Chemical Quality of Stream and Borehole Water Used by Selected Communities in Lushoto District, Tanzania

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Abstract

The chemical quality of water in two streams and three boreholes from Sunga and Mbaru wards in Lushoto, Tanzania was investigated. Water was collected at three locations along the stream, including forest areas, populated area with agricultural activities and less populated areas with agricultural activities. Borehole's water was collected from three boreholes found in each ward and analyzed for pH, hardness, BOD, phosphates, nitrates by standard methods. Nested design was applied. Data obtained was analyzed by R-Software for ANOVA. Means were separated by Tukey's honest at p<0.05. Significant differences (p<0.05) in all chemical parameters (pH: 6.92-7.34; Hardness; 23.88+64.43;Nitrite 1.73 -19.80; Phosphate 0.58-3.90; Ammonia 0.02-0.08; Lead -0.001-0.002) were observed in locations within the streams except arsenic. DDT was not detected. With the exception of phosphate in both streams, all water samples tested met TZS (2016) standards and WHO (2011) guidelines. This implies that stream water is considered unsafe for use since it exceeded the maximum phosphate limit by TZS (2016). All parameters tested in borehole water met the requirements for both standards except pH and ammonia which exceeded the WHO water guideline. It is recommended that the communities be educated on the best practices to keep water sources safe.

Keywords: Water, pH, phosphates, ammonia, Arsenic

Introduction

Drinking water is defined as potable water intended for human consumption (TZS, 2016). Potable water shall be free from chemical substances that are hazardous and injurious (TZS, 2016). Surface water pollution remains a major problem worldwide, caused by both natural processes and anthropogenic activities (Noori *et al.,* 2010). Assessment of surface water quality for drinking is vital as it can be one of the main pathways for the spreading of toxic chemicals and pathogenic microorganisms (Ouyang, 2005). The quality of surface water (stream) can be affected by point source and non-point sources of pollution (Nnane *et al.,* 2011). Point source pollution occurs from a particular identifiable source such as effluents from industries and wastewater treatment plants whereas non-point sources are runoff associated with a certain land use pattern such as sewage overflows, agriculture (e.g., fertilizers, pesticides, animal manure), or forestry land uses (Hill, 2010). Surface water has been reported to be poor in quality, since it is prone to contamination (Okeola *et al.,* 2010). Agricultural activities are the source of chemical contaminants in water sources since they involve the use of fertilizers and pesticides, which produce toxic substances that are transported as effluents into water sources (Obi *et al.,* 2007). Other sources of water pollution include industries and human activities. It has been reported that some of chemical contaminants are of health concern. These include nitrate, which rises due to excess fertilizers and can cause methaemoglobinaemia (WHO, 2004). Heavy metals are found naturally on earth and become concentrated as a result of human activities. Common sources are from mining and other industries. Lead, for example can cause adverse neurological effects whereas arsenic can cause cancer and skin lesion.

In general, inadequate supply of safe and quality water is still a challenge in developing countries. The Joint Monitoring Programme (JMP) for Water Supply and Sanitation, implemented by the World Health Organisation (WHO) and UNICEF, reported that 783 million people in the world (11% of the total population) have no access to safe water, 84% of whom live in the rural areas. In Tanzania, the most common water source used in urban area is pipe water, although groundwater is also used as a supplemental source to meet the demand. About 31.7 % of the populations living in rural areas of Tanzania rely on water from ecosystem sources (i.e., springs, streams, rivers, ponds and lakes) which are more vulnerable to all kinds of contaminants (Noel, 2011). Although the community in Lushoto district depends on stream and borehole water for cooking and drinking, there are a lot of agricultural activities along the stream, which could contaminate the water. Information on the chemical quality of water used by the community in Lushoto district is limited. Hence, this study was conducted to establish the quality and safety of water used by the community and make recommendations for improving its quality and safety.

Material and methods

This study was carried out in Mbaru and Sunga wards in Lushoto district, Tanga. The district is situated in the northern part of Tanga region. It lies between latitude 4°25' and 4°55'S, and longitude 30°10' and 38°35'E. It is one of the eight districts of Tanga region, with a total area of 4092 km^2 (URT, 2013).

Materials used for this study included water samples from the streams and boreholes, chemicals and reagents of analytical grade and double distilled water. Cool box and sampling containers were also used.

