INTERNATIONAL JOURNAL OF BIOASSAYS
ISSN: 2278-778X
CODEN: IJBNHY
OPEN ACCESS

ORIGINAL RESEARCH ARTICLE

The effects of vertical and horizontal separations between pit latrine and hand dug well on contamination water by human fecal matter in Bomachoge Borabu, Kenya.

Nyabayo C.J.[1], Chemoiwa E.J.[1], Mwamburi L.[1], Jepkogei R.M.[1], Kimutai A.[2]*
[1]University of Eldoret, P.O. Box 1125-30100, Eldoret, Kenya.
[2] Department of Biological Sciences, University of Kabianga, P.O. Box 2030-30100, Kericho, Kenya.

Received: June 23, 2016; **Revised:** July 12, 2016; **Accepted**: August 07, 2016
Available online: 1st September 2016

Abstract: In developed world, water diseases are rare due to presence of efficient water supply and human wastes disposal systems (Jorge *et al.,* 2010). However, in developing countries like Kenya, are characterized by inadequate basic resources such as safe drinking water and sewerage disposal facilities. This is due to rapid population growth. Consequently, use of pit latrines and hand dug wells are commonly used. There is concern that pit latrines may cause ecological and human health effects associated with pathogenic and chemical contaminations of ground water sources by hand dug wells. In Kenya, pit latrine disposal method could be a main source of ground water contamination. Contaminants from pit latrines excreta can potentially leach into groundwater, causing human health risks through contamination of hand dug well water. In this study we assessed vertical separation between the depths of pit latrines and hand dug wells and the horizontal separation between wells and pit latrines. These assessments were to establish the separation distance that can allow the pathogens to die off naturally or leach to underground water. A cross-sectional study design was used. The study areas of Bomachoge Borabu sub county were; Magenche, Bokimonge, Bombaba and Boochi, targeting hand dug wells and pit latrines usage within homesteads. Methods of data collection used in the study were questionnaires, measurements and laboratory water analysis. The results revealed that hand dug well water was significantly ($p<0.05$) contaminated with faecal coliforms in all study sites. In addition, usage of pit latrines and wells was significant ($p<0.05$) too. Over 60% of the population used both pit latrine system and hand dug wells for faecal disposal and as water source respectively. These results also showed that the minimum horizontal separation distance between pit latrine and hand dug well was 60 meters and vertical separation distance between depths of pit latrine and hand dug well was 1.1metre (45inches) at these distances no faecal coliforms were recorded. It was recommended that public health sensitization exercise be made in the study area.

Key words: Contamination; pathogens; buffers; sewerage; regression; correlation.

Introduction

Increase in human population in developing countries has led to increased release of large quantities of human waste, consequently, posing challenges on its disposal systems. This has become a threat to ecological and human health (UNICEF, 1997 and Kirimi, 2008). Safe faecal disposal requires high level of investment. Due to inadequate resources, this has become a crisis in developing countries (UNICEF, 1997).

In Kenyan rural and urban areas, there is a serious challenge in disposal of human faecal matter because of inadequate knowledge. This has created health problems that may affect human health and cause serious economical and other welfare losses (Kirimi, 2008).

The environmental degradation caused by inadequate disposal of human waste can be expressed by contamination of surface and underground water through seepage and soil contamination. To prevent detrimental effects of human waste like faeces, they must be properly disposed (Renkow and Otieno, 2008).

With the emerging concern on large quantities of human waste being produced, both in the form of solid and liquid waste, their management becomes one of the main focus of sustainable development plans which is based on policies and practices that are geared towards resource conserving and respect values of equity in accessing resources (Renkow and Otieno, 2008).

Inadequate or biased distribution of services and resources leads to indiscriminate disposal of human waste matter like faeces, thus increasing chances of contaminating underground water sources which cause human and ecological health impacts associated with microbiological and chemical contamination of underground water. Contamination of these water sources can be detected by the presence of indicator organisms (APHA, 1998).

***Corresponding Author:**
Dr. Albert Kimutai,
Lecturer,
Department of Biological Sciences,
University of Kabianga,
P.O. Box 2030-20200, Kericho, Kenya.
E-mail: kimutaialbert@yahoo.com

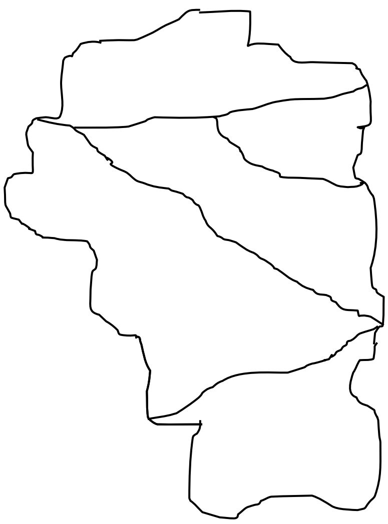
http://dx.doi.org/10.21746/ijbio.2016.09.001

Testing for the presence of faecal organisms in water is a way of determining whether a water supply is faecally polluted (APHA, 1998). Exposure to faecally contaminated water does not always translate into infection (Ellis, 1998). However, the higher the faecal bacteria level in water, the higher the chances of pathogens presence in significant numbers too (APHA, 1998).

