Editorial Manager(tm) for Journal of Urban Health
Manuscript Draft

Manuscript Number: JURH36R1

Title: Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum

Article Type: Original Research

Keywords: Water; water quality, Sanitation; sanitary practices, coliforms; contamination, slums; urban poor; poverty; urbanization; Africa, Kenya

Corresponding Author: Ms Elizabeth Wambui Kimani-Murage, MPH

Corresponding Author's Institution: African population and Health Research Center

First Author: Elizabeth W Kimani-Murage, MPH, BSc.

Order of Authors: Elizabeth W Kimani-Murage, MPH, BSc.; Augustine M Ngindu, MSc., MBCHB

Abstract: Due to rapid urbanization in a context of economic constraints, majority of urban residents in sub-Saharan Africa live in slums often characterized by lack of basic services such as water and sewerage. Consequently, the urban poor often resort to using the inexpensive pit latrines and at the same time may use wells for domestic water. Overcrowding in slums limits adequate distance between wells and pit latrines thus likely seepage of micro-organisms from faecal content from latrines to water sources. Sanitary practices in these overcrowded slums are also poor, leading to contamination of these wells. This study sought to assess sanitary practices of residents of a Kenyan urban slum and faecal contamination of their domestic water sources. This cross-sectional study involved 192 respondents from Langas slum, Kenya. Forty water samples were collected from the water sources used by the respondents for laboratory analysis of faecal contamination. Of these 40 samples, 31 were from shallow wells, 4 from deep wells and 5 from taps. Multiple tube fermentation technique was used to enumerate coliform bacteria in water. Descriptive techniques were used in data analysis. The study found that most people (91%) in the Langas slum used wells as the main source of domestic water while the rest used tap water. While most people used pit latrines for excreta disposal, a substantial percentage (30%) of children excreted in the open field. The estimated distance between the pit latrines and the wells was generally short with about 40% of the pit latrines being less than 15 metres from the wells. The main domestic water sources were found to be highly

contaminated with faecal matter. Total coliforms were found in 100% of water samples from shallow wells while 97% of these samples from shallow wells were positive for thermotolerant coliforms. Three out of the four samples from deep wells were positive for total coliforms while two of the samples were positive for thermotolerant coliforms. None of the samples from taps were positive for either total or thermotolerant coliforms. Since presence of thermotolerant coliforms in water indicates faecal contamination, owing to the short distance estimated between the wells and pit latrines, the study suggests that the pit latrines were a major source of contamination of the wells with faecal matter by seepage of micro-organisms from the faecal matter through the soil. However, contamination through surface runoff during rains is also plausible as indiscriminate excreta disposal particularly by children was also common. Owing to the faecal contamination, there is high possibility of presence of disease pathogens in the water, hence the water from the wells in Langas may not be suitable for human consumption. To address this problem, treatment of the water at community or household level and intensive behaviour change communication on sanitary practices are recommended. Efforts should be made to provide regulated tap water to this community and to other slums in sub-Saharan Africa where tap water is not accessible. However, more sampling of different water sources is recommended.

Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum[a]

Elizabeth Wambui Kimani-Murage (MPH, BSc) [1] and Augustine M. Ngindu (MSc, MBCHB)[2]

1. African Population and Health Research Center, P.O. Box 10787, Nairobi Kenya, email:

ekimani@aphrc.org

2. Moi University, Eldoret Kenya, P.O. Box 4606, Eldoret Kenya, email: ngindua@KE.AFRO.WHO.INT.

Corresponding author

Elizabeth Wambui Kimani-Murage (MPH, BSc)

African Population and Health Research Center,

P.O. Box 10787, 00100-GPO,

NAIROBI KENYA.

Tel: +254-20-2720400/1/2

Cellphone: +254-722-807268

Fax: +254-20-2720380

E-Mail: ekimani@aphrc.org and lizmurage_2003@yahoo.com

[a] This project was funded by African Population & Health Research Center, the African Medical and Research Foundation (AMREF) and Moi University, Kenya.