Equipment used included ICP-MS (Model 7900-Agilent technologies, made in Germany), GC-MS/MS (model 7010-Agilent technologies, made in Germany), Spectrophotometer (Model UV 2601-Rayleigh, made in China), Colorimeter (Model DR890, Hach from U.S.A), Centrifuge (Model 300R-Hettich, made in German), Vortex -Talboys (Troemner LLC, made in U.S.A) and pH meter (model Orion 4 star plus Thermo scientific, U.S.A).

Sampling plan and data collection

Purposive sampling plan was used to collect samples from selected boreholes and streams found in two wards in Lushoto district. Sampling was carried out from November to December 2018. Samples were obtained from two streams; Shagayu in Mbaru ward and Daa in Sunga ward. Borehole water was also obtained from the same wards. Water samples from the streams and boreholes were collected in the morning and kept in well labeled 1 Litre plastic bottles. Stream water was collected in duplicate at three points (6 samples from each stream analyzed in triplicate to make a total of 18 samples for analysis per stream and hence a total of 36 analyses for each parameter). Water samples from the boreholes were also collected in duplicate from the three boreholes found in each ward and analyzed in triplicate (6 samples in triplicate, making a total of 18 samples for analysis of each parameter). A tap from the borehole was allowed to run to waste for 3 minutes followed by rinsing of the 1 Litre plastic bottles with borehole water twice, prior to sample collection. Plastic bottles used to collect the samples were thoroughly washed and rinsed with distilled water prior to water collection. Analysis of pH was carried out at the water source. Water samples were then stored in an insulated ice box maintained at 4°C and transported to the Tanzania Bureau of Standards (TBS) laboratory for heavy metal analysis (lead and arsenic) and pesticide dichloro-diphenyl-trichloroethane (DDT). Other samples were transported to Tanga water laboratory for analysis of total hardness, phosphate, nitrate and ammonia.

Sample storage and preservation

Upon arrival at the designated laboratories, the collected water samples from both sources (boreholes and streams) were stored in a refrigerator maintained at 4°C before analysis. However, samples for heavy metals analysis were first acidified with concentrated nitric acid (HNO_3) to lower the pH to less than 2, as explained by Aremu *et al.* (2011). They were then kept in a refrigerator. The plastic containers were selected for sample storage because the probability of contaminating water specifically with the heavy metal is very low (Odoh *et al.,* 2013).

Chemical analysis of stream and borehole water

pH

The pH of the water samples was measured according to ISO 10523:2008. Results were reported to two decimal points.

Total hardness

Total hardness of water samples was determined by using 0.01 N of ethylene diamine tetra acetic acid (EDTA) titrimetric method as described in the standard methods for the examination of water and waste water according to the American Public Health Association (APHA, 2012). Results were reported as mg $CaCO_3$/ L.

Ammonia

The amount of ammonia in water from the two sources was determined by using calorimeter (Model DR890 Hach, from U.S.A). This was followed by analysis according to Nessler method 8038 which was adapted from Standard Methods for the Examination of Water and Wastewater (APHA). Results were reported to two decimal points in mg/L.

Heavy metal (Pb and As)

Analysis of heavy metals was done according to standard operating procedure (SOP) no FCL/SOPTM/13-03 which followed EPA Method 6020 and Agilent 7900 ICP-MS Manual. Blank and standard calibrations were used whereby four levels of mixed standards solution of arsenic (As) and lead (Pb) (10, 25, 50 and 75 ppb) were used to prepare calibration curve, which was used to quantify concentration of lead and arsenic in water samples. Quality control of 0.5 ppb mixed standards and blank sample (distilled water) were also run alongside the water samples. Results were reported in mg/L.

Dichlorodiphenyltrichloroethane (DDT)

Determination of Dichlorodiphenyl trichloroethane (DDT) in water was carried out by using standards operating procedure (SOP) no FCL/SOP-TM/14 developed from AOAC Official Method 2007.01 by using Gas chromatography Tandem Mass Spectrometer (GC MSMS, model 7010 Agilent technologies, German).

Concentration of each analyte (µg/L)=Concentration from curve X dilution factor whereby,

Concentration from curve = Peak Area of the analyte / Peak area of internal standard.