Materials and Methods

Study area

The study was conducted in Bomachoge Borabu sub county in, Kisii County which borders Nyamira county to the East, Narok county to the South and Homa bay and Migori counties to the South West. Kisii county covers an area of 1, 317.9 km^{2}and has a population of about 1.2million people. In terms of topography, the county is mainly hilly with several ridges to the eastern part. The most notable topographical features are the hills of Nyamasibi, 2170m a. s. l, Kiong'ayo 1710ma.s.l, Kiamwasi 1785ma.s.lKiombeta and Nyanchwa hills. The District has a highland equatorial climate with an annual average rainfall of over 1, 500mm which is reliable. The long rains occur from February to June while short rains occur from September to November. December and January are relatively dry months. Most parts of the district have red soils, which are deep and rich in organic matter. Other parts are characterized by clay, red-roam and sandy soils, which are poorly drained. The District is divided into three ecological zones, comprising of the Upper midland 75%, the lower highland 20%, and low midland 5%. The area is part of Mau catchment and has several permanent rivers and streams that drain into Lake Victoria. The main sources of water are hand dug wells, springs and roof catchments of rain water. Means of human fecal disposal are mainly pit latrines kisii county integrated development plan (2013).



Study Design and Sample Size

A cross sectional study design was used to sample households and the water sources. Water sample collection took place between June 2015 and November 2015.Water sources which were studied were collected from hand dug wells. Sampling of hand dug well water was based on criteria that sampled households that were 100m apart.

Sample Collection

Sampling the protocols described by Tebbut (1992) were followed. Sample bottles were autoclaved at 115^{0}C followed by sterilization with ethanol for about two minutes. Samples from hand dug wells were collected by suspending the sample bottles (200ml-capacity) using a nylon string and weighted with a metal mass approximately 50g to facilitate sinking through the water column. Care was taken not to disturb the bottom sediments so as to avoid making thewater samples turbid. An air space was created in the sample bottle by pouring out some little water before the lid was secured. Samples were labeled and placed in a cool box containing ice blocks and transported within six hours of collection to Eldoret Water and Sanitation (ELDOWAS) and University of Eldoret-Biotechnology laboratories in Eldoret for analysis. The depths of pit latrines were obtained from the residents through questionnaires and observation. Measurement of hand dug well depth was done using a thread tied with a 50g mass to facilitate sinking and the thread length was measured by a tape measure on the ground.

Testing for indicator organism (faecal coliforms) in water samples

Testing for fecal coliforms in water samples was done using modified membrane filtration method as described in APHA, 1998. Apparatus used were dilution bottles, pipettes, graduated measuring cylinders, Petri-dishes (60×15mm), membrane filters (0.45μm), filtration unit, absorbent pads, forceps, spirit lamps and incubators.

Laboratory testing of faecal coliforms was done using 100ml of water sample which was measured into a measuring cylinder. A small amount of dilution water was added to the funnel before filtration was done to aid in uniform dispersion of bacteria suspension over entire effective filtration surface. Sterile membrane filter papers were placed over a porous plate using a sterile forceps (sterilized by flaming).

The grid side of the filter membrane was placed to face up. The funnel unit was carefully matched over the receptacle and locked in place. The sample of the test water was passed through filter membrane under partial vacuum, 30-50ml sterile buffered water was used to rinse the filter between the samples. The funnel was unlocked immediately after all the water was filtered and the forceps was used to remove the filter membrane which was placed on sterile agar with a rotating motion to avoid entrapment of air.

The liquid medium was used and the culture dish was saturated with 1.8-2.0 ml of prepared M-ENDO medium. M-ENDO agar was prepared following the procedure shown in appendix 2. The culture agar was placed directly on the petri -dish then incubated for 22 to 24 hours at $37^oC \pm 0.5$ in incubator, after incubation, the number of bacteria colonies if any were manually counted and expressed as colonies in 100ml of sampled water.

Assessment of human fecal matter disposal facilities

Assessment of utilization of available human fecal matter disposal facilities was done by use of a questionnaire. The survey targeted the presence and use of pit latrines. Usage of the available disposal facilities among and within estates was assessed visually. Measurement of vertical and horizontal separations between pit latrines and hand dug wells were done using tape measure calibrated in meters.