ABSTRACT

Due to rapid urbanization in a context of economic constraints, majority of urban residents in sub-Saharan Africa live in slums often characterized by lack of basic services such as water and sewerage. Consequently, the urban poor often resort to using the inexpensive pit latrines and at the same time may use wells for domestic water. Overcrowding in slums limits adequate distance between wells and pit latrines thus likely seepage of micro-organisms from faecal content from latrines to water sources. Sanitary practices in these overcrowded slums are also poor, leading to contamination of these wells. This study sought to assess sanitary practices of residents of a Kenyan urban slum and faecal contamination of their domestic water sources. This cross-sectional study involved 192 respondents from Langas slum, Kenya. Forty water samples were collected from the water sources used by the respondents for laboratory analysis of faecal contamination. Of these 40 samples, 31 were from shallow wells, 4 from deep wells and 5 from taps. Multiple tube fermentation technique was used to enumerate coliform bacteria in water. Descriptive techniques were used in data analysis. The study found that most people (91%) in the Langas slum used wells as the main source of domestic water while the rest used tap water. While most people used pit latrines for excreta disposal, a substantial percentage (30%) of children excreted in the open field. The estimated distance between the pit latrines and the wells was generally short with about 40% of the pit latrines being less than 15 metres from the wells. The main domestic water sources were found to be highly contaminated with faecal matter. Total coliforms were found in 100% of water samples from shallow wells while 97% of these samples from shallow wells were positive for thermotolerant coliforms. Three out of the four samples from deep wells were positive for total coliforms while two of the samples were positive for thermotolerant coliforms. None of the samples from taps were positive for either total or thermotolerant coliforms. Since presence of thermotolerant coliforms in water indicates faecal contamination, owing to the short distance estimated between the wells and pit latrines, the study suggests that the pit latrines were a major source of contamination of the wells with faecal matter by

seepage of micro-organisms from the faecal matter through the soil. However, contamination through surface runoff during rains is also plausible as indiscriminate excreta disposal particularly by children was also common. Owing to the faecal contamination, there is high possibility of presence of disease pathogens in the water, hence the water from the wells in Langas may not be suitable for human consumption. To address this problem, treatment of the water at community or household level and intensive behaviour change communication on sanitary practices are recommended. Efforts should be made to provide regulated tap water to this community and to other slums in sub-Saharan Africa where tap water is not accessible. However, more sampling of different water sources is recommended.

Key Words: Water; water quality, Sanitation; sanitary practices, coliforms; contamination, slums; urban poor; poverty; urbanization; Africa, Kenya.

INTRODUCTION

Rapid urban growth in a climate of economic constraints has resulted in the majority of residents in Africa's large cities, and an increasing proportion of Africans overall, living in overcrowded slums and shantytowns. In these slums and shantytowns, health conditions and livelihood opportunities are poor[1-3]. Available evidence indicates that the poor urban residents of Africa exhibit higher morbidity, have poor access to health services, and consequently exhibit higher mortality rates than residents of other areas including rural residents[4-8].

The situation in Kenya is similar to other situations in Africa. The proportion of urban versus rural population in Kenya almost doubled between 1980 and 1998, increasing from 16 to 31%[9]. Rapid urbanization amidst economic degradation in Kenya has resulted in increased proportion of people living in absolute poverty in the urban areas[10]. Therefore, poverty has increasingly become a crucial urban

problem in Kenya leading to mushrooming of informal settlements in the urban parts of Kenya where the urban poor find shelter. This has overwhelmed the environmental health resources in the urban areas. Because of their illegal status, residents of informal settlements in Kenya do not receive government services such as water, drainage, sewerage and rubbish collection. Consequently, informal settlements are characterised by poor environmental conditions that predispose their inhabitants to poor health outcomes[4]. Evidence shows that children of poor families in urban areas of Kenya exhibit poorer health conditions than their rural counterparts. According to a report by African Population and Health Research Center (APHRC) in 2002[4], infant and child mortality risks are particularly higher in the slums of Nairobi than those observed in other urban areas and in rural Kenya. For instance, the under five mortality was 35 percent higher among slum residents in Nairobi city than among the rural population in Kenya. The report attributes these patterns to poor water and environmental sanitation in these slum settlements[4].

An adequate supply of safe drinking water is universally recognized as a basic human need. Yet millions of people in the developing world do not have ready access to an adequate and safe water supply. By 1996, the number of people without access to safe water in urban areas was rising sharply in developing countries due to rapid urbanization, much of which was occurring in peri-urban and slum areas[11]. With the United Nations projections of a rapid population growth in the urban areas between 2000 and 2030[12], the situation of access to safe drinking water and adequate sanitation in urban areas is likely to worsen unless there is a drastic policy change to cater for the needs of the urban poor.

Human excreta and the lack of adequate personal and domestic hygiene have been implicated in the spread of many infectious disease including cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis and schistosomiasis. It is estimated that one third of deaths in developing countries are caused by the consumption of contaminated water and on average as much as one tenth of each person's

productive time is sacrificed to water-related diseases[13]. The World Health Organization estimates that 2.2 million people die annually from diarrhoeal diseases and that 10% of the population of the developing world are severely infected with intestinal worms related to improper waste and excreta management[14-15]. In Kenya, diarrhoeal diseases are among the major illnesses affecting children of the slum residents. According to the report by APHRC in 2002, prevalence of diarrhoea was 32% among children below five years of age in the slums, which is double the rate for Nairobi and national average[4].

