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Assessment of microbiological contaminants in community water sources in lower Nyakach Division, Kisumu County, Kenya

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ABSTRACT

The importance of water as a vehicle for spreading diseases has long been recognized and many studies have demonstrated the relationship between illness and deficiencies in water supply and sanitation. This study was conducted between October 2008 and July 2009, to determine microbiological water contaminants and related human health problems in community water sources in Lower Nyakach division, Kisumu County. Water samples were collected in selected water points, analyzed using membrane filter technique and their level of microbiological contamination determined using Escherichia coli type I as bio-indicator. Household level surveys and key informant interviews were conducted and secondary data obtained from Pap-Onditi district hospital on cases of environmental and human health risks associated with water contamination. Data from field samples and survey were analyzed using the Statistical Package for Social Sciences. Multiple comparisons between sites were made by Analysis of Variance (ANOVA) and the student t-test. Statistical significance was assessed at $p \leq 0.05$. The mean counts for faecal coliforms were lower than that of total coliforms in all samples in both dry and rainy seasons although the mean counts total coliforms were higher during the rainy season than the dry season. Water samples from water impoundments showed significant differencesin total coliforms compared to recommended WHO levels and no significant differences for faecal coliforms ($\alpha = 0.05$). Water samples from shallow wells showed significance difference for faecal coliforms between three sampling sites (Pap-Onditi, Urudi and Bonde). From the survey and hospital findings typhoid fever and amoebic dysentery were the most common water-borne diseases in the study area. Faecal contaminated water possesses high human health risks which are responsible for the reported increased water-borne diseases. The study concludes that total and faecal coliforms are important parameters in monitoring faecal contamination and water quality in the area. Most of the community water sources are seasonal and largely contaminated. Consequently, frequent monitoring of water quality and levels of contaminants using total and faecal coliforms is recommended at common water points to curb potential health related risks.

Introduction

The human well-being is an important objective of economic development. Poverty, poor human settlements and lack of good water quality and inadequate sanitation facilities compound the problems of communicable diseases and negatively impact on the health and well-being of the people. Safe drinking water is a major concern for developing countries, Kenya included. Drinking water sources are continuously being polluted by pathogenic microorganisms that deteriorate water quality making water treatment, essential (Reinheimer, 1992; UNDP, 2000, 2002, 2006, 2007). These pathogens are responsible for some 25,000 deaths daily globally (Baron, 1986; Eric et al. 2000)**.** The biggest threats come from sewage and faecal contamination. These are responsible for most water-related diseases like cholera and typhoid. These diseases pose a big challenge in developing countries as they account for 80% of sicknesses, 60% of which affects children (Murray et al. 1990). Many developing countries face further additional water quality problems such as fluorides in ground water, chemical fertilizers residues from agro-ecosystems, industrial effluents, improper use of pesticides and bacterially contaminated water (Bell et al. 1994). The rapid increase in human population generates human wastes that enter surface waters, percolate into the ground and is responsible for immediate contamination and long-term deterioration of the aquatic environment (Goel 2006).

The common bio-indicators of water quality are coliform bacteria and the commonest coliform is *Escherichia coli (E .coli).* When their concentration exceed WHO recommended levels is an indication that the quality of drinking water is compromised (WHO, 2006; UN-HABITAT 2003).Presence of *E. coli*in water, is an indicator of contamination from human or animal faeces. *E. coli* concentration has been shown to be a reliable indicator of gastro-intestinal illness. Consequently, it is used as an indicator of the risk of exposure to other pathogenic organisms (USEPA, 1989; Macler and Merckle, 2000). Coliform contamination monitoring in water and food generally use microbiological indicators (Benwart 1974; McFeters 1990;

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WHO/UNICEF 2005). *E. coli*has important characteristics that qualify it as an indicator and these have traditionally been used to assess the presence of potential for pathogens and hence, the quality of water (Pegram et al. 1998; Geldreich 1986). Elevated levels of faecal indicator organisms such as *E. coli* are a cause for concern for any water body, in particular shallow wells and water impoundments.

Water supply and management is further complicated by rapid increase in population, poorly constructed pit latrines, discharge of agro-chemicals from farms, excess abstraction of aquifers and increased contaminated runoffs and long-range atmospheric transport of pollutants (Tata and Salle, 1973). Water polluted with sewage contains various pathogenic organisms which when consumed can lead to severe health effects (Flanagan, 1992). The infected persons usually excrete large number of these pathogens in urine and faeces, which ultimately find their way into the water bodies (Goel 1997).

Faecal pollution occurs because of inadequate facilities for waste disposal, collection and treatment and on-site sanitation facilities such as latrines that drain directly into water sources (Lundqvist and Gleick, 1997). Conventional methods of providing safe drinking water at household level have proved unsuccessful in lower Nyakach division, where inadequate treatment of water remains an important factor that contributes to the occurrence of infectious disease outbreaks which are categorized as water-borne, water-hygiene, water-contact and water-habitat vector diseases (Boyd and Hoerl, 1981). Infectious water-borne diseases caused by ingested pathogens from contaminated water are a major cause of morbidity and mortality, affecting people of all age groups and seriously affecting children under five years (Mutanda, 1980).

