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EVALUATION OF SUSTAINABLE USE OF UNDERGROUND WATER IN PERI-URBAN CENTERS' OF ELDORET MUNICIPALITY IN KENYA

P. WANJALA[1*], H. TSINGALIA[1], J. MAKATIANI[1], J. MAITHYA[2], M. WABUSYA[1] AND A. K. RONO[1]
[1]Department of Biological Sciences, Moi University, Kenya.
[2]Department of Biological Sciences, Garissa University, Kenya.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Author PW designed the study, wrote the protocol and interpreted the data. Authors PW, HT and J. Makatiani anchored the field study, gathered the initial data. Authors PW, HT and J. Makatiani performed preliminary data analysis. Authors PW, MW, J. Maithya and AKR managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

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ABSTRACT

The Kenyan national water quality standard recommends that water should be safe for human consumption. If not protected, ground water can easily be contaminated with many pollutants including biological pathogenic microorganisms. Waterborne diseases can be effectively controlled through proper sanitary procedures that result in use of good quality water through proper sanitary procedures. The main purpose of the study was to compare levels of pollution of ground water between 3 peri-urban centers in Eldoret Municipality; Langas, Munyaka and Huruma, using levels of coliforms and solids in underground waters as an indicator of point source pollution as varied over the dry and wet seasons. Six test sampling points were randomly selected per peri-urban area and another two water wells located above 31 m from garbage dumpsites and pit latrines were purposely selected from the three zones and served as control samples. A total of 40 samples were collected in duplicates during the dry season (January and March 2015) and another 40 samples were collected in duplicates during the wet season (April and May 2015). Standard plate count method was used for total coliforms incubated at 35±2°C for 24 hours. The total solids were determined by evaporation technique in which the total solid material was collected and determined gravimetrically. The mean total solids (TS), in each water well was within the permissible limits of 1.2 g/L. However, the means of the TS varied over the dry and wet seasons. Means, standards deviations, one way ANOVA and Pearson's correlation analysis were used to analyze the relationship between variables in relation to seasons. Analysis of the collected data was done using JMP statistical software at 0.05 level of significance. Levels of coliforms in water wells were above the National Water Quality Standards of Nil/100 mL. Pearson`s correlation was used to test the relationship between the variables under study. The levels of *Escherichia coli* in well waters was positively influenced by the distance from the pit latrine and from the garbage dumpsites (r=-0.165, p=0.007) and (r=-0.246, p=0.024). There were no significant differences between the test and control samples, (ANOVA: $F_{3, 39}$=0.2249; p<0.8487). During the dry season, total dissolved solids (TDS) levels of the test samples also showed no significant difference with the control sample (ANOVA: $F_{3, 39}$=0.7601; p=0.5239). This study concludes that topography is a key influence on proximity of water wells to pit latrines and garbage dumpsites in the study areas, thus affecting the number of

**Corresponding author: Email: piwanjala@gmail.com;*

coliforms in ground water. This study recommends the construction and use of standard communal water wells, review of the 30 m location distance of water wells and other water abstraction points from pollution sources and regular monitoring of ground water quality.

Keywords: Land tenure; point source pollution; total coliforms; *Escherichia coli;* solids; garbage disposal; ground water protection; sustainable development.

1. INTRODUCTION

All forms of life on earth depend on water for survival. From the 1.4 billion km^3 of water on earth, only about 1 percent is available for human consumption [1]. Shortage of portable water is an ever present problem on earth. Apart from quantity, water quality is equally important [2]. About 2 billion people worldwide do not have access to adequate sanitation (United Nations International Children's Emergency Fund [3]. Due to rapid population growth, people are increasingly competing for the scarce water resources. Water has become the most critical natural resource that receives little attention as a raw material and an investment opportunity [3].

Efficiency in water management in Kenya has been enhanced by transferring the responsibility of water resources management from government to public-private partnership of water services and by the decentralization of decision-making [4]. Nevertheless, little has been achieved on the ground. The poverty index still remains high and this has denied most of the people access to clean water [4]. Ground water remains the reliable source of water especially during the dry season [5]. Global driving forces, including climate change, increasing water scarcity, demographic changes and urbanization are expected to affect the resilience of water supply and sanitation systems and services (World Commission on Environment and Development [6]. As climate change scenarios become increasingly predictable, existing infrastructure will need to be upgraded and planning of new systems and services will need to be updated (World Health Organization [7].

In 2007, findings from the Kenya National Water Services Strategy revealed that the water sanitation situation is poor with only 57 percent of households using water from sources that are considered safe [5]. Sustainable access to safe water stands at 60 percent in the urban setting and drops to a low of 20 percent in the settlements of the urban poor, where half of the urban population lives [5]. Over 50 percent of Kenya's households do not have access to safe drinking water and the proportion is higher among the poor people [8].

One type of microorganism, *E. coli*, is the primary microbiological parameter used to evaluate the quality of drinking water and is of greater human health concern as it indicates recent faecal contamination of water [9]. Faecal bacteria; *E. coli* is the precise indicator to contamination by faeces of humans or other warm-blooded animals [9]. When faecal material contaminates a water supply, outbreaks of waterborne contagious diseases may occur. It is possible for some of the pathogenic organisms to travel long distances and live for extended periods outside a human or animal host.