Where ground water is used as a source of domestic water, use of pit latrines is not recommended because the two are incompatible unless the water table is extremely low and soil characteristics are not likely to contribute to contamination of ground water. Where they co-exist, though it is difficult to give a general rule for all soil conditions, the commonly used guideline is that the well should be located in an area higher than and at least 15 metres from the pit latrines and should be at least 2 metres well above the water table. Available evidence shows that increased lateral separation between the source of pollution and groundwater supply reduces the risk of faecal pollution[16]. Co-existence of on-site sanitation and use of underground water has in the past been mainly confined to the rural areas where there is adequate land to allow for adequate distance between pit latrines and shallow wells. With the rapid urbanization and rapid expansion of slum settlements in sub-Saharan Africa, on-site sanitation together with use of underground water find their way in the some urban areas because they are affordable options in the absence of government supplied services. However, the congestion in the urban slums may not allow for adequate distance between the wells and the pit latrines and this may result in seepage of micro-organisms from faecal contents into the underground water sources. Furthermore, sanitary practices for example disposal of human excreta in these slum areas is poor leading to contamination of water and consequently water-borne diseases. It is in this context and in the context of high levels of diarrhoeal

diseases in the urban slums in Kenya that this study sought to assess the sanitary practices in an urban slum in Eldoret, Kenya and faecal contamination of domestic water sources.

STUDY CONTEXT

The study was conducted between January and June 1999 in Langas, an urban slum in Eldoret municipality, Kenya, less than 10 kilometres from Eldoret town. Eldoret town is located in the Rift Valley Province, about 330 Kilometres North West of Nairobi. Eldoret, the headquarter of Uasin Gishu District is one of the fastest growing urban areas in Kenya. Langas falls under high density, low-income areas of the Eldoret municipality. It is divided into 4 administrative blocks that are further subdivided into about 2,500 plots. Each plot (1/8 of an acre) has between 1 and 30 households each with an average of 6 occupants. Settlement in Langas began in 1965 and at the time there were no basic services. Early settlers dug shallow wells for their water needs[17]. Ground water table is high and this raises the possibility of ground water contamination where on-site sanitation systems are in use.

METHODOLOGY

A cross-sectional study design was used and a sample of 192 households[b] was selected through multi-stage sampling technique as follows: two out of the four administrative blocks were randomly picked and from the two blocks, 192 plots were picked. From each of the selected plots, one household was selected to participate. The 192 households were selected as follows: starting from one corner of each of the blocks and walking across the two blocks in a more or less a diagonal line, about every plot on the diagonal line was selected until the sample of 192 was reached. From each of these plots, one household was selected to represent the plot (this depended mainly on availability of respondents and willingness to participate and the first household to be contacted in a selected plot was considered for recruitment into the sample.

[b] Initially the plan was to interview respondents from 384 households (calculated through a method for calculating a simple random sample). However, financial and logistic feasibility could not allow for the whole sample to be interviewed and given the nature of the slum as far as the main variables of interest (domestic water sources and toilet facilities) were concerned i.e. many people shared one source of water and one toilet facility, the sample size of 192 (half of the sample initially calculated) was considered adequate.

From the household, a credible respondent was interviewed. A credible respondent was a resident of the selected household who was aged 18 years and above.

For water sampling, 20 samples were taken from water points in each of the two blocks to make a total of 40 samples. This number for water samples was mainly informed by financial and logistical feasibility. In most circumstances, residents of a plot shared one water source and roughly there was one water point per plot. In a few cases, several plots shared a water point. To get the 40 samples, every 4th household[c] of the 192 households included in the interview sample was asked their source of water and a water sample was taken from this source so long as no other sample had been taken from the source. In the event that a previous 4th household shared the source with the current household, the source for the immediate next household in the study sample was considered. Of the 40 water samples, 31 were from shallow wells (defined as a hand-dug well), 4 from deep wells (defined as a drilled well) and 5 from taps (referring to tap water from the municipal council distribution system). Using the above described criteria, only one deep well was selected and purposive sampling was then used to get 3 other such wells, consequently including all the deep wells that were used by the study sample.

Questionnaires were administered to the 192 selected households to obtain information on the type of toilet facility used, major source of domestic water, method of human waste disposal, whether drinking water was boiled and perceptions on possible sources of water contamination in the area. For the method of excreta disposal and water source, the main method and source were considered in instances where there was more than one method or source respectively. The distance between the pit latrines used by the 192 households and the wells (in cases where they used wells) was estimated. Observation on environmental sanitation was also done.

[c] The 4th household from which to take a water sample was determined as the households for interviews were recruited.

Collection of water samples was done aseptically through use of sterile sampling bottles. The samples were transported within two hours of collection in a cool box containing ice packs to the Faculty of Health Sciences, Moi University microbiology laboratory for analysis. Faecal contamination of the water was determined through isolation of indicator organisms; first total coliforms and then thermo-tolerant (faecal) coliforms through Multiple-Tube Fermentation (MTF) technique. Probability tables (Mc Crady tables) were used to determine the Most Probable Number (MPN) estimates of the coliform organisms per 100mls of water. Analysis of data was generally descriptive mainly involving determination of frequencies. Stata statistical package was used to analyse the data.