In lower Nyakach division, the major water sources are impoundments that are either dug by local people or adopted from road construction sites and burrow pits that are seasonally filled up with contaminated rain or flood water runoffs (GOK, 2001). In an effort to meet the high water demand and to provide cheap, safe water for rural communities, the government of Kenya through Constituency Development Fund (CDF) in collaboration with some Non-Governmental Organizations (NGOs) has constructed additional shallow wells and water impoundments in the area. These water sources are increasingly being used to draw drinking water (Mukatsa et al. 2001**.** The hygiene of the current water sources appears compromised by contamination with water-borne disease agents. Of great concern is the increasing pollution and contamination of these water sources by the expanding human population that depend on them for livelihood and development.

The complex dynamics and significance of these water systems and their attendant environmental and human health problems need to be investigated, understood and appropriate remedial measures put in place to sustain the quality of drinking water. This is imperative because previous studies in the area have been biased towards rivers, especially river Nyando and Ombeyi. The quality of water from sources sources such as ponds, wells and water impoundments and itseffects on human health has been ignored.

This study sought to determine the levels of microbial water contamination and associated human health problems in lower Nyakach division, using *Escherichia coli* type I as bio-indicator. Specifically, the study sought to (1) to determine the level of contamination of various water bodies using *Escherichia coli* and (2) to determine the common water-borne diseases affecting members of lower Nyakach community as a result of water contamination.

Materials and methods

The Study Area

Lower Nyakach division is located in Kisumu County which border Nandi, Kericho, and Homa-bay counties to the north, east and south respectively. The area has a small shoreline to the south with Lake Victoria (GOK, 2001). It lies between longitudes 34^0 04'E and 34^0 06'E, and latitudes 0^0 23'S and O^0 25'S (figure 1). The study area has a total area of 182.6 km^2 with twenty five (25) administrative units (GOK, 2001).

The area experiences a tropical savannah type of climate with the altitude rising from 1,100m along the Kano plains to 1,800 m above sea level in Nyabondo plateau (figure 1). It experiences bimodal rainfall with the long rains from March to May and the short rains from September to November (GOK, 2001). The mean annual rainfall ranges between 600 mm to 1,630 mm while the temperature ranges between 20^{0}C to over 35^{0}C (GOK, 2001). The vegetation comprises the tropical savannah, shrubs and trees (GOK, 2001).

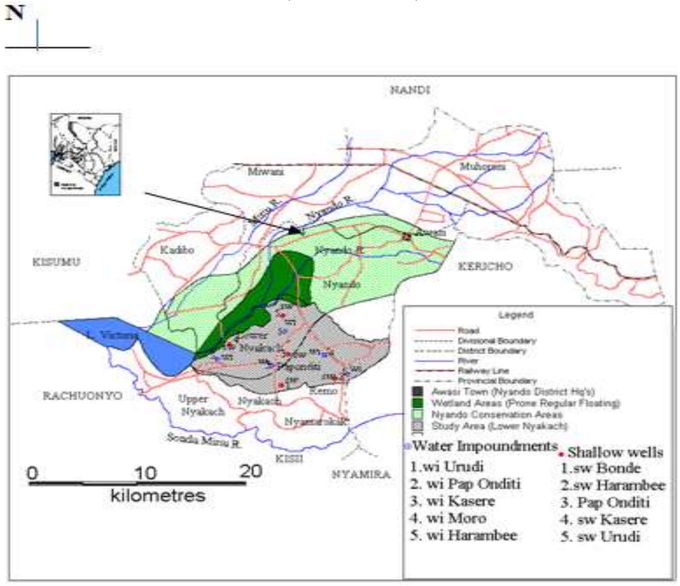

Figure 1. Map of Lower Nyakach Division in Nyando District, Kisumu County as the study area (Source: Nyando District Development Plan 2002—2008*).*

The population in 1999 was 49,302 with a projected figure of 78,518 in 2011 (Central Bureau of Statistics, 1999). The population and settlement pattern is determined by the physical set-up of the district and the relative agricultural potential of the divisions (GOK, 2001). Out of the five divisions, upper Nyakach division had the highest population density of 368 persons per km^2 compared to lower Nyakach division with a population density of 270 persons per km^2 in 1999 (GOK, 2001). The population density was projected to rise to 500 and 430 persons in the two divisions respectively in 2011 (GOK, 2001). High density areas include the major urban centers such as Katito, Pap-Onditi, Kolweny and the lakeside beaches namely; Kusa and Kong'ou.

Research design

A reconnaissance survey was conducted prior to site selection so as to familiarize with the study area, the local communities and mapping of the community water sources from which samples were later obtained. All the water impoundments not less than 5000 m^2 and shallow wells not less than 15m deep were identified. The total number of homes per village was obtained from the village elders. Using simple random sampling technique every 5th home was selected for interviews. In each home, the head of household at the time of visit was interviewed. Mapping of the selected water points was done using Geographical Positioning System (GPS) to facilitate their access and identification. Monthly water samples were collected from each of the selected water points for a duration of six months covering one dry season (January to March) and one wet season (April to July), 2009 respectively.

