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Assessment of changes in drinking water quality during distribution: A case study of Area 25 Township in Lilongwe, Malawi

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The quality of drinking water at the point of delivery to the consumer is crucial in safeguarding people's health. This study assesses changes in drinking water quality during distribution at Area 25 Township in Lilongwe, Malawi. Water samples were collected from the exit point of the treatment plant, storage tank and taps at consumers' households. All samples were tested using standard procedures for pH, turbidity, feacal coliforms, manganese, lead, zinc and residual chlorine. One-way ANOVA showed some significant water quality changes during distribution but the average values fell within World Health Organisation (WHO) and Malawi Bureau of standards (MBS) allowable levels for pH, turbidity, feacal coliforms, manganese, lead, zinc and residual chlorine (p < 0.05). Tap water at Area 25 Township is generally safe for human consumption.

Key words: Drinking water, distribution system, biochemical parameters, human health.

INTRODUCTION

Tap water is generally perceived by consumers as being safe and worth paying for. In most developing countries, like Malawi, drinking water distribution networks are made of galvanized iron pipes which are susceptible to internal corrosion and subsequent leaching of iron and other contaminants into water. There are also many other physical, biological and chemical processes that may affect the quality of water in a distribution system. Materials used in the distribution networks may therefore serve as a potential source of chemical contamination (WHO, 2011). Water may also be biologically contaminated through the development of biofilms along the interior walls of distribution systems and external entry through cracks and faults. The distribution pipes are mostly laid underground and there is little or no maintenance; a fact that makes them a potential health hazard to water consumers (Mendels, 1998). Leakages in distribution systems contribute to sediment infiltration and studies have shown that the key factors contributing to drinking water contamination in distribution systems are age of the pipes, extent of internal deposition, plus hydraulic issues such as flow rate, residence time and pressure (Napacho and Manyele, 2010). The end result is that consumers may receive water that satisfies the organoleptics (colour, odour and taste) but whose overall quality is bad. Most consumers have a tendency to believe that if the quality of water entering a distribution system is high then the quality will still remain good at the point of delivery. The intrusion of pathogens into drinking water in distribution systems, for example, may lead to outbreaks of diarrhoeal diseases. Ashbolt (2004) reported that worldwide the consumption of poor quality water and lack of proper sanitation and hygiene are responsible for an estimated1.7 million deaths annually.

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Kalua and Chipeta (2005) reported that in Malawi, nearly 50% of all illnesses are related to waterborne diseases. The ever increasing reliance on tap water and the fast growth of populations in urban centres in Malawi and other sub-Saharan Africa therefore poses a new challenge for water distribution managers.

Lilongwe Water Board (LWB) is responsible for water treatment and distribution of potable water in the city of Lilongwe. Established in 1947, the Board abstracts raw water from Lilongwe River which originates from Dzalanyama Ranges. There are two dams, Kamuzu Dam I and Kamuzu Dam II which are constructed along the river. The catchment area is approximately 1,870 square kilometers. Kamuzu Dam I was constructed in 1966 and has a storage capacity of 4.5 million cubic meters. Kamuzu Dam II was constructed in 1989 with an initial storage capacity of 9.2 million cubic meters. The dam was rehabilitated and raised in 1999 thus increasing the storage capacity from 9.2 million to 19.8 million cubic meters and now acts as a balancing reservoir and its outflow goes directly into Kamuzu Dam I. Water flows by gravity down to the abstraction point, about 20 km downstream (Lilongwe Water Board, 2011).

The Board has two main Treatment Plants (TW I and TW II) with a combined design capacity of 95,000 cubic meters per day. The treatment process involves the following major steps: screening; coagulation and flocculation; sedimentation; filtration and chlorination. There are about 40,000 metered customers which also include about 650 water Kiosks within the City (Lilongwe Water Board, 2011).

Water is only treated at the Lilongwe Water Board treatment plant before it is distributed by underground pipes to all the residential, industrial and institutional areas. Area 25 (2278.276 hectares) is found in the northern part of Lilongwe city, some 25 km from the treatment plant. Although, there have been no reports on serious contamination from consumers, systematic, independent assessment is always a good practice for quality control. The aim of this study was therefore to determine the extent of water quality changes from the treatment plant through the distribution network to consumers.

MATERIALS AND METHODS

Study area

Lilongwe City (13°59′S 33°47′E) is located in the central region of Malawi (Figure 1). It was declared Malawi's capital city in 1975 leading to rapid population growth from 102,924 in 1977 to over 900,000 people in 2009. The Board currently serves about 63% of the population (LWB, 2011). The city is characterised by an altitude of 1,036 m, an average annual temperature of 20°C, and a mean annual precipitation of 750 mm. Rain usually falls between November and March but sometimes extends to April. The seasonal variation in the rainfall patterns has effects on water quality entering a treatment plant and it would be scientifically prudent to sample at different times of the year during both dry and wet season. However, due to some constraints, the data presented in this paper only reflects the dry season.