Results

A total of 98, 96 pit latrines and hand dug wells respectively were sampled within the study site in Bomacchoge Borabu Sub County from January to August 2015. All hand dug wells were significantly ($p<0.05$) contaminated and usage of pit latrines was very common as compared to other faecal disposal methods.

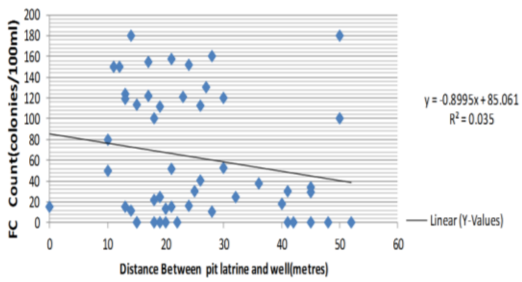


Figure 1: The relationship between the horizontal distance of the pit latrine and well to that of faecal coliform count in Bokimonge area.

Horizontal separation between pit latrine and hand dug well of Bokimonge greatly affected the level of faecal coliforms in water. The relation between distance and faecal coliforms count was correlated (r=0.035)

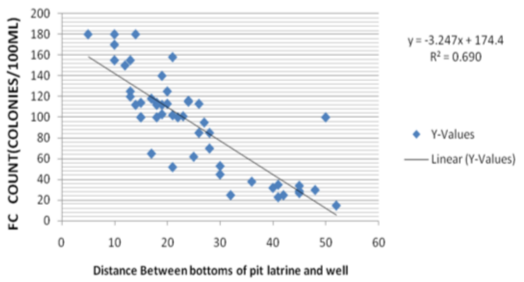


Figure 2: The relationship between the vertical distance of the bottoms of pit latrines and wells to that of faecal coliform count of Bokimonge area.

Vertical separation between depths of pit latrine and hand dug well of Bokimonge greatly affected the level of faecal coliforms in water. The relation between distance and faecal coliforms count was correlated (r=0.69)

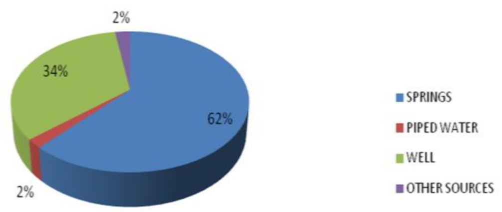


Figure 3: percentage usage of domestic water sources in Bokimonge area.

The percentage usage of drinking water sources shows that 62%, 34%, 2%, 2% used springs, wells, piped and other sources respectively

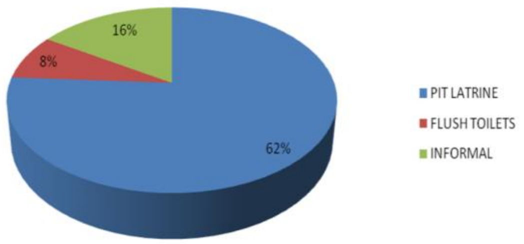


Figure 4: Percentage usage of mode of faecal disposal in Bokimonge area.

The results show that 62% used pit latrines facilities, 16% used informal methods and 8% used flush toilets as means of faecal disposal methods in Bokimonge study site.

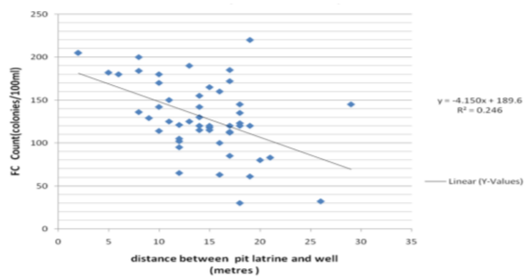


Figure 5: Relationship between horizontal distance of pit latrines and wells to that of faecal coliform count in Magenche area.

Results shows that there was a significant (p<0.05) relationship between the pit latrine and hand dug well of Magenche site in terms of faecal coliforms count. As the distance increase faecal coliforms count reduced up to 30meters where there were no faecal coliforms. At a distance of 5meters faecal coliforms count was about 200 cfu/100mls.

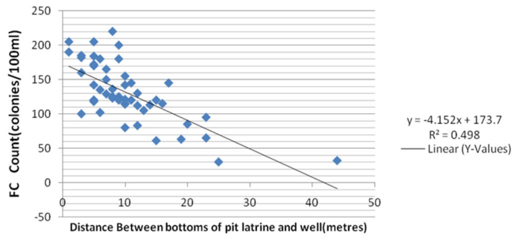


Figure 6: Relationship between vertical distance of the pit latrines and wells to that that of faecal coliform count in Magenche area.