The objective of this research was to assess contamination of fecal indicator bacteria; *E. coli* and total dissolved solids in underground waters of peri-urban centre's of Eldoret Municipality, Uasin Gishu County in Kenya, in relation to seasons and proximity to point sources of pollution.

1.1 Justification of the Study

Rapid population growth, water pollution and mismanagement of water resources have led to water scarcity. Peri-urban areas; Langas, Munyaka and Huruma, in Eldoret Municipality, are highly populated with majority of the households being low income earners. Most of the households are dependent on waters from wells because there is inadequate supply of piped water.

Waterborne diseases (i.e., dysentery, cholera, gastroenteritis and typhoid) can be effectively controlled through proper sanitary procedures that result in use of portable water [7]. Quality of groundwater is a facet of environmental health that requires routine monitoring because of its implications on human health. The cholera outbreak which began on 26th December 2014 affected a total of 30 counties in Kenya. Of the 30 Counties, 25 managed to successfully control the outbreak [3]. As of 9th May 2016, a total of 15,103 cases of cholera and 238 deaths had been reported nationally. Of the cases only 1,745 which are 12% of the total cases were confirmed through laboratory tests. There are five counties with active cholera outbreaks. Four of these counties; Wajir, Marsabit, Tana River and Mandera

experienced the first wave of the outbreak, and Garissa county reported the 2nd wave of outbreak [3]. The findings of this study will be used to create awareness among the residents of these areas and provide recommendations to the county government on status of underground water quality that the government would subsequently use to institute precautionary measures to prevent further contamination of underground water.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Eldoret Municipality, Uasin Gishu County, Kenya (Fig. 1), Uasin Gishu County covers an area of 2,955.30 Km^2, and is located at 0^o 31' N (Latitude) 35^o 17'E (Longitude). The County governance is divided into 3 Constituencies and 13 wards. There are three peri-urban areas that lie within different Constituencies; Huruma in Eldoret North, Munyaka in Eldoret East and Langas in Eldoret South. The area receives annual rainfall that range between 900 and 1,200 mm. Annual temperatures range between 8 and 27^oC. Eldoret Municipality has an estimated population of 289,380 people [10]. Economic activities in this area include; horticulture, dairy farming, wheat and maize farming, sports and tourism.

2.2 Research Design

An experimental research design was adopted to determine the levels of *Escherichia coli*, total coliforms and solids in ground waters. Three peri-urban areas (Langas, Munyaka and Huruma) were purposefully chosen in Eldoret Municipality as they are settlement areas of middle or low income earners. Each of the three areas was divided into three distinct study zones; Langas- LA (Central), LB (Kisumu Ndogo) and LC (Kasarani); Munyaka- MA (Silas), MB (Mwitirithia) and MC (Ngomongo); Huruma- HA (Pilot), HB (Nyathiru), and HC (Mwenderi). Distance proximity of water wells to pit latrines and garbage dumpsites were measured using a tape measure. This was followed by mapping of sampling points using a GPS, collection of water samples; water samples were collected half a meter deep from the surface of the water using dip sampling method. Dip sampling involved dipping a sealed narrow-mouthed one liter bottle into the water wells slowly and smoothly to the desired point of sample intake; that is, without creating turbulence and without stirring up bottom detritus. The water samples were then transported to the laboratory for analysis.

2.3 Determination of Levels of *Escherichia coli* and Total Coliforms and Findings

Apparatus and agar were sterilized in an autoclave at 121^oC and 21 psi and assembled in a laminar flow cabinet. The UV ray was switched on for further sterility and after 10 minutes the fan was switched on. For each well, 10 mL of water sample and 10 mL of distilled water blanks were used as samples for microbial analysis. From the 10 mL of each water samples, 1ml was pipetted into labeled duplicate Petri dishes. The samples were then diluted by a factor of 10 by pipetting another 1 mL of each sample separately into separate sterilized 10 mL measuring cylinders which were then brought to 10 ml, total volume. One milliliter of the dilutions was then separately pipetted into labeled duplicate Petri dishes. Fifteen milliliters of Endo Agar that had been sterilized and cooled to 45°C was poured into each Petri dish. The Petri dishes were swirled and allowed to solidify. The Petri dishes were then inverted and incubated at 35±2°C for 24 hours. Dark-red and green colonies were identified and counted. Results were recorded and calculation of the number of coliforms per ml of the sample was done [11]. For controls, 1ml of distilled water samples (Blanks) were dispensed into other Petri dishes, Endo Agar was poured into the Petri dishes and was incubated together with the well water samples. The number of coliforms was determined by multiplying the number of coliforms counted by the dilution factor and by counting the number of colonies in the Petri dishes. Confirmation of these colonies was done by the qualitative test.

2.4 Confirmation Qualitative Test for Total Coliforms

Two typical colonies were selected from the Endo Agar plate. Each colony was inoculated into a separate test tube containing 10 mL of Brilliant green lactose bile broth (BGLB), 2% broth plus a gas collector durum tube. The test tubes were incubated at 35±2°C and examined for gas production at 48 hours. All gassing durum tubes were considered positive for the presence of coliforms and were either recorded positive or negative [11].