Sampling design

Water samples were collected from the exit point of the treatment plant, storage tank and taps at eight randomly chosen consumer households. Sampling was done three times over a period of five months (July to November 2011). The samples were collected in prewashed (with detergent, dilute HNO_3, doubly de-ionized distilled water, respectively) double caped polyethylene bottles. In the field, the sampling bottles and caps were rinsed three times with the water to be sampled prior to sampling. Most of the samples were obtained directly from the tap after allowing the water to run for at least 5 minu so as to stabilise the variation in temperature. Then, the samples were acidified to 1% with nitric acid and stored at 4°C before analysis to minimise changes in physicochemical characteristics of the metals (Tuzen and Soylak, 2006).

Sample and data analysis

The standard analytical methods that were used for determination of biochemical parameters of water were from American Public Health Association series of Standard Methods of Examination of Water and Effluent (APHA, 1998). Samples were analysed within 2 h after collection. Results of laboratory analysis were subjected to data analysis using SPSS, version 16. To analyse changes in the levels of pH, turbidity, feacal coliforms, manganese, lead, zinc and residual chlorine, one-way Analysis of Variance (ANOVA) at 0.05 significance level was employed.

RESULTS AND DISCUSSION

A summary of the results is presented in the following set of tables which also compare each of the parameters with the acceptable levels as stipulated by the World Health Organisation (WHO, 2004) and Malawi Bureau of Standards (Malawi Bureau of Standards, 2005).

Manganese levels, 0.03 ± 0.002 to 0.05 ± 0.005 (Table 1), showed significant variation between the treatment point and consumer points (α = 000). Grazuleviciene and Balcius (2009) also found that the concentration of manganese varies with increase of the distance from the water treatment plant. The concentration of lead, 0.37 ± 0.061 to 0.56 ± 0.053 (Table 2) and zinc, 1.04 ± 0.071 to 1.83 ± 0.306 (Table 3) did not show significant variation from the treatment point to consumers. The levels of manganese, lead and zinc in the distribution system were found to be within the maximum accaptable levels for drinking water as stipulated by WHO and MBS. It has to be noted however that in addition to WHO and MBS guidelines which are specifically related to human health, some water quality regulators such as the United States Environmental Protection Agency (US EPA, 2012) also impose an aesthetic limit of 0.05 mg/L for manganese which is lower than the health guideline to avoid "dirty water" problems. Zinc has an aesthetic guideline of 5 mg/L relating to taste, as no adverse health effects are expected from any level likely to be encountered in water supplies.

Residual chlorine levels (Table 4) showed decreasing concentration with increasing distance from the treatment point. The concentration ranged from 2.17 ± 0.083 to 0.17 ± 0.083 mg/L at treatment point and furthest, consumer, respectively. This trend is normal and could consumer,

Figure 1. Map of Malawi showing the position of the city of Lilongwe.

Table 1. Manganese levels (given as means and standard errors of the means) compared to WHO and MBS standards.

Sample station	Mn in water (mg/l)	Maximum Acceptable Levels (MAL) (mg/l)	
		WHO*	MBS*
Treatment Plant	0.02 ± 0.002	0.40	0.10
Storage Tank	0.02 ± 0.001	0.40	0.10
Consumer 1	0.02 ± 0.002	0.40	0.10
Consumer 2	0.04 ± 0.006	0.40	0.10
Consumer 3	0.05 ± 0.007	0.40	0.10
Consumer 4	0.04 ± 0.006	0.40	0.10
Consumer 5	0.03 ± 0.004	0.40	0.10
Consumer 6	0.04 ± 0.004	0.40	0.10
Consumer 7	0.05 ± 0.006	0.40	0.10
Consumer 8	0.05 ± 0.005	0.40	0.10

*WHO and MBS standards were not exceeded in all cases.

consumer, respectively. This trend is normal and could be attributed to the fact that chlorine is still effective or being used in the distribution system. The mean levels of chlorine reaching the farthest consumer tap are at minimum levels, five times less than at the treatment point but still meet the acceptable WHO and MBS standards.

Turbidity levels (Table 5) did not show any significant variation (α = 0.214) between the treatment plant and consumer points with values ranging from 1.19 ± 0.075 to 1.32 ± 0.155 NTU. This is the normal trend for treated water if there is no pollution along the distribution system. Pollution could be in the form of soil particles, organic matter and even heavy metal entry into the distribution system causing the color of water to significantly change along the distribution system. When water is not turbid, it is not evidence enough to rule out any microbial or chemical contamination but the aesthetic quality is acceptable to most consumers.