Results shows that there was a significant (p<0.05) relationship between depths of pit latrine and hand dug well of Magenche site in terms of faecal coliforms count. As the distance increase faecal coliforms count reduced up to 25 inches where there were no faecal coliforms. At a distance of zero inches faecal coliforms count was about 200 cfu/100mls.

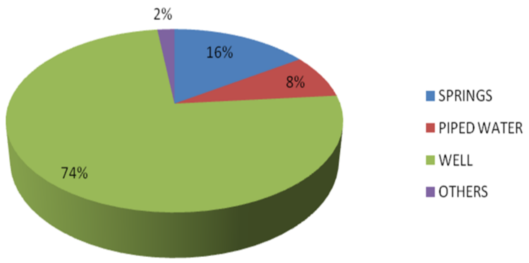


Figure 7: Percentage usage of domestic water sources in Magenche area (74%-wells, 16%-springs, 8%-piped water and 2%-unspecified).

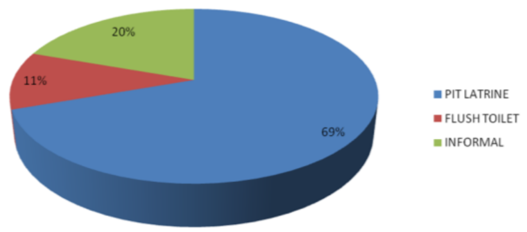


Figure 8: Percentage usage of modes of faecal disposal in Magenche area.

In the study population 69% used pit latrines, 20% informal and 11% flush toilets. Its shows that pit latrine system was the most preferred facility in Magenche site.

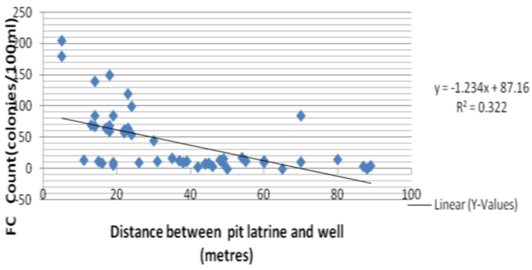


Figure 9: The relationship between horizontal distance of pit latrines and wells to that of faecal coliform count in Bombaba area.

Results show that at a distance of 5 meters the coliforms count was 200 cfu/100mls and above 90metres there were 0 cfu/100mls. This reveals that increase in horizontal distance decreases significantly (p<0.05) faecal coliforms count in hand dug well water of bombaba site.

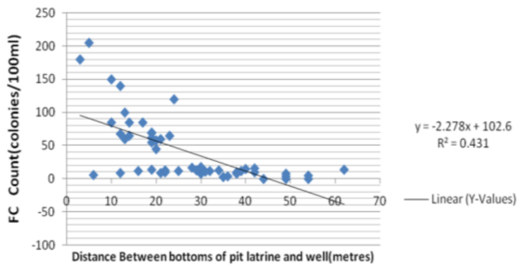


Figure 10: The relationship between vertical distance of the bottoms of pit latrines and wells to that of faecal coliform count in Bombaba area.

Results show that at a distance of 3inches the coliforms count was 200 cfu/100mls and above 45 inches there were 0 cfu/100mls. This reveals that increase in horizontal distance decreases significantly (p<0.05) faecal coliforms count in hand dug wells of Bombaba site.

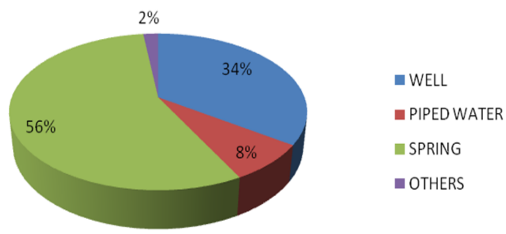


Figure 11: percentage usage of domestic water sources in Bombaba area.

Well water the most used source of water in Bombaba whereby 56% of the population used wells, 34% springs, 8% piped water and 2% other sources.

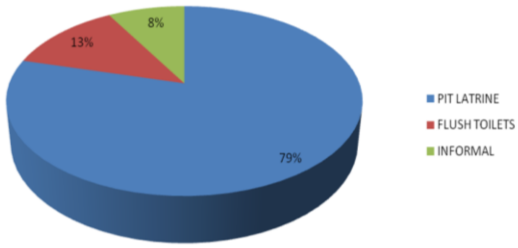


Figure 12: Percentage usage of modes of faecal disposal in Bombaba area.

The results shows that the pit latrine facility in Bombaba site was the most preferred with 79% usage whereas flush toilet followed with 13% usage and finally 8% informal method.