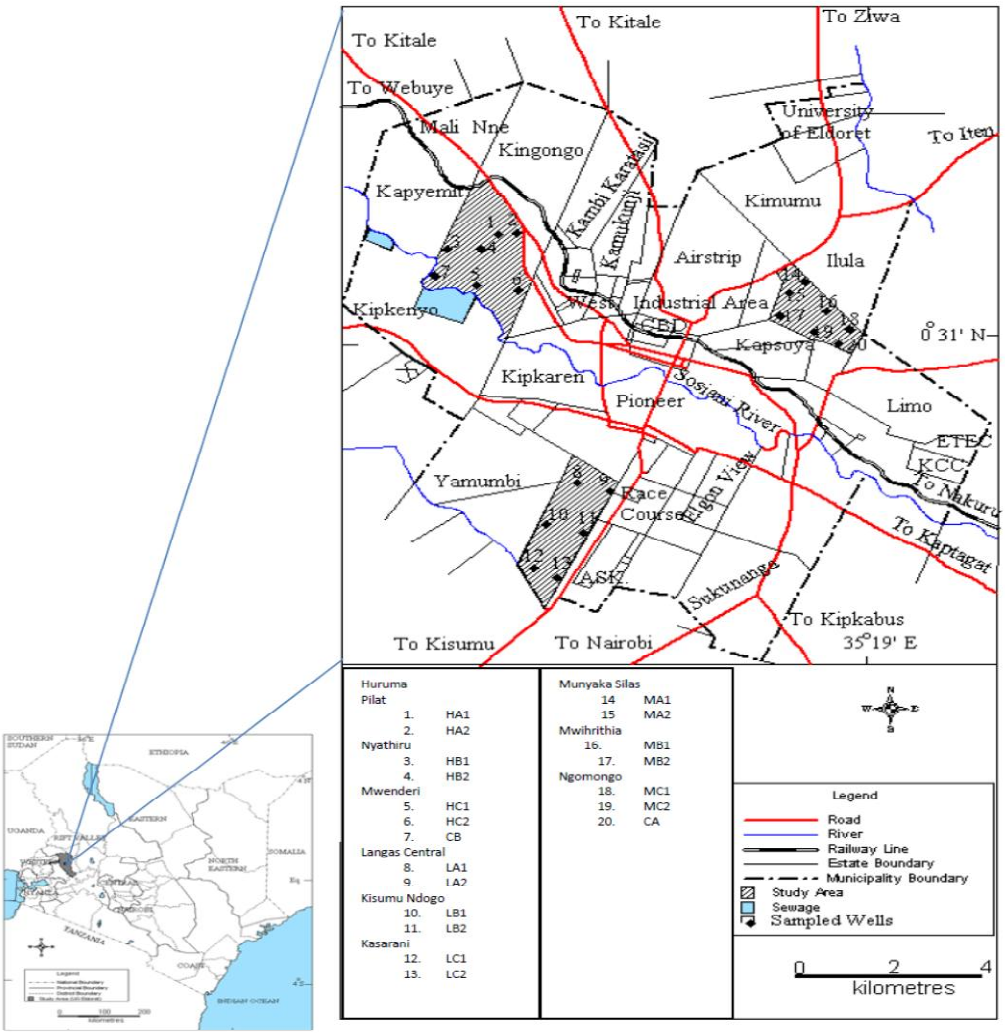

Fig. 1. Map of Eldoret Municipality showing the distribution of the wells sampled (dots in shaded areas) in Langas, Munyaka and Huruma. (Courtesy of L. Kanda, School of Arts and Social Sciences; Moi University, 2015)

2.5 Determination of Total Solids

The Total Solids were determined by evaporation technique in which the total solid material was collected and determined gravimetrically [12]. Water samples were placed in 500 mL stoppered plastic containers. Each water sample was mixed thoroughly by shaking and stirring in their respective containers. A 50 mL water sub-sample was transferred to a pre-weighed glass evaporating dish. The sample was then let to evaporate to dryness on a steam bath at 110°C for 4 hours and then dried in an air oven at 110°C for 1 hour. Increase in weight over that of the pre-weighed empty dish was recorded as the weight of total solids [12]. The dried sample was then left to cool to room temperature in desiccator and weighed to the nearest grams using a three decimal place analytical balance. This was followed by calculations as illustrated below (Ref a).

Calculation for total solids

$$\text{Total solids}\,\frac{g}{L} = \frac{(W1-W2)}{V} \times 1000\ldots\ldots\ldots\ldots \text{(Ref a)}$$

Where:

W1=Mass of dried residue and evaporating dish in grams (after evaporation),

W2=Initial weight of the evaporating dish in grams.

V=Volume of water sample taken in milliliters.

Three replicate samples were measured and the mean value recorded [12].

