Treatment Plant	6
Waste water tap	Treatment Plant	6
Site 2	Dam (unprotected)	6
Baraton Kiosk	Baraton Centre	6
Storage tank	Treatment Plant	6
Waste water tap	Treatment Plant	6

(Table 1a):

Tube No.	1	2	3	4
Dilution	1:10	1:100	1:1000	1:10000
Volume of original	0.1	0.01	0.001	0.0001
Fluid/ml	(or 10^1)	(10^{-2})	(10^{-3})	(10^{-4})

Table 2: VBC and MPN Estimates for Water Samples Drawn from the Dam and Taps

	Viable Bacteria Count (VBC)		Most Probable Number (MPN)	
	At 22^0C	At 37^0C	of TTC	of E. coli
Dam	(CFU/ml)	(CFU/ml)	(CFU/100ml)	(CFU/100ml)
Unprotected				
Site 1	$1.0 \pm 1.0 \times 10^0$	$1.0 \pm 1.0 \times 10^0$	$1.0 \pm 1.0 \times 10^0$	$1.0 \pm 1.0 \times 10^0$
Site 2	$1.0 \pm 1.0 \times 10^0$	$1.0 \pm 1.0 \times 10^0$	$1.0 \pm 1.0 \times 10^0$	$1.0 \pm 1.0 \times 10^0$
Pipeborne				
Baraton Kiosk	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$
Storage Tank	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$
Waste water	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$	$0.0 \pm 0.1 \times 10^0$

Table 3: Regression Analysis of E. coli (Dependent variable) with Thermotolerant coliforms (TTC) (Independent variable) for Dam Water

ANOVA	df	SS	MS	F	P
Regression	1	2.7	2.7	16.2	0.028
Residual	3	0.5	0.167		
Total	4	3.2			

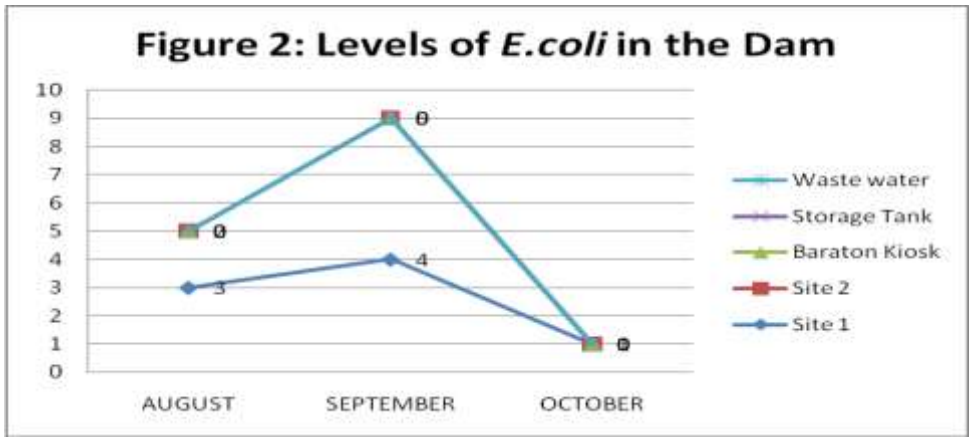
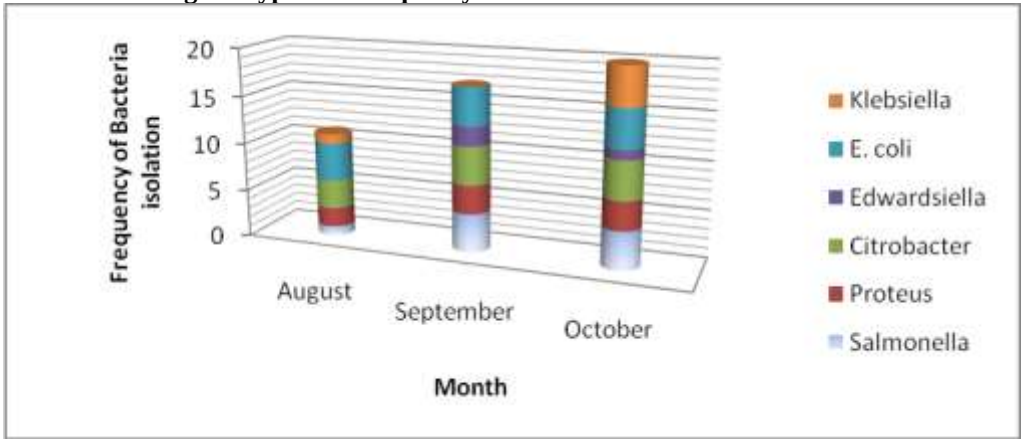


Table 4: Physical Parameters of water samples

Water Samples	PH	TEMP. ^{0}C	TURBIDITY	COLOR
Dam	6.1	24	0.13	Pale Green
Storage Tank	8.2	21	0.07	Colorless
Baraton Kiosk	7.2	20.8	0.03	Colorless
Waste Water	9.2	20.3	0.13	Brown

Fig. 3: Type and Frequency of Bacteria isolated in Dam water



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