Chromatographic condition used

GC column –15 mm x 0.25 mm x 0.25 mm HP-5MS part number 19091S-433 (Agilent, U.S.A). Inlet, Carrier gas: He (Flow rate 1.5 mL/min Injection volume-1 µl); Inlet temperature–280°C; Inlet mode-spilt-less, Purge flow to spilt vent: 30 mL/min at 0.75 min; Gas saver on (20 mL/min at 2.0 min); Inlet liner – split-less, single taper.

Nitrate

The amount of nitrate in water was determined by using 4500-NO3–B. Ultraviolet Spectrophotometric (Model UV 2601–Rayleigh, made in China) was used to measure the absorbance of the water samples as described by American Public Health Association (APHA, 2012). Results were expressed in mg/L.

Phosphate

The amount of phosphate in water was determined by ascorbic acid method as described in (APHA, 2012) and absorbance was measured at 880 nm. Results were reported in mg/L.

Statistical data analysis

Cross sectional design was used in this study. Samples for chemical parameters (pH, total hardness, nitrate, ammonium, lead, arsenic and DDT) were drawn from three points for each of the two streams: forest, populated with agricultural activities, less populated and agricultural activities. The same design was also applied to boreholes water.

Nested design was applied using the following model $Y_{ijk} = \mu + \beta_j + \alpha_{(j)i} + \varepsilon_{ijk}$ and

$$Y_{ijk} = \mu + \lambda_k + \rho_{(\mathrm{k})\chi} + \varepsilon_{ijk}$$

whereby:

Y_{ijk} = Dependant variable,
μ = General mean,
β_j = 1, 2, (stream),
$\alpha_{(j)i}$ = 1,2,3 (effect of location nested within stream),
λ_k = 1,2 (ward),
$\rho_{(k)}^{\chi}$ = (effect of borehole nested within the ward), and
ε_{ijk} = Random error

Data was analyzed using R-statistical package software. Nested design was applied on the stream and boreholes water to determine the effect of location nested within a stream and the effect of boreholes in the wards. Analysis of Variance (ANOVA) was carried out to determine the significant difference between the location within the stream and boreholes. Means were separated using Tukey's Honest at $p<0.05$.

Results and discussion

Chemical properties of the stream water

The effect of location nested within and among the streams

The chemical properties of streams studied are presented in Table 1. These results summarize the mean values and standard deviation for pH, total hardness (T.H), Nitrate (NO_3), phosphate ($PO4^{3-}$), ammonia (NH_3), arsenic (As), lead (Pb), and DDT.

pH

The mean pH of water in the two streams ranged between 6.92 ±0.02 and 7.34 ±0.01. No significant differences in pH were found between the water samples from Shagayu stream. The pH of water from forest area in Daa stream was low and significantly different ($p<0.05$) from the two areas with agricultural activities. Change in pH within the stream might be due to the nature of open water bodies, which are exposed to various pollutants that can influence the variation of pH (Napacho and Manyele, 2010). The use of alkaline detergents in the nearby streams and discharge of alkaline waste water from the households into the stream can also result in increase in pH. This observation is also supported by Napacho and Manyele (2010) who reported pH values in stream that ranged from 7.8 to 8.0 in stream. They suggested that the high pH obtained could be attributed to different activities done near the stream, such as washing clothes and cars. A similar observation was also reported by Chang (2008) who observed increased pH in stream water was mainly associated with increased use of alkaline detergents and alkaline material from waste water from the household.

In this study it was revealed that pH recorded at the forests in both streams was slightly acidic. This might be associated with decomposition of pine tree leaves, which could add acidity to the soil and influence the acidity of nearby stream. This finding concur with to the study reported by Tremblay *et al.* (2009) who found a decrease of pH in water stream in Montmorency forest in Canada was due to release of organic acid from decomposition of trimmed branches of tree. Furthermore, the mean pH values for the two streams showed a slight variation (Table 1), which might be attributed to soil type and land use activities along the respective streams. This observation had been reported (Njue *et al.,* 2016). It was found that soil and land use activities affected the proportion of major ions in water bodies.

Total hardness

The study results for total hardness in three locations within two streams ranged from 23.88 ± 0.30 to 64.43 ± 0.40 mg/L. Although no statistically significant differences in total water hardness were observed between the forest area and Ludende in Shagayu stream, these differences were obvious in the rest of the locations (Table 1). Non-significant differences observed in two locations might be caused by the influence of similar geology of these locations. A previous study conducted by Seiyaboh and Izah (2017) assessed the impact of anthropogenic activities in stream water and found that total hardness ranged from 38.3 to 50 mg/L. Yisa and Jimoh (2010) reported total hardness of 33-60 mg/L.