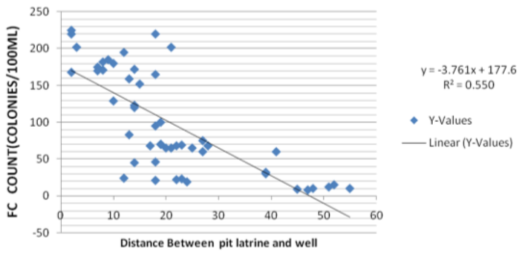


Figure 13: Relationship between distance of pit latrines and wells to that of faecal coliform count in Boochi area.

Results show that at a distance of 5 meters the coliforms count was 200 cfu/100mls and above 48 meters there were 0 cfu/100mls. This reveals that increase in horizontal distance decreases significantly ($p<0.05$) faecal coliforms count in hand dug wells of Boochi site.

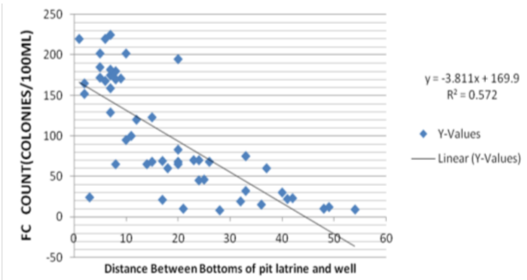


Figure 14: Relationship between vertical distance of the bottoms of pit latrines and wells to that of faecal coliform count in Boochi area.

Results show that at a distance about zero inches the coliforms count was 200 cfu/100mls and above 45 inches there were 0 cfu/100mls. This reveals that increase in vertical distance decreases significantly ($p<0.05$) faecal coliforms count in hand dug well water of Boochi site.

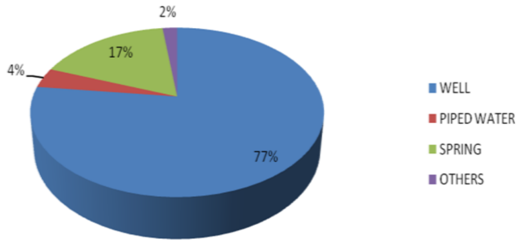


Figure 16: Percentage usage of domestic water sources in boochi area.

Well water the most used source of water in Boochi whereby 77% of the population used wells, 17% springs, 4% piped water and 2% other sources.

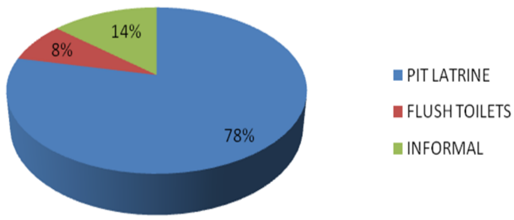


Figure 17: percentage usage of different modes of faecal disposal in Boochi area.

The results shows that the pit latrine facility in Boochi site was the most preferred with 78% usage whereas flush toilet followed with 14% usage and finally 8% informal method.

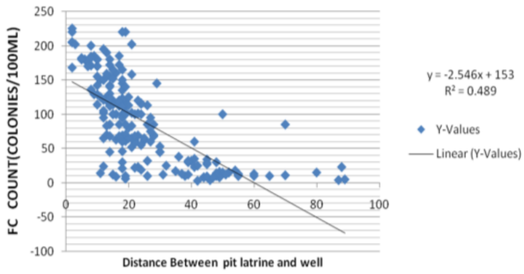


Figure 18: General relationship between horizontal distance of pit latrines and wells to that of faecal coliform count in Bomachoge- Borabu Sub-County.

Results show that at a distance of 5 meters the coliforms count was 240 cfu/100mls and above 60 meters there were 0 cfu/100mls. This reveals that increase in horizontal distance decreases significantly ($p<0.05$) faecal coliforms count in hand dug wells of Bomachoge sub county study sites.

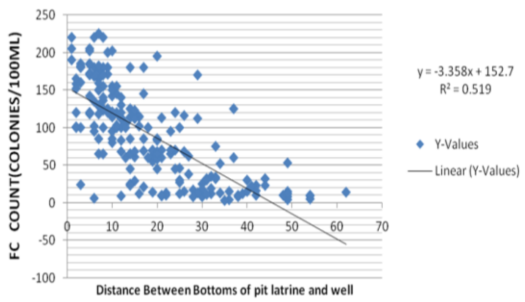


Figure 19: General relationship of the distance between the bottoms of pit latrines and wells to that of faecal coliform count in Bomachoge-Borabu Sub-County.

Results show that at a distance about zero inches the coliforms count was above 200 cfu/100mls and above 45 inches there were 0 cfu/100mls. This reveals that increase in vertical distance decreases significantly ($p<0.05$) faecal coliforms count in hand dug well water of Bomachoge sub county study sites.