2.6 Determination of Total Suspended Solids (TSS)

Whatman filter papers (Number 540) were dried for 30 minutes in an oven at 100°C. The filter papers were then cooled to room temperature in a desiccator then weighed. The filtration apparatus was assembled and the pre-weighed filter papers were wetted with distilled water. The samples were stirred up and 50 mL of the samples was pipetted onto the filter paper while stirring. The filter was washed three times with distilled water. The residue trapped on the filter paper was dried in a vacuum oven at 100°C for 1 hour. It was then allowed to cool to room temperature in a desiccator and weighed to the nearest mg as follows (Ref b) [12]:

$$\text{Total suspended solids g/L} = \frac{(W1-W2)}{V} \times 1000 \ldots \text{(Ref b)}$$

Where:

W1=Mass of dried residue and filter paper in grams (after evaporation),

W2=Initial weight of the filter paper in grams,

V=Volume of water sample taken in milliliters.

Three replicate samples were measured and the mean value recorded [12].

3. RESULTS AND ANALYSIS

3.1 Levels of Total Coliforms

The mean total coliforms in well waters varied in the three study areas: Munyaka 333±0.06 cfu/ml and 69±0.01 cfu/ml, Huruma 381±0.01 cfu/ml and 108±0.00 cfu/ml and Langas 142±0.00 cfu/ml and 320±0.22 cfu/ml during the dry and wet seasons respectively (Table 1). Total coliforms increased in the wet season in Langas while in Munyaka and Huruma, the number of total coliforms decreased. The total coliforms in the well waters in the study areas differed significantly, Munyaka, one- sample t(df) =11, (t=3.872, p=0.012), Langas df=11, (t=6.433, p=0.001), Huruma df=11, (t=3.999, df=5, p=0.010) during the dry season. During the wet season, total coliforms were only significantly different in Huruma df=11, (t=8.852, p=0.000).

3.2 Levels of *Escherichia coli*

The mean colonies of *Escherichia coli* in well waters differed in the three study areas and in different seasons. Munyaka had a mean value of 61±0.07 cfu/ml and 38±0.06 cfu/ml, Huruma 58±0.06 cfu/ml and 20±0.08 cfu/ml and Langas had a mean of 14±0.00 cfu/ml and 66±0.07 cfu/ml during the dry and wet seasons respectively (Table 2). There were no significant differences in the mean number of *Escherichia coli* in Munyaka during the dry and the wet seasons, one- sample (df)=11, (t=2.248, p=0.074). There was also no significant difference in Langas during the dry and wet season, one sample t (df=11) =2.283, p=0.071) and Huruma one sample t (df=11) =2.234, p=0.076) during the dry and wet seasons. Average numbers of *E. coli* in the protected wells (Controls) were similar in the dry season 4±0.53 cfu/ml and 4±0.12 cfu/ml in the wet season (Table 2). One way ANOVA revealed that there was a significant difference in the level of *E. coli* among the test samples during the dry and wet season over the study areas (ANOVA: $F_{2,\ 72}$=28.922, p=0.000). *Escherichia coli* concentrations were on average higher in the dry season as compared to the dry season.

3.3 Pairwise Correlation between Variables in Water Samples and the Proximal Distances from Pit Latrines and Garbage Dumpsites

The results show that the water quality in wells located near the pit latrines had higher contamination than those located further from the wells (Table 3). The levels of *Escherichia coli* in well waters was positively influenced by the distance from the pit latrine and from the garbage dumpsites (r=-0.165, p=0.007) and (r=-0.246, p=0.024) respectively (Table 3).

3.4 Solids

3.4.1 Total solids (TS)

There was a large variation of 0.04-0.08 g/L in total solids between seasons and among the study areas. Total solids in well waters of Munyaka had a mean value of 0.08±0.002 g/l and 0.04±0.004 g/l, Huruma 0.08±0.004 g/l and 0.07±0.005 g/l and Langas 0.07±0.004 g/l and 0.06±0.004 g/l during the dry and wet seasons respectively (Table 4). During the dry season, the mean level of TS in the control sample was 0.03±0.00 g/L. This was significantly lower (ANOVA: $F_{3,\ 39}$=25.85; p<0.0001) when compared to TS levels in samples collected in Munyaka, Huruma

or Langas (Table 4). TS level of Langas was significantly lower when compared to levels in samples collected from Munyaka (ANOVA: $F_{3, 39}$=25.85; p=0.0247) or Huruma (ANOVA: $F_{3, 39}$=25.85; p=0.0236), whereas the latter two level showed no significant differences (ANOVA: $F_{3, 39}$=25.85; p=1.0000) (Table 4). During the wet season, the level of total solids in the water samples collected from Munyaka were significantly lower when compared to those from control sample (ANOVA: $F_{3, 39}$=9.22; p=0.0107), Huruma (ANOVA: $F_{3, 39}$=9.22; p<0.0001) or Langas (ANOVA: $F_{3, 39}$=9.22; p=0.0236). With respect to seasons, total solids showed a downward trend from the dry to wet season. While there was a sudden drop in TS in Huruma well waters from the dry to wet season, the appeared to have been little change in TS in Langas and Munyaka between the dry and wet season (Table 4).