Wannamethee *et al.* (2011) reported that there was no serious health effect due to consumption of hard water but in a very rare case it could be associated with human disease like cardiovascular and cerebrovascular diseases, particularly to elderly people. Furthermore, the

Table 1: Chemical properties of water from three locations nested within the streams

Stream	Position	pH	Hardness (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)	NH_3 (mg/L)	Pb (mg/L)	As (mg/L)	DDT (µg/L)
A	1A0	6.92±0.02[a]	23.88±0.33[a]	1.73±0.01[a]	0.90±0.01[b]	0.08±0.01[a]	0.001±0.0[a]	0.0001±0.0[a]	ND
	2A1	7.23±0.02[b]	34.28±0.50[b]	5.95±0.19[c]	*2.50±0.09[e]	0.07±0.01[a]	0.002±0[b]	0.0001±0.0[a]	ND
	3A2	7.34±0.01[b]	38.20±0.23[c]	6.81±0.12[d]	*3.90±0.06[f]	0.06±0.02[a]	0.003±0[c]	0.0001±0[a]	ND
MEAN		**7.15±0.18**	**32.12±6.23**	**4.83±2.29**	**2.45±1.29**	**0.06±0.02**	**0.002±0.001**	**0.0001±0.0**	**ND**
B	1B0	6.98±0.05[a]	43.40±0.40[d]	5.00±0.11[b]	0.58±0.03[a]	0.02±0.01[b]	0.001±0[a]	0.0001±0[a]	ND
	2B1	6.92±0.04[a]	42.50±0.50[d]	19.80±0.28[f]	*2.36±0.06[d]	0.07±0.005[a]	0.001±0[a]	0.0002±0[a]	ND
	3B2	6.97±0.07[a]	64.43±0.45[e]	14.24±0.28[e]	2.00±0.05[c]	0.03±0.01[b]	0.001±0[a]	0.0001±0[a]	ND
MEAN		**6.96±0.06**	**51.07±9.76**	**13.01±6.29**	**1.63±0.78**	**0.09±0.06**	**0.001±00**	**0.0001±0**	**ND**
TZS 789		5.5-9.5	600	45	2.2	0.5	0.01	0.01	1
WHO 2011		6.5-8.5	500	50	NR	0.2	0.01	0.01	1

Values in the same column having the same superscript letters are not significantly different ($p>0.05$) (Tukey's Honest)
A-Daa stream; B-Shagayu stream; NR- Not a requirement. ND-Not Detected; * Failed to meet the standard requirement
1A0-Forest for stream A, 2A1- Kwamamkoa (populated with agricultural activities), 3A2- Komboheo (less populated with agricultural activities),
1B0-Forest for stream B, 2B1- Ludende (populated with agricultural activities), 3B2- Kumbamtoni (less populated with agricultural activities),

hardness of water is not considered as a pollution parameter but an indication of low salinity due to the presence of calcium and magnesium ions expressed as $CaCO_3$ (temporary hardness).

Nitrate

The mean nitrate in the two streams ranged between 1.73 ± 0.01 mg/L and 19.80 ± 0.28 mg/L. There were significant differences ($p<0.05$) in nitrate within locations in the two streams. Low level of nitrate was recorded at the forest, which this might be attributed to the fact that at that particular location, there was no agricultural activity or human settlement, which could influence the rise of nitrate.

Compared to the forest, increased level of nitrate was observed in both populated and less populated areas with agricultural activities in both streams. This may probably be due to application of fertilizers in farms and discharge of wastes that ultimately ended up in the stream. Same findings have been reported (Jacobs *et al.,* 2017; Ngoye and Machiwa, 2004). Although nitrate is considered to be of less environmental problem, in high concentration (above 40 mg/L), it may lead to a disease called "methaemoglobinemia" or "blue baby syndrome" in children (Sarda and Sadgir, 2015). Shagayu stream had a relatively higher level of nitrate than Daa (Table 1). Higher levels of nitrate might be due to cultivation of mixed crops along the stream, such as potatoes, carrots and cabbages, which require greater input of fertilizers that contribute to nitrate leaching from the soil to the stream. The major source of nitrate is from domestic sewage, animal waste, agricultural waste and runoff from the settlement (Christensen *et al.,* 2012).