Discussion

The major domestic water sources in Bomachoge Borabu Sub County are hand dug wells and natural springs. Results indicated that hand dug wells were generally the most accessed among domestic water sources. Responses from questionnaires indicated that the hand dug well was used for multiple domestic purposes which included drinking, bathing, watering livestock and washing clothes. Reports from other studies indicated that the hand dug well was the most utilized resource (Kabogo and Kabiswa (2008) and Kabede (1978). Therefore, utilization of well water in other areas is similar to that observed in the present study.

The preference in utilization of hand dug well water in Bomachoge Sub County was based on their proximity within the homestead which makes it convenient to fetch and in addition, the water is free of charge.

Findings of the current study also indicate that preference of well was quite varied among locations. Hand dug well water accessibility was highest at across the sub county. Similar preferential report has published in literature (Dzwairo, *et al.* 2006). The report identified several factors including topography of the area as the driving force towards accessibility of hand dug well water.

The higher preference of well water within Sub County was probably due to the topography of its sub county which is hilly. The natural springs are located on the lower side which means that the population would carry the water up-hill, which reduces preference. Since wells are mostly contaminated due to frequent usage (Gakukia, *et al.* 2010) than other domestic water sources, it is possible that the status of the hygiene of a particular population could be responsible for the magnitude of its faecal contamination. Dzwairo, *et al.* (2006) noted that degree of faecal contamination is complex and must be approached from several dimensions if contamination of domestic water sources is to be tackled effectively.

The present study demonstrated that hand dug well water contaminated by faecal coliforms. Faecal coliforms have widely been used as indicators of quality of drinking water (WHO/UNICEF, 2004). Although presumed to be harmless, (Olivieri, *et al.*, 1997) presence of faecal coliforms is an indicator of likely presence of other pathogenic organisms (Bartram and Balance, 1996 and Olivieri*et al.*, 1977). Also the intensity of faecal coliforms in water is usually taken as a measure of degree of contamination of water sources (Cheesbrough, 2006). Different modes of human faecal disposal contribute variously to the contamination of different water sources (Howard *et al.*, 2003).

Contamination of domestic water sources is more serious in developing than in developed countries as was noted in Tanzania (Kauzeni, 1981 and Norconsult, 1981) and Java (Lloyd, 1990), where domestic water sources were found to be heavily contaminated with faecal coliforms. Whereas, in developed countries, on-site sanitation facilities were properly sited, designed, constructed and maintained in settlement areas (Lerner, 1996), This conditions presumably limited the risk of groundwater contamination by human faecal materials.

Faecal disposal management in three estates (Magenche, Bokimonge, Bombaba and Boochi) that were studied involves use of pit latrines and informal methods. The main mode of human faecal matter disposal in the four areas was pit latrines with over 50% of the residents using the facility (fig 4, 8, 12&17) This mode of human faecal disposal is reported to be also common in many developing countries, (Esrey, *et al.,* 2001 and Gakukia, *et al.*, 2010).

Pit latrines are the most preferred structures due to their affordability in terms of construction and utilization. They also work under the principle of "drop and store" (Esrey, *et al.*, 2001) as compared to flush toilets that are more expensive to install (Lenton, *et al.*, 2005). The later also require a lot of water to run. Despite the numerous merits, pit latrines contribute to the highest risk of contaminating domestic water sources. Improper construction, design and unhygienic management of pit latrines in urban areas may lead to environmental degradation expressed by contamination of surface and ground water through seepage and direct faecal contact with the soils as noted by Obabori (2009).

Pitlatrines easily contaminate underground water sources through seepage and infiltration of it is contents. In addition, contamination worsens when the pit latrines are poorly designed, constructed and managed. Probably this is the main source of high level of faecal coliforms count found in the drinking water sources. If the design and infrastructure are poor the clean disposable facilities may not function to the expected levels in terms of hygiene. The economic power of an area may not play a major role in hygiene if the culture of residents is unhygienic and human faecal disposal structures are not properly designed and maintained (Shannon, 2003).

Informal methods of human faecal disposal are important sources of domestic water contamination in Bomachoge sub county, especially the main domestic water source like hand dug wells this has also been observed by Dzwairo *et al.*, (2006). The situation is complicated by the fact that there is no order or regularity in the way disposals are made, thus making the existing safe disposal policies implementation difficult.

Use of informal disposal methods is a worldwide issue, House, *et al.*, (2004), reported that in Bangladesh a large population used informal faecal matter disposal methods, a similar situation was reported in Kenya by Guardian Development Network (2010) which revealed that 10% of Kenyan population use informal methods for faecal matter disposal Yeager *et al* ., (1999) also noted that majority of young children defecate informally on soil and their mothers use grass for anal cleaning thus contaminating the ground with faeces.