Table 1. Mean (±Standard error of mean) total coliforms (cfu/1 ml) in samples from different water wells in three centers during dry and wet seasons

	Dry season		Wet season	
	n	**Total coliforms (cfu/1 ml)**	**n**	**Total coliforms (cfu/1 ml)**
Control	4	98±0.25 a	4	17±0.06 a
Munyaka	12	333±0.06 b	12	69±0.01 b
Huruma	12	381±0.01 b	12	108±0.00 c
Langas	12	142±0.00 c	12	320±0.22 d

Means (±Standard error of mean) within the same column followed by different letter (s) are significantly different at p=0.05

Table 2. Mean (±Standard error of mean) *Escherichia coli* (cfu/1 ml) in samples from different water wells in three centers during dry and wet seasons

	Dry season		Wet season	
	n	***Escherichia coli* (cfu/1 ml)**	**n**	***Escherichia coli* (cfu/1 ml)**
Control	4	4±0.53 a	4	4±0.12 a
Munyaka	12	61±0.07 b	12	38±0.06 b
Huruma	12	58±0.06 b	12	20±0.08 b
Langas	12	14±0.00 a	12	66±0.07 c

Means (± Standard error of mean) within the same column followed by different letter (s) are significantly different at p=0.05

Table 3. Correlation probability between values test variables and distances of water wells from pit latrines and garbage dumpsites over the two seasons

Variable	By variable	Correlation	n	Signif. Prob.
T coliforms (Dry season)	Distance latrine	-0.391*	40	0.042
T coliforms (Dry season)	Distance dumpsites	-0.375*	40	0.001
E. coli (Dry season)	Distance latrine	-0.165*	40	0.007
E. coli (Dry season)	Distance dumpsites	-0.246*	40	0.024

**. Correlation at 0.05 level of significance*

Table 4. Mean (±Standard error of mean) total solids (g/L) in samples from different water wells in three centers during dry and wet seasons

	Dry season		Wet season	
	n	**Total solids (g/L)**	**n**	**Total solids(g/L)**
Control	4	0.03±0.002 c	4	0.07±0.004 a
Munyaka	12	0.08±0.002 a	12	0.04±0.004 b
Huruma	12	0.08±0.004 a	12	0.07±0.005 a
Langas	12	0.07±0.004 b	12	0.06±0.004 a

Means (±Standard error of mean) within the same column followed by different letter (s) are significantly different at p=0.05

3.4.2 Total suspended solids (TSS)

In the dry season, the level of TSS in the control water samples were significantly lower than the levels in the test samples from the three centers (ANOVA: $F_{3, 39}$=69.42; p<0.0001). Similarly, in the wet season, the level of TSS in the control water samples were not significantly different from that of Munyaka (ANOVA: $F_{3, 39}$=12.42; p=0.9981) or Langas (ANOVA: $F_{3, 39}$=12.42; p=0.1750). The level of TSS in Huruma water samples were significantly higher (ANOVA: $F_{3, 39}$=12.42; p<0.0001) than the rest of the test and control samples (Table 5). There was a sudden transition drop in the levels of TSS in Munyaka, while in Huruma and Langas, the transition was moderate.

Pearson's correlation analysis revealed significant relationships between total solids, total suspended solids and total dissolved solids with distance from the pit latrine and the distance from the garbage dumpsites (r=-0.726, p=0.000) and (r=-0.531, p=0.016) respectively (Table 6). Pearson's correlation analysis further revealed that there was a significant relationship between total suspended solids and the distance from the pit latrine and from the garbage dumpsites (r=-0.743, p=0.000) and (r=-0.611, p=0.004) respectively (Table 6). There was further significant relationship between total dissolved solids during wet season and the distance from the pit latrine and from the garbage dumpsites (r=0.638, p=0.002) and (r=0.595, p=0.006) respectively (Table 6).

Table 5. Mean (±Standard error of mean) total suspended solids (g/L) in samples from different water wells in three centers during dry and wet seasons

	Dry season		Wet season	
	n	Total suspended solids (g/L)	n	Total suspended solids (g/L)
Control	4	0.01±0.00 c	4	0.03±0.00 bc
Munyaka	12	0.07±0.00 a	12	0.03±0.00 c
Huruma	12	0.06±0.00 a	12	0.05±0.00 a
Langas	12	0.05±0.00 b	12	0.04±0.00 b

Means (±Standard error of mean) within the same column followed by different letter (s) are significantly different at p=0.05

Table 6. Correlation probability between values test variables and distances of water wells from pit latrines and garbage dumpsites over the two seasons

Variable	By variable	Correlation	n	Signif. Prob.
Total solids (Dry season)	Distance latrine	-0.726*	40	0.000
Total solids (Dry season)	Distance dumpsites	-0.531*	40	0.016