Phosphate

Mean phosphate value among the three locations in Daa and Shagayu streams ranged from 0.58 ± 0.03 to 3.90 ± 0.06 mg/L. Significant differences ($p<0.05$) in phosphate was observed in all locations within both streams as shown in Table 1. The highest level of phosphate was observed in Daa stream at Komboheo (agricultural area with less population) while the lowest level was observed at the forest in Shagayu stream. With the exception of forest in both streams and Kumbamtoi in Shagayu stream, other locations observed had higher levels of phosphate than those recommended by the Tanzania standard. The higher level of phosphate recorded at Komboheo might be associated to its location. Komboheo was located down the stream whereby all the detergents poured and flushed by people washing clothes at Kwamamkoa (midstream). Studies conducted by Saria (2015) and Fadiran *et al.* (2008) found that the increased level of phosphate in stream close to agricultural area may be caused by the application of fertilizers near the stream and detergents from the households.

It has been reported that higher concentration of phosphate in water can affect the digestive system of animal and human (Dawood *et al.,* 2014). Daa stream was found to be more polluted and did not comply with the recommended Tanzania standard (TZS, 2016) while Shagayu stream met the requirement. However, Ludende exceeded the phosphate limit set by the Tanzania standard. WHO has not established the limit of phosphate in drinking water (Table 1).

Ammonia

The mean value for ammonia in both streams at the three locations ranged from 0.02 ± 0.01 mg/L to 0.08 ± 0.01 mg/L (Table 1). Significant differences ($p<0.05$) in ammonia were observed in two locations found in Shagayu stream, including forest area and less populated area with agricultural activities. Low level of ammonia observed at the forest might be probably due to the fact that there were neither agricultural activities nor human settlement, which could discharge wastes to the water bodies. This finding is also supported by Ngoye and Machiwa (2004) and Huang *et al.* (2013). Moreover, low concentration of ammonia observed at Ludende and Kwamamkoa (populated with agricultural activities) is contrary to the finding reported by Ngoye and Machiwa (2004) who found high level of ammonia (from 1.3 ± 0.7 to 2.6 ± 0.6 mg/L) in the area where stream water was adjacent to agricultural activities.

Results of ammonia at Kumbamtoi and Komboheo (less populated area with agricultural activities) was in agreement with the finding reported by Effendi *et al.* (2015) who found ammonia ranging from 0.0059 - 0.0178 mg/L. In his observation he stated that low level of ammonia was due to low population and less application of inorganic fertilizer. It has been reported that there was no health-based guideline proposed due consumption of water contaminated with ammonia. However, it can compromise disinfection efficiency, resulting in nitrite which causes the failure of filters for the removal of manganese and cause taste and odour problems (WHO, 2003). The mean values for the two streams are indicated in Table 1. All samples from both streams met the requirement set by TZS (2016) and WHO (2011) and hence safe for human use with respect to ammonia.

Lead

Results for lead in two streams showed that all samples drawn from three locations had low level of lead which was below recommended limit by TZS (2016) and WHO (2011). Although the mean lead levels were slightly higher in Kwamamkoa and Komboheo and statistically different ($p<0.05$) from all other locations, these results were within the acceptable limits by both the TZS (2016) and WHO (2011) standards. The slight variation might be influenced by deposition of various wastes in the water body. Previous study reported by Nyairo *et al.* (2015) showed low level of lead with mean concentration of 0. 009 mg/L in Amala streams of river Mara, Kenya, which is adjacent to forest, agricultural area and human settlement. Lead is mainly introduced into water bodies through different ways such as the disposal of batteries, agricultural runoff from fields that use sewage sludge as fertilizers, atmospheric deposition of exhaust from vehicles, and sewage discharge (Alsaffar *et al.,* 2016). High level of lead may lead to a wide range of effects, including neurodevelopmental effects, mortality due to cardiovascular diseases, impaired renal function, hypertension and impaired fertility (WHO 2011; Brochin *et al.,* 2008). Regarding the quality of streams in terms of lead, it was found that Daa stream had a mean concentration of 0.002 ± 0.001 mg/L while Shagayu stream had 0.001 ± 0.00 mg/L.