Ten water impoundments and 8 shallow wells were identified out of which, five popularly used water impoundments and 5 shallow wells were selected for sampling using simple random sampling technique (figs 2&3).

Figure 2: Site 1- impoundment sampling site

Figure 3: Site 1-shallow well sampling site

Household surveys, focus group discussions and key informant interviews using questionnaires and check lists were used to collect data between October 2008 and July 2009. These methods sought to obtain information on the sources of water for domestic use, water usage and availability and obtain information on the health status of the population. Water from different sources was sampled and analyzed to determine its quality using total faecal coliforms as indicators of contamination using Membrane Filter Technique. Data on water quality related diseases was obtained from Pap-Onditi district hospital records, where the majority of the resident population normally go for medical attention.

Water sampling for microbial Analysis

Triplicate water samples were collected from the water impoundments and shallow wells in the sterile 100-ml plastic bottles. The samples were then wrapped with Aluminum foil to protect photosensitive microorganisms. Sampling was done monthly for three months during the dry and wet season that covered the research period.

The sample bottles were labeled according to the sampling site for both the shallow wells and water impoundments. The date and time of collection were indicated on the sampling bottles. These were then kept in a clear plastic bag and finally placed in a cool box with ice packs (below 4^0C) for transportation to the laboratory. In the laboratory, the samples were placed in a refrigerator at – 4^0C, where they were processed and analyzed within 6 hrs.

The pH, temperature and conductivity were measured *in-situ* by use of portable meters. The respective probes were inserted in the water 6 inches underneath and the readings taken accordingly for the water impoundments. Water from shallow wells was drawn using a sterilized container and the parameters measured at the site of collection.

Sample Analysis

The membrane filter technique was used to analyze the water samples from all the sampling sites (Greenberg et al.1992). This method gives a direct count of the total colony forming numbers of coliforms and faecal coliforms present in a given sample of water. The samples were analyzed for *E. coli* which is indicator microorganism in the subsets of total coliform family.

Nutrient absorbent pads were used to detect and quantify coliform and other enteric microorganisms. Nutrient absorbent pads were aseptically added to the petri-dishes using a dispenser. Sterile Membrane Lauryl sulphate lactose broth was used to saturate the pad and the excess broth was removed. Membrane Lauryl sulphate lactose broth is a differential and selective culture broth medium for the detection of coliform and other enteric microorganisms. The petridishes were covered with lids and labeled according to the sites and water types. These were left for 2hrs at room temperature for resuscitation of the stressed microorganisms and later transferred into the incubator chamber at 37^0C for Total coliforms and 44^0C for faecal coliforms for 24hrs incubation. Microbial water quality from the various water sources used in the study area was analyzed with respect to the presence of Total and faecal coliforms.

Total coliforms and faecal coliforms were enumerated by the use of cellulose membrane filters. Coliform organisms exhibits golden yellow colony forming units extending on to the membrane with a diameter of more than 2 mm with Membrane Lauryl sulphate lactose broth within 18–24hrs. Swarming organisms exhibits diameters of less than 2 mm which does not extend onto the membrane. The golden yellow colonies with a diameter of more than 2mm were counted as coliforms after 24hrs and the results expressed as colony forming units per 100-ml. Faecal coliforms characterized luxurious growth at 44^0C. The colony forming units per sample were counted and converted to represent the colony forming units in 100-ml of the original sampled water. The number of coliforms/thermo-tolerant coliforms per 100-ml was determined as follows:

$$\text{TCC/FCC (100- ml)} = \frac{\text{NO.TC/FC colonies counted}}{\text{NO.ml of sample filtered}} \times 100$$

Confirmatory tests were done by swabbing 5 randomly picked colonies with golden yellow colour extending on to the membrane. These were sub-cultured in Lauryl Tryptose broth and incubated at 37^0C for Total coliforms and 44^0C for faecal coliforms for 48 hrs. The sub-cultured colonies exhibited growth and produced gas which is characteristic of *Escherichia coli* type I.

The statistical packages of SPSS and EXCEL were used to analyze the various statistical relationships between variables. Multiple comparisons between sites were made by analysis of variance and the student t-test. Statistical significance was assessed at $p \leq 0.05$. Household survey data were defined in SPSS for categorical response variables to be quantified and presented in form of bar graphs and tables.The means were calculated to represent mean bacterial population per 100-ml water. Statistical analyses were carried out in order to detect differences between water qualities at the different sites.

Results

Status of water quality status

The Total and faecal coliform counts in all the water sources were highfor rain season and relatively low for the dry season. Although WHO guidelines (2006) recommends the absence of microbial indicators in any 100ml of drinking water, this study recorded significantly higher numbers of total and faecal coliforms. Figures 4 and 5, shows the mean numbers of microbial indicator numbers per 100ml in water impoundments and shallow wells in the sampled communities. Each sample point is the mean of the triplicate monthly sample for the rainy and dry seasons.