**. Correlation at 0.05 level of significance.*

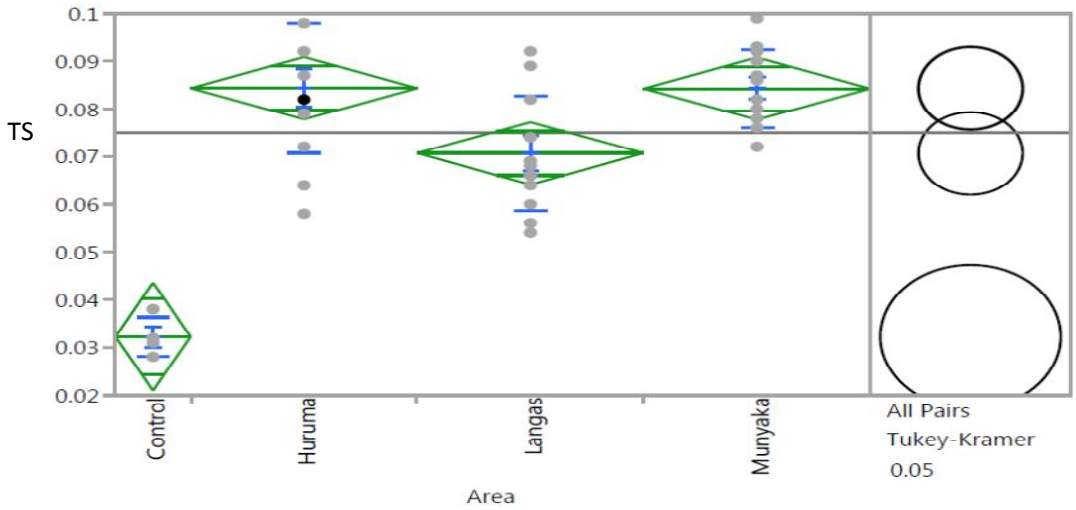

Fig. 2. Tukey-Kramer one way analysis of total solids by area over the dry season; 0.05 level of significance

Table 7. Means of total solids in the three study areas over the dry season

Level	Number	Mean	Std error	Lower 95%	Upper 95%
Control	4	0.032250	0.00557	0.02096	0.04354
Huruma	12	0.084333	0.00321	0.07782	0.09085
Langas	12	0.070667	0.00321	0.06415	0.07718
Munyaka	12	0.084250	0.00321	0.07773	0.09077

Std error using a pooled estimate of error variance; at 0.05 level of significance

The study revealed that there was significant difference in mean values of total solids between the test samples and the control in the three study areas over the dry season; Huruma - A, Munyaka - A, Langas- B and Control- C, (Table 8).

Table 8. Connecting letters report of solids over the dry season

Level	Letter	Mean
Huruma	A	0.08433333
Munyaka	A	0.08425000
Langas	B	0.07066667
Control	C	0.03225000

Levels not connected by the same letter are significantly different

The study revealed that there was significant difference in values of total solids among the test samples and the control in the three study areas over the dry season; Huruma and control ($p< 0.0001$), Contol sample and Munyaka ($p< 0.0001$), Langas and control ($p< 0.0001$), Huruma and Langas ($p=0.0236$), Huruma and Munyaka ($p=0.0247$), (Table 12). The study further revealed that there was no significant difference in values of total solids among the test samples and control sample in the three study areas over the dry season; Huruma and Munyaka ($p=1.0000$), (Table 12).

The study revealed that there was significant difference in mean values of total solids between the test samples and the control in Munyaka over the wet season; Munyaka - B, The study revealed that there was no significant difference in mean values of total solids between the test samples and the control in Langas and Huruma over the wet season; Langas - A and Control- A, Huruma – A (Table 11).

Table 9. Ordered difference report of total solids over the dry season

Level	-Level	Difference	Std Err. Dif.	Lower CL	Upper CL	P-value
Huruma	Control	0.0520833	0.0064265	0.034775	0.0693913	< 0.0001*
Munyaka	Control	0.0520000	0.0064265	0.034692	0.0693079	< 0.0001*
Langas	Control	0.0384167	0.0064265	0.021109	0.0557246	< 0.0001*
Huruma	Langas	0.0136667	0.0045442	0.001428	0.0259052	0.0236*
Munyaka	Langas	0.0135833	0.0045442	0.001345	0.0258219	0.0247*
Huruma	Munyaka	0.0000833	0.0045442	-0.012155	0.0123219	1.0000

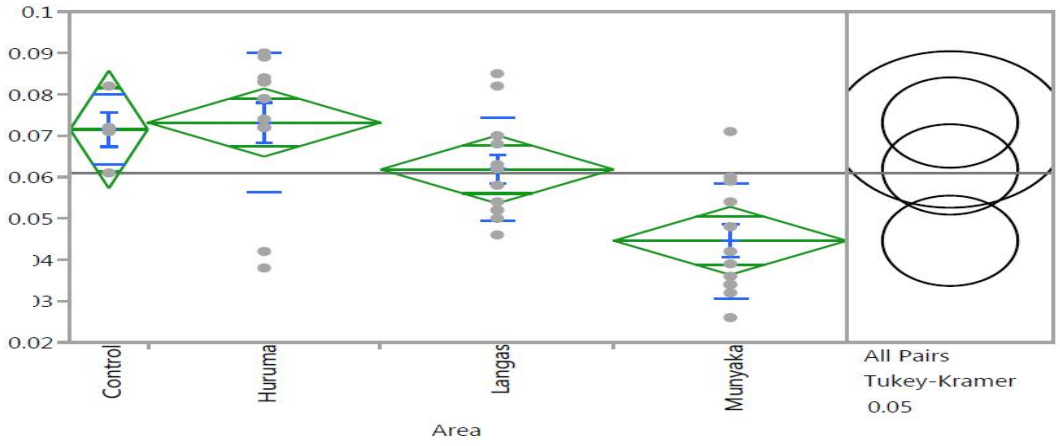

Fig. 3. Tukey-Kramer one way analysis of total solids by area over the wet season; 0.05 level of significance