In the current study it was also found that children faeces were commonly disposed on open ground in most homesteads among the four areas of Bomachoge Borabu Sub County and this was presumed to be the cause of contamination of domestic water sources, through surface runoffs which carry the faeces and polluted soils into the water sources.

Apart from disposal methods, physical factors have also been implicated in contamination of domestic water sources by faecal coliforms (Sugden, 2004 and Kimani and Ngindu, 2007). The distance between pit latrine and hand dug wells at which there are no faecal coliforms count found has been defined by several authors including Ben and Kolsky (1999); Morgan (1990); Kimani and Ngindu (2007) and WHO (2007). As evidenced in the current study the distance between well and pit latrine affects faecal contamination in the well. Contamination at various distances may depend upon soil types and hydraulic gradient or slope of an area.

The depths of both well and pit latrine did not influence well water faecal coliform contamination. In the current study Bomachoge Borabu Sub county generally has low water table of about 30 meters feet for hand dug wells while pit latrines depths are averagely 15 meters (kisii county development plan 2013). According to Sugden (2004) the pit latrine should always be above the water table during all seasons and 15 meters below the surface is the minimum depth necessary to ensure the pit latrine contents remain dry and allow pathogens to die off naturally before reaching the water table. In comparison with the current study it was found that water table was too close from the pit latrine depth, explaining why vertical separation between bottom of pit latrine and water table had influence on drinking water contamination by faecal coli forms. Apparently informal faecal disposition was quite rampant in these areas of study and this seems to be anothersource of hand dug well water contamination, and this may occur at the surface or through subterranean means. In addition, surface runoffs are predominant mechanisms through which well-water source is faecally contaminated (Dhaneshwar, *et al.*, 1985 and Nordberg and Winblad, 1990).

Topography of the area may also influence faecal coliform contamination on spring water. It is expected that hilly area contributes more to faecal coliforms contamination on spring water than flat areas, hilly areas increases the flow than flat areas. This situation was explained by Ben and Kolsky (1999), that as the flow rate increases micro-organisms penetrate deeper and infiltration increases into the ground. This influences natural spring water contamination since spring water originates from the underground.

References

1. APHA, (1998) Standard methods for examination of water and wastewater.20th edition, American Public Health Association(APHA), American Water Works Association(AWWA) and Water Pollution Control Federation(WPCF), Washington D.C.p.210-215; p.320-322.

2. Bartram, J. and Richard Balance (1996) Water quality monitoring; E and FN SPON, and imprint of Chapman and Hall, 2ndEdition.2-6 Boundary Row, London SE 18HN UK. 3:245-274.

3. Ben Cave and Pete Kolsky, (1999) Ground water, Latrines and Health Task No.163-London School of Hygiene Tropical Medicine, UK, WEDC, Loughborough university press, UK. 17(4):7-14.

4. Cheesbrough, Monicah (2006) District Laboratory Practice in Tropical Countries. Part II. Steven and sons limited. Hertford, England.p.115-145.

5. Dhaneshwar, R.S., Basu, A.K., Biswas, A.K., Ganguly, A.K. and Sanyal, P.B. (1985) Evaluation of rural water supply in hill regions of West Bengal; Journal of the Indian Water works Association, 17(2):185-191.

6. Dzwairo B. ZvikombereroHoko, DavidLove, EdwardGuzha (2006) Assessment of impacts of pit latrines on ground water quality in rural areas of Zimbabwe, Morandero District. waterline publication 31:79-80.

7. Ellis, J.B., (1998) Urban discharges and receiving water quality impacts. "Proceedings, LAWPRC 14" Biannual conference, Brighton, UK, p.18-21.

8. Esrey.S., Andersson, I., Hillers, A. and Sawyer, R. (2001) Closing loop ecological sanitation for food security. Stockholm (Sweden), SIDA.21:600-623.

9. Guardian Development Network (GDN) (2010) Poor Sanitation Breeds Diseases and Exploitation in Kenya's slums NETWAS publication. 2:2-4.

10. Gakukia.R., U. Pokorski and P. Onyango (2010) Up scaling Access to Sustainable Sanitation-Kenya. Water Service Regulatory Board Publication (WASREB) 1:5-10.

11. House S, (2004) Emergency water sources-Guidelines for selection and treatment, WEDC, 3rdedition, ISBN.1843800691. p.34-37.

12. Howard, G. Pedley, S., Barret.m., Nalubega, M. and Johal, K. (2003) Risk factors contributing to Microbiological contamination of shallow groundwater in Kampala, Uganda.

13. Jorge W.Santo Dominingo, Nicolas J.Ashbolt (2010) Fecal pollution on water. World Health Organization publication.41:3539-3552. Water res.publication., 37(14) 3421-3429.