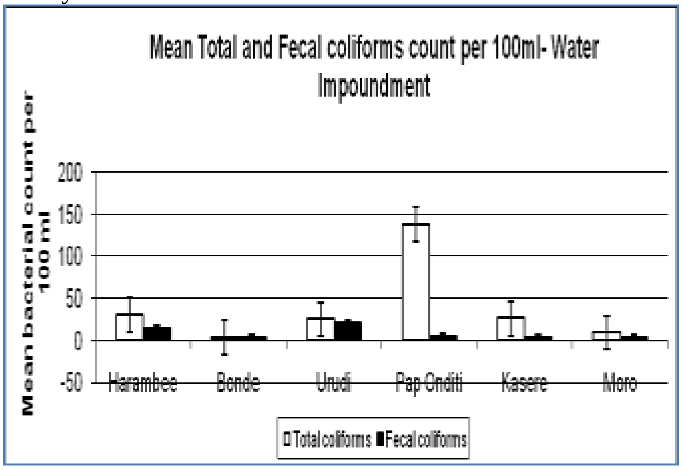

Figure 4: Mean Total and Faecal coliforms count per 100mlimpoundment water

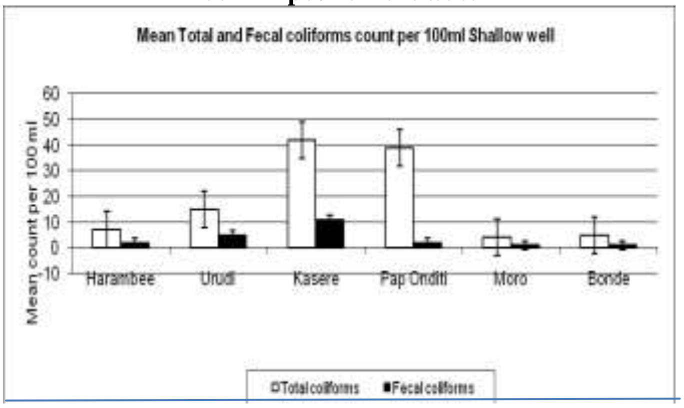

Figure 5: Mean Total and Faecal coliforms count per 100ml shallow wells water.

Water Sources

Results of this study show that communities living in lower Nyakach division access water from various sources but water impoundments were the most common sources of water for domestic use in the five administrative areas (Fig. 5). It was common to see people especially children bathe, wash clothes, fetch water for drinking and cooking from such water points. Furthermore, watering animals and engaging in many other activities that contribute to water contamination also increases the incidence of water-borne diseases with the resident pathogenic microorganisms being the main cause. Water sources located near densely populated trading centres like Harambee and Pap-Onditi impoundments were quite unhygienic due to high level of wastes inflows pausing higher environmental and human health risk.

Pap-Onditi study area had diverse sources of water for domestic use which included rivers 5%, shallow wells 4%, water impoundments 62% and roof catchments 13%. Results also reveal that more than two thirds of the respondents in Pap-Onditi, Asao, and central Nyakach study areas depend on water impoundments for domestic use

Water Uses

Use of water for domestic purposes in lower Nyakach division is to a small extent dependent on the source. Combined activities for water uses are cooking, bathing and drinking. Figure 6 shows percentage water uses from various sources. Water impoundment is the most common source for use even though roof catchment and shallow wells are also used.

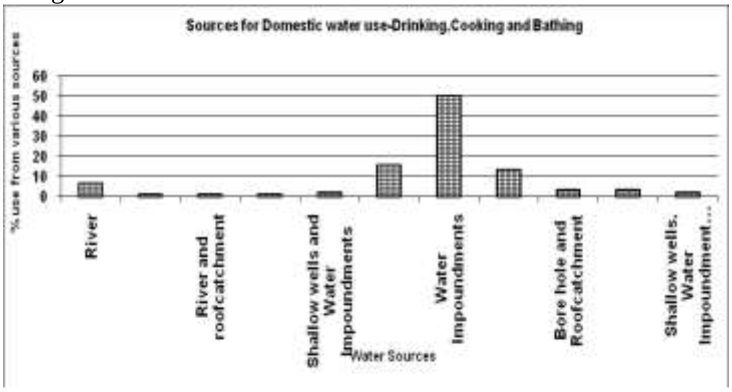

Figure 6: Water sources and usage

The findings from lower Nyakach division revealed that not all water sources used by the residents are permanent sources. Actually, water from shallow wells is the only available source for 78.3% of the respondents throughout the year. The other important sources such as rivers, water impoundments and ponds are highly seasonal as indicated in table 3. The table also rates the availability of stored rain water throughout the year by those able to access storage facilities to be 57%.

Table 3: Availability of water for domestic use by community members throughout the year in lower Nyakach division

Water source	Availability throughout the year (%)		
	Yes	No	Total
Rivers	14.3	85.7	100
Shallow wells	78.3	21.7	100
Water impoundments	36.1	63.9	100
Roof catchments	57	43	100

Further analysis of the findings from lower Nyakach division revealed that some 72.7% of the respondents resort to shallow wells as alternative sources in case their traditional sources dry up, and other water sources such as Lake Victoria (11%), tap water (9.1%), and distant rivers (7.2%). Elsewhere, the findings revealed that different gender groups prefer bathing and washing at varying spots. For instance, some 45% of the female respondents commonly bathe at their homes as opposed to only about 23% of men. However, 10% of males and 12% of women prefer washing and bathing at the water points. Majority of the people sampled 68% prefer to bathe and wash at home while 22% prefer at the water point (Fig. 7).