Table 10. Means of total solids over the wet season

Level	Number	Mean	Std error	Lower 95%	Upper 95%
Control	4	0.071500	0.00702	0.05725	0.08575
Huruma	12	0.073167	0.00406	0.06494	0.08139
Langas	12	0.061833	0.00406	0.05361	0.07006
Munyaka	12	0.044583	0.00406	0.03636	0.05281

Std error uses a pooled estimate of error variance

Table 11. Connecting letters report of total solids over the wet season

Level	Letter	Mean
Huruma	A	0.07316667
Control	A	0.07150000
Langas	A	0.06183333
Munyaka	B	0.04458333

Levels not connected by the same letter are significantly different

Table 12. Ordered difference report of total solids over the wet season

Level	-Level	Difference	Std Err. Dif.	Lower CL	Upper CL	P-value
Huruma	Munyaka	0.0285833	0.0057354	0.013137	0.0440300	< 0.0001*
Control	Munyaka	0.0269167	0.0081111	0.005972	0.0487616	0.0107*
Langas	Munyaka	0.0172500	0.0057354	0.001803	0.0326967	0.0236*
Huruma	Langas	0.0113333	0.0057354	-0.004113	0.0267800	0.2159
Control	Langas	0.0096667	0.0081111	-0.012178	0.0315116	0.6359
Huruma	Control	0.0016667	0.0081111	-0.020178	0.0235116	0.9969

The study revealed that there was significant difference in values of total solids among the test samples and the control in the three study areas over the wet season; Huruma and Munyaka (p=< 0.0001), Contol sample and Munyaka (p=0.0107), Langas and Munyaka (p=0.0236) (Table 12). The study further revealed that there was no significant difference in values of total solids among the test samples and control sample in the three study areas over the wet season; Huruma and Langas (p=0.2159), Contol sample and Langas (p= 0.6359), Control and Huruma (p=0.9969) (Table 12).

4. DISCUSSION

Findings of the coliform counts in this study are similar to those by Taulo [13] in Lungwena, Malawi. The microbiological quality of water was found to be poor as a result of poor environmental sanitation. Possible sewage pollution is indicated by the presence of coliform bacteria, which may be confirmed by further testing for faecal bacteria, such as faecal coliform or *E. coli*. Climatic conditions, land use patterns, vegetative cover, topography, soil and geologic characteristics, condition of the water well, location of potential pollution sources, and agricultural management practices can affect the transport and contamination of groundwater by bacteria. Various factors affect the microbiological quality of groundwater [14]. In areas where the depth to bedrock is shallow, there is little interaction with the soil and, therefore, contaminants are not effectively removed [14].

Suspended solids consist of fine particles of organic and inorganic matter, which is regarded as a type of pollution because water high in concentration of suspended solid may adversely affect taste in drinking water. The major dissolved components of ground waters include the anions of bicarbonate, chloride and sulphates, and the cations of sodium, calcium, magnesium and potassium. The values of total solids varied from a minimum of 0.061 g/l during the wet season to a maximum of 0.075 g/l during the dry season. This may be attributed to less runoff water levels in dry season and diluted waters during the wet season. All water samples were within permissible limits of KNWQS of total dissolved solids in Kenya (1.2 g/L). Total dissolved solids in the study area groundwater samples reveal a fairly larger range of variation from 0.03 - 0.095 g/L. These results are similar to those of Edeonovo [15] who found that the total solids (TS) values were within the range of 0.06 – 0.26 g/L. The permitted limits are 0.03 g/L or below.

Findings of TSS ranged between 0.01- 0.06 g/L and were higher during the wet season as compared to the dry season. As revealed by Pearson's correlation analysis, TSS was negatively correlated to distance

from pit latrines and distance from garbage dumpsites. A decrease in distance of a well from a pit latrine or a garbage dumpsite showed an increase in levels of TSS. Shivendra [16] had similar findings in their research on impacts of on-site sanitation system on ground water in different geological settings of peri-urban areas in India.

Total Dissolved Solids of well waters had a mean value of 0.022 g/L and 0.021 g/L during the dry and wet seasons respectively. These results are much lower than those of Kwame [17], who found all the six sources of water that he studied in Ghana, had levels of TDS that ranged from 0.0893 to 0.9687 g/L. Kwasi [18] in the Offinso District of Ashanti region reported TDS values of 0.0740 to 0.1051 g/L. The values in both studies were within the WHO standard value of 1.0 g/L. Mc Cutheon [19] reported that the palatability of water with TDS level less than 0.6 g/L is generally considered to be good whereas water with TDS greater than 1.2 g/L becomes increasingly unpalatable.

5. CONCLUSION AND RECOMMENDATION

This study concludes that proximity to pit latrines and garbage dumpsites affected number of total coliforms and faecal coliforms (*E. coli*), which is affected by topography of land in the study areas. Total solids (TS), total suspended solids (TSS) and total dissolved solids (TDS) varied from wet to dry season with elevated levels in the wet season. From total suspended solids (TSS) results it is an indication that sediments are a major source of pollution and is linked to proximity to pit latrines and garbage dumpsites.