Arsenic

The mean arsenic values in three locations of both streams are shown in Table 1. Results obtained from the three locations were very low, almost negligible. In addition, there was no significant difference in arsenic levels ($p>0.05$) between the three locations in the two streams. Low level of arsenic might be attributed by non-application of arsenical pesticides in the study area. The mean arsenic values in the two streams had the same concentration as shown in Table 1. Arsenic level in water could be due to human activities such as application of arsenical pesticides in agricultural areas (Vowinkel *et al.,* 2001). High arsenic level in water can cause cancer in lungs, bladder and skin. Also, skin lesions and peripheral vascular diseases have been reported in population consumed water contaminated with arsenic (WHO, 2011).

DDT

The water samples analyzed from both streams were below detection limit for dichloro-diphenyl-trichloroethane (DDT), which was 0.05µg/L. This implies that all samples met the TZS (2016) and WHO (2011) recommendations. This might be attributed to the fact that the use of DDT in agriculture was banned in Tanzania since 1997 (URT, 2005). In human beings, high concentration of DDT leads to neuropsychological conditions, such as brain tumors (Leena *et al.,* 2012). A study by the same author found a concentration ranging from none to 0.49 µg/L of total DDT in the upper and downstream of river Ganga, India which was near agricultural area and human settlement. The source of the DDT was discharge of agrochemicals from flood plains and medical waste from hospital which was channeled direct to the river (Leena *et al.,* 2012). Therefore, since all water sampled met the requirement then water deemed safe for use with regard to DDT.

Chemical quality of boreholes water found in two wards

Water from the boreholes, which were found within the two wards were tested and compared, and the summary of their results are presented in Table 2.

Table 2: Chemical properties of water from three boreholes located at Sunga and Mbaru wards in Lushoto districts

Ward	Code	Parameters							
		pH	**Total Hardness (mg/L)**	**NH_3 (mg/L)**	**PO_4 (mg/L)**	**NO_3 (mg/L)**	**As (mg/L)**	**Pb (mg/L)**	**DDT (µg/L)**
Sunga	1A	*6.37±0.10[a]	124.20±0.24[c]	0.08±0.01[b]	0.20±0.02[a]	7.83±0.11[a]	0.0002±0.00[b]	0.005±0.001[d]	ND
	2A	6.73±0.04[b]	64.40±0.39[a]	0.02±0.01[a]	2.04±0.02[d]	13.00±0.13[b]	0.0001±0.00[a]	0.01±0.001[a]	ND
	3A	6.89±0.01[c]	67.40±0.33[b]	*0.32±0.01[d]	0.20±0.01[a]	0.60±0.14[c]	0.0001±0.00[a]	0.0001±0.0[c]	ND
Mean		**6.67±0.23**	**85.30±28.3**	**0.14±0.10**	**0.81±0.80**	**8.79±3.10**	**0.0001±0.00**	**0.006±0.005**	**ND**
Mbaru	1B	7.10±0.01[d]	65.60±0.47[a]	0.02±0.01[a]	0.6±0.02[b]	2.00±0.02[d]	0.0001±0.00[a]	0.01±0.0[a]	ND
	2B	7.10±0.01[d]	219.63±1.05[e]	0.02±0.00[a]	0.20±0.01[a]	2.79±0.07[e]	0.0001±0.00[a]	0.001±0.0[b]	ND
	3B	7.17±0. 10[d]	204.03±1.36[d]	0.18±0.01[c]	0.9±0.05[c]	3.2 9±0.18[f]	0.0001±0.00[a]	0.002±0.0[b]	ND
Mean		**7.12±0.05**	**163.1±71.20**	**0.07±0.06**	**0.57±0.31**	**2.66±0.58**	**0.0001±0.0**	**0.004±0.004**	**ND**
TZS 789		5.5-9.5	600	0.5	2.2	45	0.01	0.01	1
WHO 2011		6.5-8.5	500	0.2	NR	50	0.01	0.01	1

Values in the same column having the same superscript letters are not significantly different at $p > 0.05$ (Tukey's Honest);
NR-Not a requirement, ND-Not detected, * Failed to meet the WHO standards
1A-Alufea, 2A-Madukani, 3A-Kwemashui, 1B-Masereka, 2B-Ludende, 3B-Chambogo

pH

pH of the boreholes for the two wards ranged from 6.37±0.10 to 7.17±0.10. The pH of boreholes water from Sunga was neutral and was significantly different ($p<0.05$) from all other boreholes water from Mbaru, which were below pH 7 (Table 2). The pH values recorded in this study are related to that of a previous study by Saana *et al.* (2016) who reported pH value ranging from 6.14–7.50. From the results obtained, the least pH value was observed at Alufea in Sunga ward while the maximum value was recorded at Chambogo (Table 2).