RESULTS

Method of Excreta Disposal

Majority of respondents (98%) said that adults used pit latrines while the rest said adults defecated indiscriminately. Similarly, majority of respondents (70%) said that children used pit latrines while 30% said children used open field/defecated indiscriminately. Most of the pit latrines (95%) in the community were traditional while the rest were ventilated improved pit latrines (VIP latrines). A walk through the community confirmed the report that some people excreted indiscriminately as human excreta was observed strewn all over the compounds.

Source of Domestic water

Most people (89%) said they used shallow wells as the major source of domestic water while 2% said they used water from deep wells and the rest said they used tap waster from the municipal council (Table 1). The shallow wells often had no concrete slab and often the aperture was not covered at all or was poorly covered with a loose lid that was not lockable while the deep wells had a piped system. Those who used

deep wells were mainly the more affluent people in the community who often owned the plot in which the well was situated. Tap water was mainly from water kiosks where water was being sold to the slum residents. Respondents who did not use the tap water said that the water from water kiosks was expensive and unaffordable to be used for domestic purposes[d]. Other factors that were mentioned as hindering use of tap water from the kiosks included problems of unreliability, that is, some respondents said that sometimes the kiosk near their house could stay for a whole day or more without being opened. Some of the respondents reported that the nearest water kiosk was too far from their homes.

<<Table 1 here>>

Distance between Pit Latrine and Well

The wells were very close to the pit latrines. In many circumstances (38%), the distance between the wells and the pit latrines was estimated to be less than 15 metres (the commonly used guideline is that the distance should be at least 15 metres). Most wells (about 59%) were estimated to be at a distance between 15 and 30 metres from the pit latrines (Table 2). The distance between pit latrines and wells for the wells from which water samples were taken was similar to that of other wells (Table 3)

<<Table 2 and 3 here>>

Boiling of Drinking Water

Despite the short distance estimated between the pit latrines and the wells and the poor sanitary practices like indiscriminate excreta disposal, when asked if they boiled drinking water, only 42% of those who reported using wells said they did.

[d] Water sold at water kiosks cost more than 5 times what residents in the formal urban areas in Eldoret, who had water meters paid to the municipal council for water.

Residents Perception of Contamination

Respondents pointed out various possible sources of contamination of the water sources in the area. These included children dipping dirty objects into water source (34%) as the main source of contamination, drawing water from the source with dirty containers (27%), domestic animals defecating around water sources (19%) and people washing clothes (5%) at the water source among others. Interestingly, no one mentioned closeness of the well to the pit latrines as a possible source of contamination.

Water Analysis Results

Forty water samples were analysed; 31 from shallow wells, 4 from deep wells and 5 from taps.

Wells

Shallow Wells

All the samples (31) taken from shallow wells were positive for total coliforms. The most probable number of total coliforms for most of the samples (71%) was 1100+ per 100ml. The minimum number of total coliforms was 63 while the maximum was 1100+ coliforms per 100ml water.

Only one of the samples had no thermotolerant coliforms at all while most had 1100+ thermotolerant coliforms per 100ml.

Deep (drilled) wells

Of the four samples taken from the deep wells, three were positive for total coliforms while one was negative. The highest number of total coliforms was 240. For thermotolerant coliforms, two samples were negative. The maximum number of thermotolerant coliforms was 23.

Taps

For the 5 samples taken from taps (municipal tap water), all of them were negative for total coliforms and consequently thermotolerant coliforms.

DISCUSSION

This paper provides evidence on the extent of contamination of main domestic water sources in Langas slum and suggests the most probable sources of this contamination. The evidence points to the fact that the suggested most probable sources of contamination are hardly mentioned among the many sources perceived to contaminate the water sources by the residents of the slum, which has implications on how interventions ought to be thought of.

The results indicate that majority of the community members used pit latrines and at the same time used wells as the major source of domestic water. The conditions found in Langas do not fulfil the recommendations given for co-existence of onsite sanitation and use of ground water for domestic purposes which indicate that there should be adequate lateral separation between the pit latrine and the well to reduce chances of faecal contamination of the ground water[16]. The distance between the wells and the pit latrines was estimated to be generally short with about 40% pit latrines estimated to be at a distance less than 15 metres from the wells. This raises a high risk of contamination of the water sources through seepage of disease causing micro-organisms through the soil from the pit latrines to the wells.