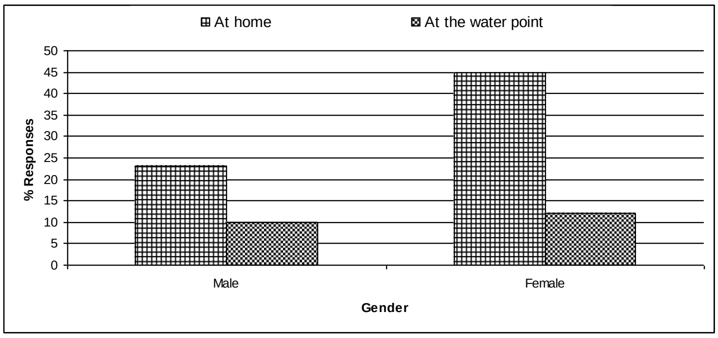

Figure 7: Commonly preferred bathing and washing points.

Health Status

The results showed that 70.5% of the respondents acknowledged that a member of their household had suffered from water related diseases. The prevalence of water related diseases was also found to be higher in central Nyakach, Pap-Onditi and Nyalunya administrative areas than Asao administrative area (Fig. 8).

Table 6 indicates that the majority of residents of central Nyakach (100%), Pap-Onditi (91.1%) and Asao (90%) draw water from unprotected sources such as water impoundments, shallow wells and rivers. Figures 9 and 10 correlates mean counts of Total and faecal coliforms from the sample sites that had been selected for both water impoundments and shallow wells at Harambee in central Nyakach, Bonde in Nyalunya, Urudi in Asao, Pap-Onditi, Kasere and Moro in Pap-Onditi administrative areas respectively.

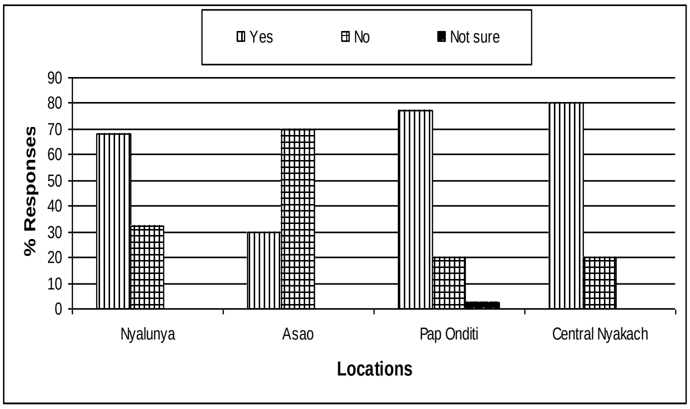

Figure 8: Water disease prevalence by administrative area indicating whether a family member has suffered water related disease

Table 6: Protection of water points

Site	Hygiene status of water point (%)		
	Protected	Unprotected	Total
Nyalunya	58	42	100
Asao	10	90	100
Pap-Onditi	8.9	91.1	100
Central Nyakach	0	100	100