This study recommends that there is need to determine groundwater flow models, to better define the limits of chemical transport and pathogen dispersion from sources of pollution to water abstraction sites. Preventive methods such as proper well site selection and construction should be followed to ensure ground water supplies are safeguarded against contamination by any material that is lethal to human health. Further, construction of standard communal water wells and availing of garbage collection tanks with frequent garbage collection by County Governments which will ensure standards are followed on their construction and on waste disposal is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kenya National Water Development. Water: A shared responsibility. The 2nd UN World Water Development Report; 2006. Berghahn Books. Available:http://www.berghahnbooks.com on 28/042015.
2. Fairweather-Tait S, Hurrell RF. Bioavailability of minerals and trace elements. Nutritional Research Reviews. 1996;9(1):295-324.
3. United Nations Children's Fund (UNICEF). Kenya: Cholera outbreak overview as of 9-May- 2016 – Relief Web, 2016. Available:http://reliefweb.int/report/kenya/kenya-cholera-outbreak-overview-9-may-2016 on 18/06/2016.
4. Sustainable Development Report on Africa. Sustainable Consumption and Production for Sustainable Growth and Poverty Reduction; 2009. Available:http://www.uneca.org/sites/default/files/PublicationFiles/sdra3.pdf on 18/04/2015.
5. Kenya Integrated Household Budget Survey report (KIHBS). Report on Wellbeing in Kenya; 2005/06. Available:http://statistics.knbs.or.ke/nada/index.php/catalog/8/.pdf on 20/06/2014
6. World Commission on Environment and Development (WCED). Our Common Future: Transmitted to the General Assembly as an Annex to document A/42/427 - Development and International Cooperation: Environment; 1987.
7. World Health Organization (WHO). pH in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. World Health Organization, Geneva; 2013.
8. Moraa H, Otieno A, Salim A. Water governance in Kenya: Ensuring accessibility, service delivery and citizen participation; 2012. Available:www.ihub.co.ke/ihubresearch/.../2012/july/1343052795_537 on 16/05/2015.
9. Ekeleme AC, Ibearugbulem, Hippolitus O, Ugwuegbulam JC. A chemical prediction of groundwater quality in parts of Owerri Imo State in South Eastern Nigeria. IJCE, Construction and Estate Management. 2015; 3(1):62-72. Available:http://www.bing.com/search?q=A+Chemical+Prediction+of+Groundwater+Quality+In+parts+of+Owerri+Imo+state+in+South+Eastern+Nigeria.&form=U313DF&pc=U313 on 20/09/2015.
10. Kenya Institute for Public Policy Research and Analysis (KIPPRA). Kenya Economic Report: Creating an Enabling Environment for

Stimulating Investment for Competitive and Sustainable Counties. Nairobi: Kenya Institute for Public Policy Research and Analysis; 2013. Available:http:/www.kippra.org on 20/01/2015.

11. Andrews WH. Microbiological methods: Total coliform and *E. coli* counts. Association of Official Analytical Chemists Official Methods of Analysis, 17th Edition, Revision 1. Gaithersburg, Maryland. 1998;29-30.
12. American Public Health Association (APHA). Standard Method for Examination of Water and Waste Water. 19th Edition, Published by E and F N Poan, Washington D.C. 1995;2-56.
13. Taulo S, Wetlesen A, Abrahamsen R, Mkakosya R, Kululonga G. Microbiological quality of water, associated management practices and risks at source, transport and storage points in rural community of Lungwena, Malawi. African Journal of Microbiology Research. 2008;2:131-137.
14. Oram B, Halsor S, Redmond B R. Water quality your private well: What do the results mean? The International Journal of Engineering and Science (IJES). 2014;3(7):41-47.
15. Edeonovo J. Quality assessment of borehole waters in Enugu urban (Thesis, Nnamdi Azikiwe University, Nigeria; 2010. Available:http://www.naulibrary.org/dglibrary/admin/book_directory/Thesis/9961.pdf on 28/4/2015
16. Shivendra BT, Ramaraju HK. Sanitation in periurban areas of developing countries. Journal of Academy Industrial Research. 2013; 1(8):476-480.
17. Kwame M. Assessment of drinking water quality in Ehi community in the Ketu- North district of the Volta region of Ghana (Master's thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana); 2011. Available:http://ir.knust.edu.gh/xmlui/bitstream/handle/123456789/4103/MENSAH%20MAWULI%20KWAME%20THESIS%202011.pdf?sequence=1 on 16/05/2015.
18. Kwasi A. Evaluation of the microbiological and physicochemical quality of borehole water in the Offinso district of Ashanti region (Master's thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana); 2010. Available:http://ir.knust.edu.gh/bitstream/123456789/780/1/BENJAMIN%20KWASI%20AMANKONA.pdf on18/04/2015.
19. Mac Cutheon SC, Martin JL, Barnwell Jr. TO. Water quality. In Maidment DR, (Ed.). Handbook of hydrology. Mc Graw Hill, Inc., New York. 1983;11, 1–11, 73.