Presence of indicator organisms (*Escherichia coli* or thermotolerant coliform bacteria) in water indicates recent contamination of the water source with faecal matter and hence possible presence of intestinal pathogens. According to World Health Organization (WHO) guidelines, Escherichia coli or thermotolerant coliform bacteria should not be detectable in any water intended for drinking[18]. The laboratory analysis results of water samples in this study show that faecal matter heavily contaminated the water sources and especially the shallow wells. None of the shallow wells met the WHO requirements for water intended for drinking. The presence of indicator organisms in the water samples collected from the wells indicates likelihood of seepage of organisms from faecal matter in the pit latrines through the

soil to the water sources exacerbated by there being a very short distance between the pit latrines and the wells. Poor sanitary practices are also likely sources of pollution of the water sources. Sanitary practices were found to be generally poor from observation and from responses from the respondents. Thirty percent of children excreted indiscriminately and consequently there were a lot of indiscriminately disposed excreta observed. Rains are likely to wash off indiscriminately disposed excreta into shallow wells particularly so if the wells are not protected. Therefore, this may have also contributed to the contamination of the generally open shallow wells with faecal matter. Other studies have also attributed contamination of water sources to wet seasons[19]. Despite the contamination of water, it was evident that it was not a common practice for the slum dwellers to boil the water as only 42% of those who used water from wells said the boiled drinking water.

The illegal status of the slum areas in Kenya has hindered the expansion of municipal services to serve them. This has resulted to the poor being denied access to safer drinking water and proper sanitation. The results of this study suggest that water from the tap (which was from the municipal council) was safe for human consumption according to WHO guidelines[18]. However, it is important to note that though presence of thermotolerant coliforms indicates the presence of faecal contamination and potential presence of pathogens, absence of the same does not necessarily mean absence of pathogens and further investigations would be worthwhile.

Langas is not the only area with the problem of safe drinking water; other urban centres of the developing world have experienced similar problems[19-22]. Similar to Langas, in the slums of Nairobi, Kenya, though wells are not a common source of water, slum residents are forced to buy tap water at exorbitant prices from vendors who operate without regulatory mechanisms[23–24]. If the Millennium Development Goals; to reduce by half the proportion of people without sustainable access to safe

drinking water by 2015 and to achieve a significant improvement in lives of at least 100 million slum dwellers, by 2020[25] are to be met, there is a dire need for reconsideration of the slum areas in the developing world as far as water supply is concerned as these slums are home to about 70% of all urban residents in sub-Saharan Africa[26].

However improving the water quality at source alone may not be the ultimate solution because improving water quality at source may not always ensure a reduction in the transmission of water related diseases. Studies[27-30] have shown significant deterioration in water quality between the source and the point of use. Esrey concluded that improving water had no health impact if the sanitation was not improved and that improving both water and sanitation together were synergistic in producing larger impacts than either alone[31]. Though the results of this study suggest need for provision of safer water sources, In this community and in many other slum communities with evident poor sanitary practices, intensive behaviour change communication on sanitary practices is also paramount as this has been found effective in reduction of water-borne diseases elsewhere[32-35].

While the findings from this study are worthwhile and act as an eye opener for the situation of quality of water in the rapidly growing informal settlements in the urban areas in Kenya and in the rest of Africa, more sampling of different water sources is highly recommended.

CONCLUSION

It is evident that most of the sources of domestic water in Langas slum is polluted with coliforms and does not meet the WHO guidelines for drinking water quality. This poses a health hazard to the residents of the slum as they are at risk of water borne diseases. The results of this study also suggest that tap water may be safer, but additional sampling is needed. The ideal intervention in the long-run may therefore be provision of adequate piped water to all slum dwellers. However, this may take sometime and simpler

interventions could be put in place in the mean time. Basic sanitary improvement may be worthwhile at the moment. Covering the shallow wells and possibly installing hand-pumps or mechanical pumps at the wells could improve the situation. Basic treatment of the water at community or household level for instance by chemical disinfection using chlorine, filtration for example using simple household filters and boiling should also be promoted. These interventions may have a great impact on the health of the slum dwellers as access to safe drinking water and basic sanitation services for populations at risk would result in 200 million/year fewer diarrhoeal episodes and 2.1 million/year fewer deaths caused by diarrhoea[35].

COMPETING INTERESTS

There are no competing interests.

AUTHORS' CONTRIBUTIONS

EWK-M conceived and designed the study, collected and analysed the data, developed the manuscript and gave final approval for publishing.

AN participated in the design of the study, supervised laboratory water analysis and the whole research process, revised the manuscript and gave final approval for publishing.

ACKNOWLEDGEMENTS

Data collection was funded by African Medical and Research Foundation (AMREF) Kenya, Water and Sanitation (WATSAN) project Eldoret. Analysis of water samples and partial analysis of data was funded by Moi University. Further data analysis and preparation of this manuscript was funded by African Population and Health Research Centre (APHRC). We specifically acknowledge Mr. Araka, Mr. Nkonge and Mr. Obala of Moi University, Dr. Eliya Zulu, Dr. Nyovani Madise, Dr. Fredrick Mugisha and Dr. Jean Christopher Fotso of APHRC, for technical assistance.