The water pH (Table 6) ranged from a mean of 7 to 8 in the distribution system. This is within the WHO standard of drinking water quality. However, the levels from the treatment point to the consumer showed a significant dif-

Table 2. Lead levels (given as means and standard errors of the means) as compared to WHO and MBS standards.

Sample Station	Pb in water (µg/l)	Maximum Acceptable Levels (MAL) (µg/l)	
		WHO*	MBS*
Treatment Plant	0.37 ± 0.061	10.0	5.00
Storage Tank	0.71 ± 0.033	10.0	5.00
Consumer 1	0.50 ± 0.021	10.0	5.00
Consumer 2	0.51 ± 0.023	10.0	5.00
Consumer 3	0.08 ± 0.037	10.0	5.00
Consumer 4	0.67 ± 0.028	10.0	5.00
Consumer 5	0.22 ± 0.011	10.0	5.00
Consumer 6	0.33 ± 0.082	10.0	5.00
Consumer 7	0.56 ± 0.053	10.0	5.00
Consumer 8	0.11 ± 0.038	10.0	5.00

*WHO and MBS standards were not exceeded in all cases.

Table 3. Zinc levels (given as means and standard errors of the means) as compared to WHO and MBS standards.

Sample Station	Zn in water (mg/l)	WHO* and MBS* maximum acceptable levels (MAL) (mg/l) **NGL
Treatment Plant	1.04 ± 0.071	3.00
Storage Tank	1.16 ± 0.051	3.00
Consumer 1	1.19 ± 0.058	3.00
Consumer 2	1.29 ± 0.051	3.00
Consumer 3	1.25 ± 0.073	3.00
Consumer 4	1.23 ± 0.033	3.00
Consumer 5	1.83 ± 0.306	3.00
Consumer 6	1.27 ± 0.034	3.00
Consumer 7	1.31 ± 0.036	3.00
Consumer 8	1.28 ± 0.055	3.00

*WHO and MBS acceptable levels were not exceeded in all cases. **NGL = No guidelines are given but levels above 3 mg/l are considered unacceptable.

Table 4. Residual chlorine levels (given as means and standard errors of the means) as compared to WHO and MBS standards.

Sample Station	Residual chlorine in water (mg/l)	WHO* and MBS* acceptable minimum range at delivery point (mg/l)
Treatment Plant	2.17 ± 0.083	5.0 mg/l
Storage Tank	1.00 ± 0.000	0.2 -1.0
Consumer 1	0.98 ± 0.022	0.2 -1.0
Consumer 2	0.86 ± 0.073	0.2 -1.0
Consumer 3	0.68 ± 0.081	0.2 -1.0
Consumer 4	0.49 ± 0.130	0.2 -1.0
Consumer 5	0.40 ± 0.109	0.2 -1.0
Consumer 6	0.40 ± 0.055	0.2 -1.0
Consumer 7	0.37 ± 0.047	0.2 -1.0
Consumer 8	0.20 ± 0.083	0.2 -1.0

*WHO and MBS acceptable standard were met in all cases.

Table 5. Turbidity levels (given as means and standard errors of the means) as compared to WHO and MBS standards.

Sample Station	Turbidity (NTU)	WHO* and MBS* maximum acceptable Levels (MAL) (NTU)
Treatment Plant	1.19 ± 0.075	5.00
Storage Tank	0.97 ± 0.087	5.00
Consumer 1	1.03 ± 0.097	5.00
Consumer 2	1.24 ± 0.050	5.00
Consumer 3	1.09 ± 0.072	5.00
Consumer 4	1.11 ± 0.061	5.00
Consumer 5	1.08 ± 0.036	5.00
Consumer 6	1.32 ± 0.155	5.00
Consumer 7	1.11 ± 0.082	5.00
Consumer 8	1.22 ± 0.130	5.00

*WHO and MBS acceptable levels were not exceeded in all cases.

Table 6. pH values in water (given as means and standard errors of the means) as compared to WHO and MBS standards.