14. Kabede, H. (1978) Improving village water supplies in Ethiopia A case study of socio-economic Implications.Addis Ababa, Ethiopia, United Nations Economic Commission for Africa.16(3):45-58.

15. KabogoIsaacand Charles Kabiswa (2008) Pit latrines and their Impact on Groundwater in small Towns in Uganda; Ecological Christian Organization, Publication; A case study of Bugiri Town Council14th.-17th October2008 .p.8-17.

16. Kauzeni, A.S. (1981) Settlements' expectations and attitudes towards traditional and improved water supplies and pre-conditions for successful rural water development programs; The case study of Rukwa region (Research Report; no.50). University of Dar es Salaam. Tanzania, Bureau of Resource Assessment and Land use planning.50:70-80.

17. Kimani-Murage and Augustine M. Ngindu (2007) Quality of water the slum dwellers use. A case of a Kenyan slum. The Newyork Academy of Medicine; publication p.1-8.

18. Kirimi, N.P. (2008) Management of municipal waste in Kenya especially in urban areas with high population density. Report presented to the 4th annual conference of town management, Doula Cameron, 4th July 2008. 4: 4-9.

19. KisiiCounty Integrated Development Plan (KCIDP) 2013-2017.pp1-5.

20. Lenton, Roberto, Albert Wright, Kristin Lewis (2005) Health, dignity and development.UN

21. Millennium Development Task Force on water and Sanitation no.91.New York.P.14-15.

22. Lerner, D.N. (1996) Urban groundwater an asset for the sustainable city. European Water Control, 6:43-51.

23. Lloyd, B. (1990) Diagnostic surveillance for risk assessment, protection and improvement of Drinking water sources in Indonesia; Working meeting on drinking water source protection, 30th June – 1stJuly, 1990.The Hague Netherlands, IRC International water and Sanitation centre for diarrhea research /CARE Bangladesh/Environmental Health Project USAID. 8(1):18-22.

24. Morgan, Peter. (1990) Rural water supplies and sanitation, Zimbabwe.Macmillan publishers. 26(2):7-8.

25. Norconsult, (1981) Water master plans for Rukwa and Kigoma regions; Interim report; Part IV; Selected working papers; Hovik, Norway, Norconsult .7 (5): 14-16.

26. Nordberg, E. and Winblad, U. (1990) Environmental hygiene in SIDA-Supported programmes in Africa; review and recommendations: Stockholm, Sweden, Swedish International Development Authority.24(2):326-346

27. Obabori, A.O. (2009) An appraisal of the concept of sustainable environment under Kenyan law. Journal of Human Ecology.28 (2):134-142.

28. Olivieri. V. P., Kazuyoshi Kawata and Say-Hua Lim (1977) Microbiological impacts of storm seweroverflows: Some aspects of the implications of microbial indicators for receiving water The John Hopkins University press, MA 21205, U.S.A. p.47-53.

29. Renkow, M. and Otieno, D.O. (2008) "Does Municipal solid waste compositing make common sense?" Journal of Environment management.53: 339-347.

30. Shannon Nicole Stokes (2003) Mapping Ground water Vulnerability to contamination in Texas GIS

for water resources CE 394K3 Term Project Presentation One.University of Texas at Austin.p.23-27.

31. Sugden.S. (2004) WELL.Factshheet; The microbiological contamination of water supplies IRC International Water and Sanitation Centre publication.2(1): 3-7.

32. Tebbut T.H.Y. (1992) Principles of water quality control, 4th Ed. Perggman press London.p. 120-150.

33. UNICEF, EHP, USAID (1997) A manual of Hygiene Promotion Towards better programming Water, Environment and Sanitation. Technical Guideline Series-No.3.EHP Applied Study No.5 First Edition: May 1997 A sanitation Handbook p.80-85.

34. WHO/UNICEF (2004) Joint Monitoring Programme for Water Supply and Sanitation; Meeting the MDG drinking water and sanitation target: A mid-term assessment of progress JMP publication. 2(1):7-20.

35. Yeager B.A., Huttly, S.R., Bortolini. R., Rojas M, and Lanata. C.F. (1999) Defecation practices of young children in "A Peruvian shanty town." soc.sc.med. 49(4):531-541.

Cite this article as:

Nyabayo C.J., Chemoiwa E.J., Mwamburi L. and Jepkogei R.M. Kimutai A. The effects of vertical and horizontal separations between pit latrine and hand dug well on contamination water by human fecal matter in Bomachoge Borabu, Kenya. *International Journal of Bioassays* 5.9 (2016): 4782-4790.

DOI: http://dx.doi.org/10.21746/ijbio.2016.09.001

Source of support: Nil

Conflict of interest: None Declared