REFERENCES

1. Lamba D. The forgotten half; environmental health in Nairobi's poverty areas. *Environment and Urbanization.* 6 (1). April:164-168.
2. Todaro M. Urbanization and rural-urban migration: Theory and policy. *In Economic development in the third world.* New York: Longman; 1989:263-289.
3. United Nations Center for Human Settlement (UN-HABITAT). An Urbanizing World: Global report on human settlements. Oxford University Press; 1996
4. African Population and Health Research Center (APHRC). Population and Health Dynamics in Nairobi Informal Settlements. Nairobi: African Population and Health Research Center; 2002
5. Brockerhoff M, and Brennan E. The poverty of cities in developing countries. *Population and Development Review* 1998, 24(1): 75-114.
6. Magadi MA, Zulu EM, Brockerhoff M. The inequality of maternal health care in urban sub-Saharan Africa in the 1990s. *Population Studies* 2003, 57(3): 347-366.
7. Taffa N. A comparison of pregnancy and child health outcomes between teenage and adult mothers in the slums of Nairobi, Kenya. *International Journal of Adolescent Medical Health* 2003, 15 (4): 321-329.
8. UNICEF. Poverty and exclusion among urban children. Innocent Digest No. 10, UNICEF Innocent Research Centre. 2002. [www.unicef-isdc.org]
9. World Bank. World development report 1999/2000. London: Oxford University; 1999.
10. Central Bureau of Statistics (CBS) Kenya. Economic survey 2000. Nairobi: Government Printers; 2000.
11. WHO/UNICEF/WSSCC. *Water* supply and sanitation sector monitoring report 1996 (sector status as of 31 December 1994). WHO/EOS/96.15. Geneva: WHO; 1996.

12. United Nations Population Division. World Urbanization Prospects: the 1999 Revision. New York: United Nations; 2000.
13. World Health Organization. Guidelines for Drinking Water Quality Second edition Vol. 3. Geneva: WHO; 1997.
14. Murray CJL, Lopez, A.D (eds). The Global Burden of Disease, Vol. II, Global Health Statistics: A compendium of incidence, prevalence and mortality estimates for over 200 conditions. Harvard School of Public Health on behalf of the World Health Organization and The World Bank, Cambridge, MA; 1996.
15. WHO/UNICEF. Global Water Supply and Sanitation Assessment. Geneva: World Health Organization; 2000.
16. ARGOSS. Guidelines for assessing the risk to groundwater from on-site sanitation. Kampala Workshop proceedings, 2001.
17. Rose Musyoka. Informal Land Delivery Processes in African Cities. Working Paper 4, 2004. URL:http://www.idd.bham.ac.uk/research/Projects/informal_land/working%20paper%204.pdf. Accessed in March 2007.
18. World Health Organization. Guidelines for Drinking Water Quality Second edition Vol. 2. Geneva: WHO; 1996.
19. Hebert J.R. On-site water contamination in an urban slum. *Water International*, 1983, 8 3, Pages 127-132.
20. Joshi S.D., Musaddiq M. Studies on distribution of E. coli and Salmonella in drinking water - A six month's survey report. *Pollution Research*, 2003, 22 1, Pages 121-124.
21. Newman R.D., Wuhib T., Lima A.A.M., Guerrant R.L., Sears C.L. Environmental sources of Cryptosporidium in an urban slum in north-eastern Brazil. American *Journal of Tropical Medicine and Hygiene*, 1993, 49 2, Pages 270-275.

22. Molbak K., Hojlyng N., Jepsen S., Gaarslev K. Bacterial contamination of stored water and stored food: A potential source of diarrhoeal disease in West Africa. *Epidemiology and Infection*, 1989, 102 2, Pages 309-316.

23. African Population and Health Research Center (APHRC): Health and Livelihood Needs of Residents of Informal Settlements on Nairobi City. Nairobi: African Population and Health Research Center; 2002, Occasional Study Report No.1.

24. Kimani E.W, Zulu E.M. and Undie C. Health and Livelihood Implications of Marginalization of Slum Dwellers in Provision of Water and Sanitation Services in Nairobi City. Poster presentation at the 4th international conference on urban health, 26th to 28th October, 2005 in Toronto, Canada.

25. UN Millenium Development Goals URL: http://www.un.org/millenniumgoals Accessed in October 2006

26. UN-Habitat. Slums of the World. The Face of Urban Poverty in the New Millenium? Global Urban Observatory. Nairobi: UN-Habitat; 2003.

27. Genthe B, Strauss N, Seager J, Vundule C, Maforah F, Kfir R. The Effect of Type of Water Supply on Water Quality in a developing Community in South Africa. *Wat. Sci. Tech*. 1997, 35(11): 35 – 40.

28. Lindskog P Lindskog U. Bacterial contamination of water in rural areas. An intervention study from Malawi. *J Trop Med* 1988, 91: 1-7.