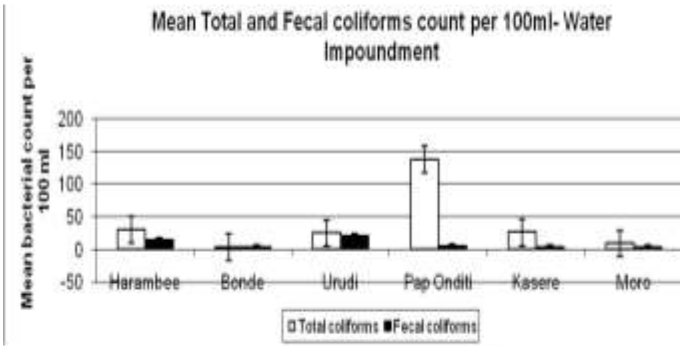

Figure 9: Mean count Total &Faecal coli forms in water impoundment

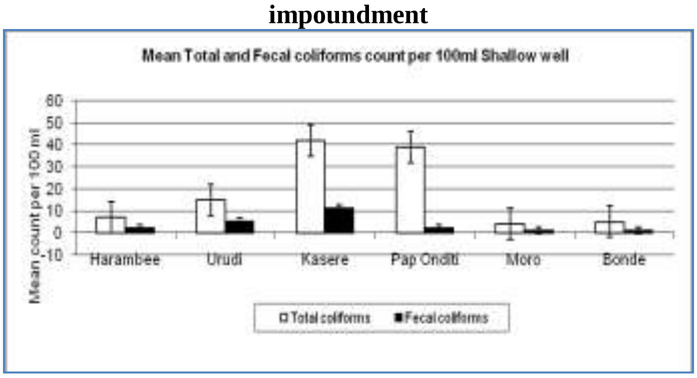

Figure 10: Mean count Total & Faecal coliforms in shallow wells

Faeces disposal in Lower Nyakach division

Pit latrines were found in 83.3% of the 250 homesteads visited although most of them were in very poor condition. The rest (16.7 %) either use their neighbour's latrine or resort to open fields in the bushes. Human waste from the latrines has potential loads of bacteria to contaminate the nearby water sources such as the open ponds which dominate administrative areas in lower Nyakach division. However, the presence of pit latrines varied across the administrative areas (Table 7). For instance, a section of households surveyed lacked pit latrines, Asao (40 %); Nyalunya (16%); Pap-Onditi (13.3 %); and central Nyakach administrative area (10%). It was found that 62.7% of the homesteads surveyed had semi-permanent latrines while those with mud-walled grass thatched roof latrines were about 21.3%. This assessment also revealed that only 2.7% of the latrines had brick walls. A proportion of all the latrines observed (13.3%) had weak semi-permanent (mud) walls and were almost falling down. The study further established through the social survey conducted that several households in lower Nyakach division lack modern toiletry leading to poor sanitation. Many people use poorly constructed and improperly located pit latrines which collapse during heavy rains discharging faecal matter in the nearby water bodies. This leads to frequent outbreaks of water-borne diseases such as cholera and typhoid fever.

Table 7: Availability of pit latrine in a homestead

Administrative area	Whether homestead has a latrine (%)		
	Yes	No	Total
Nyalunya	84	16	100
Asao	60	40	100
Pap-Onditi	86.7	13.3	100
Central Nyakach	90	10	100

Common diseases reported in lower Nyakach

Typhoid fever was the most common water-borne disease mentioned by 49.4 % of the respondents while amoebic dysentery was mentioned by 30.6% and skin rashes by 16.5%. The prevalence of cholera was mentioned by only 3.5% of the respondents (table 8). However, records from Pap-Onditi district hospital which handles 88.1% of the residents showed no observed cases of cholera in the last five years for persons less than five years and above suggesting misdiagnosis by the respondents. Table 8 gives the relative occurrence of some of the water related diseases in most of the sampled households. Annual hospital data over a period of five years showed that amoebic dysentery is the most common infection within the community cutting across all age brackets (Figures 11 and 12). However, hospital data of 2009 indicates typhoid fever as the leading water-borne disease among individuals less than five years (Fig.13 and 14).

When infected with common water-borne diseases, 91.2% seek medical attention in hospitals, while 5.9% and 2.9% buy drugs over the counter and use herbal medicines respectively. Secondary hospital data shows that in the year 2009, children under the age of five years suffered typhoid fever than the last four years (2008-2005). In Pap-Onditi site alone, laboratory water quality test showed high counts of total coliforms both in water impoundments and shallow wells.

Results further revealed that water related diseases are most common during the dry season (98.5% of the respondents). This is because of high contamination rate of the little available water during the dry spell.

Table 8: Disease and Number of times suffered by members in households interviewed in Lower Nyakach division

Diseases	Number of times household members have suffered water-borne diseases (%)			
	Once	Twice	Thrice	Severally
Amoebic dysentery	20	4	27	37.5
Cholera	4	3	6.6	0
Typhoid	54	50	40	50
Skin rushes	24	5.9	26.4	12.5

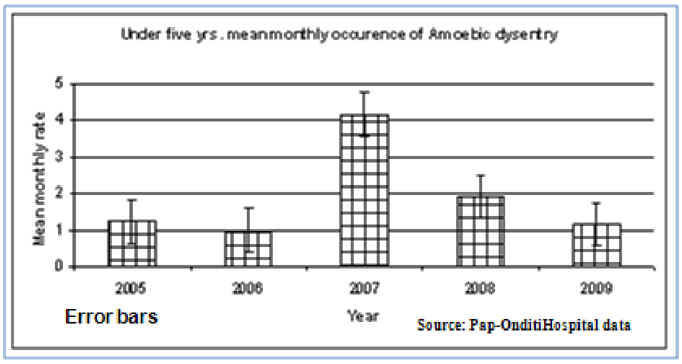

Figure 11: Patients under five years mean monthly occurrence of amoebic dysentery at Pap-Onditi district hospital

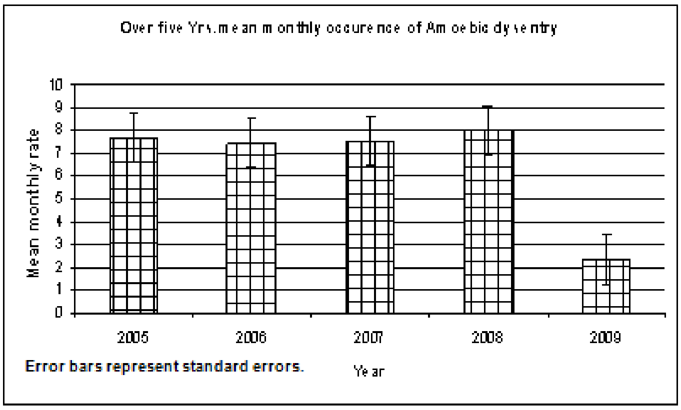

Figure 12: Patients over five years mean monthly occurrence of amoebic dysentery at Pap-Onditi district hospital (source: Pap-Onditi Hospital data).