Sample Station	pH	Acceptable range	
		WHO*	MBS*
Treatment Plant	7.4 ± 0.1	6.5 – 8.5	5.0 – 9.5
Storage Tank	7.1. ± 0.3	6.5 – 8.5	5.0 – 9.5
Consumer 1	7.5 ± 0.1	6.5 – 8.5	5.0 – 9.5
Consumer 2	7.2 ± 0.2	6.5 – 8.5	5.0 – 9.5
Consumer 3	7.6 ± 0.3	6.5 – 8.5	5.0 – 9.5
Consumer 4	7.7 ± 0.1	6.5 – 8.5	5.0 – 9.5
Consumer 5	7.5 ± 0.2	6.5 – 8.5	5.0 – 9.5
Consumer 6	7.4 ± 0.1	6.5 – 8.5	5.0 – 9.5
Consumer 7	7.7 ± 0.2	6.5 – 8.5	5.0 – 9.5
Consumer 8	6.9. ± 0.1	6.5 – 8.5	5.0 – 9.5

*WHO and MBS acceptable levels were not exceeded in all cases.

Table 7. Feacal coliform levels in water as compared to WHO and MBS standards.

Sample Station	Feacal coliform in water (cfu/100 mL)	Maximum Acceptable Levels (MAL) (cfu/100 mL)	
		WHO*	MBS*
Treatment Plant	0	0	0
Storage Tank	0	0	0
Consumer 1	0	0	0
Consumer 2	0	0	0
Consumer 3	0	0	0
Consumer 4	0	0	0
Consumer 5	0	0	0
Consumer 6	0	0	0
Consumer 7	0	0	0
Consumer 8	0	0	0

*WHO and MBS acceptable levels were not exceeded in all cases.

ference ($\alpha = 0.003$). This might be attributed to leaching of salts from the distribution pipes (Schock, 1999; Agatemor and Okolo, 2007).

There was no variation in the bacteriological quality of water (Table 7) between the treatment point (no colonies/ml) and consumer point (no colonies/ml). This signifies that there was no feacal contamination between the treatment point and consumer point to cause any risk of water borne diseases. The WHO and MBS standards for drinking water standard require that there should be no fecal coliforms in drinking water and that if any are found, an intervention should be instigated to resolve the problem.

It should also be noted that samples were only taken in the dry season when source water is be expected to have low turbidity and little variation in quality. Depending on the efficiency of treatment, some changes in the water quality leaving the treatment plant might be expected in wet weather when some parameters such as turbidity and manganese levels in the source water may increase.

Conclusion and recommendation

Based on laboratory assessment, tap water provided by Lilongwe Water Board to residents of Area 25 Township in Malawi is safe for human consumption with respect to residual chlorine, manganese, pH, zinc, turbidity, lead and fecal coliform bacteria as the levels met both the WHO and MBS standards for drinking water quality. However, as the data presented in this study only reflects the dry season, it would be expected that turbidity and manganese levels are higher in wet weather and therefore warranting further research

REFERENCES

Agatemor C, Okolo PO (2007). University of Benin water supply system: microbiological and physico-chemical assessments. Environmentalist 27:227–239.

American Public Health Association (APHA) (1998). American Water Works Association and Water PollutionControl Federation, Standard methods of the examination of water/wastewater, 20th Edition. APHA, AWWA, and WPCF, New York.

Ashbolt N J (2004). Microbial contamination of drinking water and disease outcomes in developing regions. Toxicology 198(1):229-23.

Gražulevičienė R, Balčius G (2009). Assessment of iron and Manganese Concentration Changes in Kaunas City Drinking Water Distribution System. Environ. Res. Engin. Manag. 50(4):37-43

Kalua PWR, Chipeta WPC (2005). 'A Situation Analysis of Water Sector in Malawi.' A paper presented at the workshop on Situation Analysis of Water Sector in Malawi.

Lilongwe Water Board (2011). Madzi Bulletin. http://www.lwb.mw/index.php?option=com_content&view=article&id=101&Itemid=87

Malawi Bureau of Standards (2005). Drinking water specifications, 1st revision, MS 214:2005.

Mendels P (1998). Dealing With Disaster and a Fragile Infrastructure. New York Times, January 12.

Napacho ZA, Manyele SV (2010). Quality assessment of drinking water in Temeke District (part II): Characterization of chemical parameters. Afri. J. Environ. Sci. Technol.4(11):775-789.

Schock MR (1999) Internal corrosion and deposition control. In Association AWW (ed) Water quality and treatment: a handbook of community water supplies. McGraw-Hill pp. 1–17.

Tuzen M, Soylak M (2006). Evaluation of Metal Levels of Drinking Waters from the Tokat-Black Sea Region of Turkey. Polish J. Environ. 15(6):915-919.

US EPA (2012). Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals. http://water.epa.gov/drink/contaminants/secondarystandards.cfm.

WHO (2004). Guidelines for drinking water quality, 3rd edition. World Health Organization, Geneva.

WHO (2011). Manganese in drinking water. Background document for development of WHO guidelines for drinking water quality. WHO/SDE/WSH/03.04/104/REV/1. http/www.lwb.mw/online water monitoring.htm.