29. Mertens TE, Fernando MA, Marshall TF, Kirkwood BR, Cairncross S, Radalowicz A. Determinants of water quality, availability and use in Kurunegala, Sri Lanka. *Tropical Med Parasitology* 1990, 41: 89--97.

30. Verweij PE, van Egmond M, Bac DJ, van der Schroeff JG, Mouton RP. Hygiene, skin infections and type of water supply in Venda, South Africa. *Trans. R. Soc. Trop Med and Hyg* 1991, 85: 681-684.

31. Esrey SA. Water, waste, and well-being: a multi-country study. *American Journal of Epidemiology* 1996, 143(6): 608-23.

32. Ahmed, N.U., Zeitlin, M.F., Beiser, A.S., Super, C.M. and et al. Community-based trial and ethnographic techniques for the development of hygiene intervention in rural Bangladesh. *International Quarterly of Community Health Education*, 1991 12, 183-202. Ref ID: 3679

33. Alam, N., Wojtyniak, B., Henry, F.J., and Rahaman, M.M. Mothers' personal and domestic hygiene and diarrhoea incidence in young children in rural Bangladesh. *International Journal of Epidemiology*, 1989, 18(1):242-247. Ref ID : 2686

34. Esrey SA, Feachem RG, Hughes JM. Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities. *Bull World Health Organ* 1985; 63(4):757-772.

35. Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization* 1991, 69 (5): 609-621.

Table 1: Source of domestic water among 192 sampled households in Langas Slum, Kenya

Source of domestic water	Frequency	%
Tap	17	8.9
Shallow Well	171	89.1
Deep Well	4	2.1
Total	192	100

Table 2: Distance between pit latrine and wells for all wells in the study in Langas Slum, Kenya

Distance	Frequency	%
1-15 metres	67	38.3
15-30 metres	103	58.9
30 metres and above	5	2.9
Total	175*	100

* This total reflects only wells, thus excludes taps.

Table 3: Distance between pit latrine and well for wells whose water was sampled in Langas Slum, Kenya

Distance	Frequency	%
1-15 metres	14	40
15-30 metres	19	54
30 metres and above	2	6
Total	35*	100

* This total reflects only wells whose water was sampled, thus excludes taps.

David Vlahov, PhD
Editor-in-Chief
Journal of Urban Health

Dear Sir,

Responses to the Reviewers' Comments

Thank you very much for having our manuscript revised. We are very grateful for the great comments from the reviewers. We generally agree with the reviewers comments and have addressed all the comments raised.

Kindly find below a report of the responses to the specific reviewers comments.

Kind regards,

Elizabeth Kimani-Murage

COMMENTS FOR THE AUTHOR AND RESPONSES TO THE REVIEWRS

Reviewer #1

Comment
Abstract:
This study's most significant finding relates to 100% of shallow wells being contaminated with coliforms. This should be more clearly stated in the abstract.

Response
Thanks for noting this; this would have been an important oversight. We have revised the abstract to bring the issue of shallow wells being 100% contaminated more clearly as suggested.

Comment
Methods (page 5):
Please identify where in Kenya Eldoret is. How far is this from Nairobi?

Response
We appreciate this suggestion. We may have assumed that people would place the study site by just mentioning Eldoret. We have described it a bit more clearly particularly in relation to Nairobi.

Comment
Methods (page 5):
These samplings included shallow wells, deep wells as well as tap water from the municipal system. The strength of the study lies in the analysis of the 31 shallow wells and while thermo-tolerant coliforms were found overall in 90% of the wells, the number of samples from deep wells and taps is insufficient to compare them to the shallow wells. While this does not meet rigid statistical analysis criteria, field research in itself is difficult and I would continue to include the information on deep wells and tap water.

Response
We acknowledge the comment, but you suggest, it may be good to maintain the results for deep wells and taps though the samples are few but recommend for more sampling.

Comment
Results (page 8) - Possible sources of contamination of water sources This should be relabeled as "Residents perception of contamination" as no scientific studies were done. Table 5 should be deleted because this flies in the face of the general premise of the manuscript that latrines were located close to shallow wells and, in fact, under water which would imply that under-earth ground water is contaminated.

Response
Thanks for the comments. We have done as advised by the reviewer.

Comment
Discussion (page 10):
The Discussion section should provide for discussion on ground water contamination from adjacent wells. A sentence or two on the mechanism with appropriate references would be important. In addition, contamination of wells from heavy rain is possible and this should also be introduced into the Discussion section.

Response
The discussion section has been revised

Comment
Discussion (page 10) - last paragraph:
Delete "This implies that the water from shallow wells may not be suitable for drinking but drilling deep may improve the situation." The reference to drilling deep or the conclusion on deeper water being safer is not meet significant p values by the study because of insufficient sampling size.

Response
We have done as advised by the reviewer

Comment
Conclusion (page 12) - first paragraph:
Substitute the word "coliform" and delete "fecal matter".