The slight acidic pH observed might be attributed by soil type that permits dissolution of acidic materials from agriculture and which bring about slight acidity in the water (Oko *et al.,* 2014). In addition, discharge of acidic materials into the ground through agricultural and domestic activities might also attribute to acidic condition of the borehole water (Yusuph *et al.,* 2018). Neutral pH observed at three boreholes located at Mbaru ward showed no significant differences ($p>0.05$). These results are comparable with study reported by Christine *et al.* (2018) who recorded the neutral pH at the boreholes water located at Kakamega County in Kenya. Long term exposure to pH beyond the permissible limit affects skin and the mucous membrane of cells (Nishtha *et al.,* 2012; Napacho and Manyele, 2010). Therefore, with the exception of pH for sample drawn from Alufea which was below WHO limit, all water sampled met the TZS (2016) and WHO (2011).

Hardness

The total hardness in boreholes water ranged from 64.40 ±0.39 to 219.63±1.05 mg/L. There was a significant differences ($p<0.05$) in water hardness for all boreholes in both wards. The greater variation observed in water hardness could probably be due to the presence of minerals such as limestone in the soils. A study in six districts of the Northern region of Ghana found the mean hardness of borehole water to range from 22 to 178.07 mg/L (Saana *et al.,* 2016). According to Napacho and Manyeli (2010) hardness or softness in water varies from place to place due to nature of the geological properties of that particular area. Chigut *et al.* (2017) categorized water-based on hardness whereby soft (75 mg/L), moderately hard (75–150 mg/L), hard (150–300 mg/L) and very hard (300 mg/L). Most of the water sampled was found to be moderately hard with few samples being hard including water from Chambogo and Ludende. Hard water can cause formation of precipitates in piping and fittings, which can cause water blockage and reduce the interior diameter of piping. However, long term consumption of extremely hard water might lead to an increased incidence of urolithiasis, prenatal mortality and cardiovascular disorders (Shigut *et al.,* 2017; Wannamethee, *et al.,* 2011).

Ammonia

The ammonia content of sampled borehole water ranged from the mean value of 0.02 ±0.00 to 0.32 ±0.01 mg/L. Significant differences ($p<0.05$) in ammonia were observed in boreholes located at Alufea, Kwemashui and Chambogo (Table 2). High level of ammonia was recorded at Kwemashui, which might be attributed to the location of borehole which is close to agricultural activities. A study by Adekola *et al.* (2015) found the mean level of ammonia in boreholes in Gassol, Nigeria to be 0.21 mg/L. This was explained as being due to agricultural activities from intensive rearing of farm animals. Therefore, with the exception of borehole located at kwemashui, which had higher than the WHO acceptable ammonia limit, all the water sampled met the maximum recommended limit by TZS (2016) and WHO (2011). However, the mean value of ammonia in both wards (Table 2) met the requirement for both standards and hence safe.

Nitrate

The level of nitrate ranged from 0.60 ± 0.14 to 13 ± 0.13 mg/L (Table 2). Significant differences in nitrate levels ($p<0.05$) were observed in all boreholes water from the two wards. High level of nitrate revealed at Madukan might be caused by waste discharges from the household and agricultural activities taking place around the area. This observation is also supported by other researchers (Oluma *et al.,* 2010; Nkamare *et al.,* 2012). They stated that although nitrate naturally occurred in groundwater, high concentration of nitrate could be associated with animal and human waste, decomposition of plant debris, nitrogen fertilizer, household solid waste or sewage discharge on land. Different studies reported the level of nitrate in borehole water including a study by Mpenyana *et al.* (2012), which reported concentration of nitrate ranging from 0.45-7.27 mg/L. Sanaa *et al.* (2016) reported nitrate ranged from 0.0-6.0 mg/L whereas Adekola *et al.* (2015) reported values ranging from 0.17 -32 mg/L. Variation in nitrate level observed in this study might be attributed by the fact that most of boreholes in Sunga ward were close to agricultural areas.