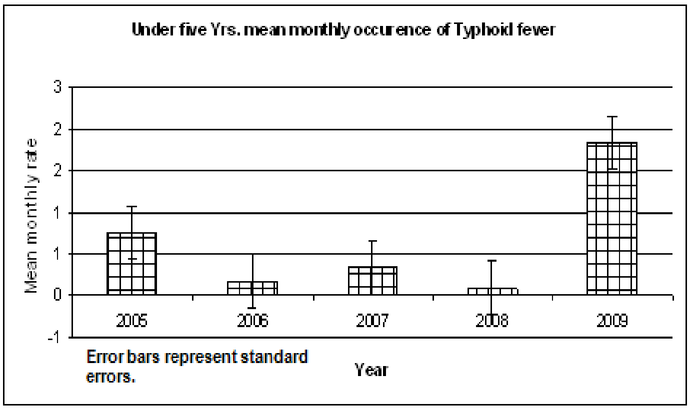

Figure 13: Patients under five years mean monthly occurrence of typhoid fever at Pap-Onditi district hospital (source: Pap-Onditi Hospital data).

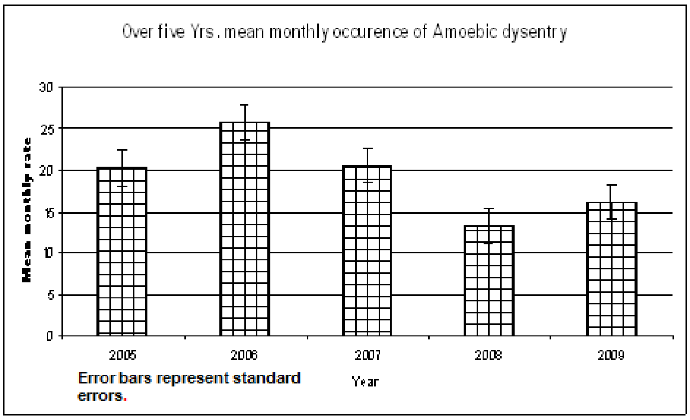

Figure 14: Patients over five years mean monthly occurrence of typhoid fever at Pap-Onditi district hospital (source: Pap-Onditi Hospital data).

Sanitation survey results

All the five water impoundments studied were not fenced leading to contamination by grazing animals. There was also a lot of washing done at the water points which allowed dirty water to drain back into the main water body, especially at Pap-Onditi, Urudi and Harambee sites (pH-8.9). In comparison, shallow wells had drainage systems that carried waste water away from the immediate vicinity into a seepage area downwards. Only four out of the six shallow wells studied were fitted with hand pumps. Due to lack of regular maintenance of the hand pumps, some of them had wall cracks which allowed dirty water back into the wells. Eighty percent of the homes visited had pit latrines although the majority of them were under very poor condition.

Discussions

The main objective of this study was to determine microbiological water contaminants and the associated environmental and human health threats in common community water sources in lower Nyakach division using *Escherichia coli* type I as bio-indicator. The findings of this study concur with those of other studies. Joyce et al.(1996) found that *Escherichia coli* level in water were above the upper detection range for their standard water analysis techniques which was 1800 CFU/100-ml in the Maasail and region of the Kenyan Rift valley. Water samples examined for the presence of indicator microorganisms in this study showed that during the dry season, the mean counts for Total coliforms in the sites sampled were high in rainy than dry seasons. The mean counts for faecal coliforms were slightly lower than that of Total coliforms in both dry and wet seasons.

Obiri-Danso et al. (2008) investigated nine wells and boreholes in Kumasi Ghana and found that microbial indicator organisms were present in all the samples throughout the study irrespective of the time of sampling. In boreholes at Ayeduase, Oduom and Kentinkrono the geometric mean numbers of total coliforms were between 4.19×10^6 and 6.61×10^6 MPN 100- ml^{-1}. Average faecal coliform numbers were 100 times lower compared to total coliforms. Geometric mean (GM) for faecal coliform numbers ranged between 1.75×10^4 and 2.80×10^4 while geometric mean of enterococci was between 10^3 –10^5 times lower. In well water samples, geometric mean numbers of microbial indicators were similar to boreholes. The geometric mean for total coliforms ranged between 3.07×10^6 and 1.68×10^7 MPN 100- ml. The geometric mean for faecal coliforms ranged between 1.50×10^4 and 5.19×10^4 while geometric mean numbers of enterococci in the wells were eight.

Okotto and Ayalew (2009) studied shallow wells in Kisumu, Kenya and Addis Ababa, Ethiopia and reported high counts of microbial indicator organisms. In both cities all the sampled wells showed contamination greater than 200 TTC/100-ml. Kenya applies World Health Organization Standards for its drinking water, where a zero presence of coliforms in a 100-ml sample of drinking water is recommended (WHO 2006). Thus the study concluded that water impoundments and shallow wells in the study area were contaminated with *Escherichia coli* pathogens.