Response
This has been done

Comment
Conclusion (page 12 and 13):
Page 12; Move third paragraph (second paragraph of conclusion) to the Discussion section. Revise sentence 1 paragraph 4 to read "The results of the study also suggest that piped water ___may be safer, but additional sampling is needed." Move paragraph 4, from second sentence onward into the discussion section. Move paragraph 2, page 13 to the discussion section.

Response
Thank you for these suggestions. These suggestions have been addressed.

Reviewer #2

Comment
This paper addresses an important public health issue, the quality of drinking water in a slum settlement in Kenya. The underlying interest of this piece of work relates to the now well-known concern about Africa's rapid urbanization amidst declining economies, leading to inability of local and national authorities to provide basic services to the growing urban population. Investigating some of the factors contributing to poorer health outcomes among the urban poor and consequently, to increased intra-urban inequities in health, is therefore commendable.

The authors have made a quite good investment in literature review, with a relatively good balance of peer-reviewed articles and policy documents from WHO, UNICEF and other international agencies; the introduction section lays down the public health importance of the topic quite well; the presentation of results is quite appropriate. The main drawback of the paper is the writing style which needs to be improved. The purpose of the discussion section was almost missed; and the methodology section raises a number of questions that need to be clarified. Below are specific comments.

Response
Thanks for the complements. Concerning the discussion section, revision has been done as indicated below to cater for the reviewer's comments. Thanks for the observations.

1. Major comments

Comment
Introduction section
The necessary materials are present. The only concern is the style of writing which needs to be substantially improved.

Response
Thank you. The introduction has been sharpened.

Comment
Methodology section
The first paragraph on page 5 does not belong to the Methodology section. It would be good to expand the paragraph as part of a Background section.
It is not clear why the sample size of 192 (households) was chosen.
To enable the reader to get a better understanding of the sampling frame, the authors should indicate the approximate number of plots, and explain how the 192 were chosen (e.g. did they have access to an exhaustive list of all blocks?). The same applies to the selection of households within blocks (did the authors have a list of all households in the blocks?).
Water sampling: The reason for taking 40 samples is not mentioned. The procedure to draw these 40 samples is not clear: Selecting the 4th household from a list of 192 households can be problematic if the numbering of households in the list which is used does not reflect the proximity.
Whether the questionnaire was administered to the 192 selected households, or only the 40 households selected for water samples, is not clear. This can only be guessed from Table 1.

Response
This section has been made clearer on the text and further explanations to address the reviewer's comments have been made in the foot notes.

Comment
Results section
It is mentioned the proportion of adults or children, yet the methodology section does not make any reference to the composition of sampled households (adults or children).
It is not clear what "bush" means in a typical highly populated slum like the one studied.
..a few more affluent members _ had water piped into their residence: Why not provide the exact figure?
General rules for Tables: Indicate the source; expand the titles (e.g. for Table1: Source of domestic water among 192 households in the slums of Langas, Kenya); Provide explaining footnotes when the total is different from expectation (e.g. in Tables 2-4).

Response
Thanks for the comment. The proportions mentioned have no relation to the respondents…they reflect what the respondents said rather…e.g. 98% of the respondents said that adults used pit latrines (as opposed to 98% of respondents who were adults using pit latrines). The style/language has been revised to make this clearer. Other issues raised here have been addressed.

Comment
Discussion section
This section needs to be completely re-written. Its purpose is to discuss the study findings, not to present other background or policy information. It should also compare the findings with those from other studies, and indicate some of the limitations of the study.

Response
The discussion has been greatly revised to address the reviewers comments

2 Other comments: Writing style and typos
General: The punctuation is not consistent across the text (e.g. the period should come after the citations).
Page 3, ' 2, sentence 1: Urban population should not be measured as a percentage. The fact that the percent of urban population doubled does not mean that the urban population itself doubled.
Page 3, ' 2, sentence 2: Replace "_ resulted in increase in the proportion _" with "_ resulted in increased proportion of _".
Page 3, ' 2, last sentence but one: Use the past tense to report a study finding (the under five mortality was _). This also applies to other sentences (e.g. Page 3, ' 2, last sentence).
Page 6, ' 1, sentence 2: "_ the reason for this was determined". First, reasons are asked to the respondents (not determined). Second, the expression "for this" is not appropriate.
Page 6, ' 1, last sentence: No need to mention "_ and notes taken".
Page 7, ' 2, sentence 2: "had no" is written twice.
Page 7, ' 2: If the authors make reference to Kenya shillings, they should indicate that it is the local currency, they should give the exchange rate with say, US $. It might be more than enough to just indicate that slum dwellers pay more than five times _ Page 7, ' 2, last sentence but one: The text between parentheses should not start with capital letter.
Page 7, ' 2, last sentence: Use of semicolon after "that is", is not appropriate.

Response
Thanks for these careful observations. The issues raised have been addressed.