Phosphate

The mean value for phosphate ranged from 0.20 ± 0.02 mg/L to 2.04 ± 0.02 mg/L. In Daa stream, significant differences in phosphate ($p<0.05$) were observed in borehole located at Madukani, Masereka and Chambogo. The highest value of phosphate was recorded at Madukani (Table 2), which might be attributed by domestic sewage and the use of detergent due to observation of activities such as washing clothes and riding motocycles around the boreholes. In addition agricultural effluents with fertilizers could also contribute to the rises of phosphate in borehole water. This observation was also reported by other researchers (Murhekar, 2011; Oko *et al.,* 2014). A finding by Oko *et al.* (2014) reported the mean value of 1.14 mg/L in borehole water located in two wards in Wukari, Nigeria. Likewise, the finding reported by Ukpong and Okon, (2013) found mean phosphate level in boreholes ranged from 0.01 mg/L -1.07 mg/L in Uruan local government area, Nigeria. High level of phosphate in water can affect the digestive system of both animal and human (Dawood *et al.,* 2014).The mean values of phosphate in two wards were shown (Table 2). All sampled water from both wards were below the recommended level by TZS (2016).

Arsenic

The mean value ranged from 0.0001 mg/L to 0.0002 mg/L. Significant differences ($p<0.05$) in arsenic level were observed in a borehole located at Alufea. This variation might be caused by soil type of a particular area since arsenic is natural occurring in rock and soil. This observation was also reported by Ratnaike (2003) and Musa *et al.* (2008) who found that arsenic contamination in borehole was caused by natural geological sources leaching into aquifers and disposal of arsenic containing materials. Previous study conducted by Musa *et al.* (2008) reported arsenic level in borehole water that ranged from 0.002 to 0.008 mg/L. This is in agreement with the finding of this study. Long-term exposure to arsenic in drinking water can cause skin lesions, skin cancer, lung and bladder cancer (Hilma *et al.,* 2016; WHO 2011). In addition, consumption of water contaminated with arsenic has been associated with cardiovascular disease in children an average of 7 years (WHO, 2011). Therefore, all water samples complied with TZS (2016) and WHO (2011), suggesting that with respect to arsenic borehole water is fit for human use.

Lead

The mean concentration of lead ranged from 0.0001 ±0.0 mg/L to 0.01 ± 0.0 mg/L as shown in Table 2. Various studies conducted by Ukpong and Okon (2013) and Chinedu et al. (2011), did not detect any lead at all. Exposure to lead in drinking water is associated with a wide range of effects, including various neuro-developmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes (WHO, 2011). Therefore, all water samples tested were within the recommended level by TZS (2016) and WHO (2011) water guideline.

DDT

This pesticide was banned for use in Tanzania since 1997 (URT, 2005). All the samples tested for DDT were below detection limit which was 0.05 μg/L. A study by Shukla et al. (2006) reported level of DDT ranged from 0.15-0.19 μg/L in underground water which is contrary to the finding of this study. In his observation he stated that concentration of DDT obtained was possibly due to transfer of organochlorine pesticides from agricultural and health protection activities carried out near Hyderabad, India. DDT has a possible long-term toxicity as it remains in the environment for a long time (WHO, 2011). Exposure to DDT in water may lead to human health including lung damage, cancer and injury of reproductive and nervous system (Mansour, 2004). Therefore, based on these results, all samples analyzed complied with the maximum limit recommended by TZS (2016) and WHO (2011). Borehole water is considered safe for human consumption due to non-detectable levels of DDT in the analyzed borehole water samples.

Conclusion

Access to quality and safe water is essential, regardless of the water source. In this study all tested samples from the two streams, fall within recommended level proposed by TZS and WHO except for phosphate from Shagayu (Ludende) and Daa stream (Kwamamkoa and Komboheo), which was found to be high in both areas with agricultural activities. Therefore, improper discharges of waste from the nearby streams and other points to the streams should be prohibited to keep water safe especially in populated areas with agricultural activities. For borehole water however, all chemical parameters tested were within the permissible limit by TZS and WHO except for ammonia (from Kwemashui) and pH (at Alufea) in Sunga ward which were above WHO recommended levels. Despite this, borehole water sampled in Lushoto district was safe and of good quality for household use, based on the Tanzanian standard.

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