Secondary data from Pap-Onditi district hospital for the period between 2005 and 2009 indicated that 60% of isolates from children less than five years were Enterotoxigenic *Escherichia coli* (ETEC) organisms which are capable of causing diarrhea in children and infants. The bacterial pathogens isolated from these children were mainly *Entamoeba histolytica* and *Salmonella species*. This finding contrasts that of Mutanda (1980) and Mutanda et al. (1988a) who investigated infants with diarrhea at Kenyatta National Hospital in Nairobi, Kenya and found that 40% isolates were from ETEC organisms. Waiyakiet al.(1984) in their study carried out at the Coast General Hospital in Mombasa, Kenya also showed that 3.7% of the total isolates were *Salmonella typhi* species. Gorbach and Khurana (1972) in Chicago reported that as high as 80% of the hospitalized children with diarrhea were infected with ETEC organisms. Among the Apache children hospitalized with diarrhea and studied by Sack et al. (1975) an ETEC rate of 18% was reported. Similarly, a study by Joyce et al. (1996) on the Maasai community showed that 23% of the isolates were *Entamoeba histolytica* and 13% *Salmonella typhi* species. Enterotoxigenic *Escherichia coli* are among the many enteric species of bacteria which are capable of producing toxic and pathogenic substances that are bactericidal to human and their presence in water or food is a bio-indicator of pollution or contamination by faecal matter.

Annual hospital data from Pap-Onditi district hospital over a period of five years showed that amoebic dysentery is the most common infection within the community cutting across all age brackets. However, hospital data of 2009 indicates typhoid fever as the leading water borne disease among individuals under five years of age (Figure 12). Analysis from the questionnaires established thattyphoid fever was the most common water-borne disease mentioned by 49.4 % of the respondents, followed by amoebic dysentery 30.6% and skin rashes 16.5% (Table 8).The study concluded that the common water-borne diseases affecting the majority of residents in lower Nyakach division are typhoid fever and amoebic dysentery.

Through the household survey conducted, it was found that 16% of the respondents in Nyalunya, 40% in Asao, 13.3% in Pap-Onditi and 10% in Central Nyakach lacked pit latrines leading to poor sanitation. Studies done by Niemeijer and Frank (1988) in the Kano plains neighbouring Nyando district showed that 45% of the total homes surveyed lacked pit latrines. Through observations made during the social survey, the study established that many people use poorly constructed pit latrines which collapse during heavy rains. This leads to faecal matter being discharged in the water bodies resulting to frequent outbreaks of water-borne diseases. Rheinheimer (1992) while studying aquatic microorganisms showed that the discharge of wastewater to surface waters used for drinking, bathing, recreation or food processing poses a risk of enteric illness to the users. Poor water quality has profound and linked health and socio-economic effects since ingestion of water contaminated by pathogens and toxic chemicals leads to the spread of water-borne diseases.

It was established that about 40% of the respondents do not treat their water before use. In comparison, studies by Niemeijer and Frank (1988) in the Kano plains showed that most residents use water from rivers or sometimes water from stagnant sources (water impoundments) for drinking purposes without boiling and as a consequence, high rate of diarrhea have been observed. They further reported that high incidence of childhood diseases among one year olds and a large proportion of the reported gastro-intestinal complaints are as a result of diarrhea due to bacterial contamination. Chapman (1992) indicated that faecal matter might contain a variety of intestinal pathogenic microorganisms that cause diseases ranging from mild gastro-enteritis to serious and possibly fatal diarrhea, dysentery, cholera and typhoid fever.

Conclusions

The study established that due to lack of effective management mechanisms and proper appreciation of their true worth, community water sources continue to be degraded unabated through unsustainable human activities by conversion and overexploitation. Pressure on these water sources have been aggravated by human settlement and population increase. It was found that the main problem for lack of proper planning and management of community water sources is lack of sufficient research and reliable data.

Protection of water sources from contamination will help reduce the spread of water-borne diseases in the study area. In most administrative areas, water impoundments and shallow wells which are the major sources for domestic water are not protected. This poses health risk to the majority of the residents who use the water raw without any form of treatment.

Recommendations

Water quality laboratories should be established two in every division for water analysis to regularly test water from designated water points and ensure safe water for basic human needs.

We should strengthen community participation in water quality monitoring by establishing local water management committees. Shallow wells should be properly protected by providing them with hand pumps and locating them (30 m) away from any contamination sources, such as pit latrines and open waste dump sites to prevent contaminated water infiltration.

We should empower and educate the public on the importance of water quality. Education of the public on personal hygiene should be enhanced and the need for water treatment to reduce the level of transmission of pathogenic microbes to humans should be stepped up to create commitment and positive attitudes towards the conservation and sustainable utilization of the water sources.

Finally, we should establish continuous local community water quality monitoring program. Full inventory of the local community water sources and demand driven research and monitoring should be carried out annually to improve scientific information and knowledge base to determine their administrative area, type, status, values and threats. This will promote innovative planning and integrated approach towards the conservation and management of the local community water sources in Kenya.

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