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Evaluation of Factors Predisposing to Bacterial Contamination of Drinking Water Sources: A study at Kitale Municipality, Kenya

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Faecal contamination of drinking water was assessed using various water sources in households in four peri-urban areas of Kitale Municipality, Kenya. We measured counts of faecal and faecal thermotolerant coliforms in Municipal treated water, well, spring and borehole water within 115 selected households. Borehole recorded no faecal contamination but (28%) of treated tap water, 100% of well and river water had fecal contamination. Bacteriological analysis involved the use of Membrane filter technique to isolate total coliforms and faecal thermo-tolerant coliforms contaminants on Endo agar and MacConkey agar respectively. These were further identified by subculture, microscopy and biochemical tests. We isolated mainly faecal coliforms and faecal thermotolerant coliforms which included *Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Proteus species, Salmonella* species, *Shigella, Citrobacter* , *Enterobacter* species and *Streptococcus faecalis.* Demographic data was obtained by use of self administered questionnaires on residents and water supply operators. Some of the risk factors found to have significant influence on the quality of drinking water included depth of well / borehole, distance from possible contaminating source, poor housing and sanitation , delay in repair of burst pipes and absence of protective cover in wells, type of water source and boreholes.

Key words: Faecal coliforms, predisposing factors, culture, biochemical tests.

Introduction

Contaminated drinking water is a principal cause of the diarrhoeal disease that results in 2.5 million childhood deaths yearly. The presence of bacteria and pathogenic organisms is of great concern when considering the safety of drinking water. Pathogenic organisms can cause intestinal infections, dysentery, hepatitis, typhoid fever, cholera, and other illnesses. International water-quality standards permit no detectable level of harmful pathogens at the point of distribution (WHO, 2004). However, microbiological water quality can deteriorate in the course of collection, transport, and home storage. Thus, access to a safe source alone does not ensure the quality of water that is consumed (El Attar L, Abdel Gawad A et al, 1982). Human and animal wastes are a primary source of bacteria in water. These sources of bacterial contamination include runoff from feedlots, pastures, and other land areas where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks and sewage treatment facilities. Bacteria from these sources can enter wells that are either open at the land surface, or do not have water-tight casing, (Cairncross S, 1996). To determine the risk factors for faecal contamination, we examined environmental as well as human factors affecting drinking water quality in various sources such as well, river, spring, borehole and treated tap water.

Materials and Methods

Sampling was done between May and September 2005, in four residential estates of Kitale Municipality. Selection of households was based on socio-economic status of residents namely; low income, middle level and high income. Simple random sampling was employed to select households to be included in the study from various categories of water sources such as tap, well, borehole, spring and river water sources. Despite their close proximity to Kitale town, majority of the residents especially in the low and middle level income had no piped water facilities and mainly relied on well, river or spring water. Most of the residents in the high income category had piped water facilities and in addition some had boreholes to supplement piped water during dry seasons when water rationing was rampant.

Water facilities in Kitale municipality were obtained from surface and underground sources. Water resources in the district are mainly from rivers flowing from Mt.Elgon and Cherangani hills. The main river is Nzoia joined by a number of streams on its way to L. Victoria. Treated water supply in Kitale Municipality was found to generally inadequate is and cannot keep pace with the growing urban population. It was noted to be affected by changes in seasonal variations of rainfall that reduced volume of rivers, dams and boreholes serving the area. Several households use wells as alternative sources of water (Government Printers, 2001).

Sample collection and testing

Sample collection was done using bacterial purity test kit while applying to WHO procedures and guidelines of water collection from various sources. A thorough assessment of the surrounding environment was made and recorded. We also used researcher administered questionnaires to obtain views from residents and water supply operators.

The test kit contained a sterilized sampling bottle, an information form, sampling instructions, and a return mailing box. Use of the bacterial test kit was necessary to help ensure the test were accurate. The bottle in the kit is completely sterilized to ensure that the sample is not contaminated by bacteria in the bottle. The kit contains detailed instructions on how to collect the water sample and to avoid outside contamination and to obtain a good representative sample.

The sample were stored in a cool box and delivered to the laboratory within 48 hours with the accompanying form filled accurately. One hundred milliliters (ml) (about 3.4 fl. oz.) of the sample is then drawn through a membrane filter. This filter is placed on a nutrient broth culture plate and placed in an incubator for 24 hours bacterial purity test kit at 35° C (95° F) for culturing. The plates then are removed from the incubator and the number of coliform bacteria colonies enumerated.

Results and Discussion

Relationship between presence/absence of raised protective platform and bacterial contamination

Analysis of faecal coliform counts on wells revealed that only 69.5% of the wells had a protective platform while 30.5% had none. Feacal contamination was rated 94.4% in non-protected wells compared to 5.6% in non-protected wells. Chi square test showed a significant relationship between presence of protective platform and bacterial contamination, ($p<0.05$). The presence of a protective platform has some profound effect on shielding wells and boreholes from contamination by surface run-off and other sources.

Relationship between distance from pit latrine and bacterial contamination of well / borehole

Distance from pit latrine in km	**Bacterial counts**	**BACTERIAL CONTAMINATION**		
		YES	**NO**	**TOTAL**
0-10	Count % within category % within site	60 98.4% 54.5%	1 1.6% 6.7%	61 100.0% 61.2%
11-20	Count % within category % within site	42 85.7% 38.2%	7 14.3% 46.	49 100% 39.2%
>20	Count % within category % within site	8 53.3% 7.3%	7 46.7% 46.7%	15 100.0% 12.0%
Total	Count % within category % within site	110 88.0% 100.0%	15 12.0% 100.0%	125 100.0% 100.0%

Chi square tests

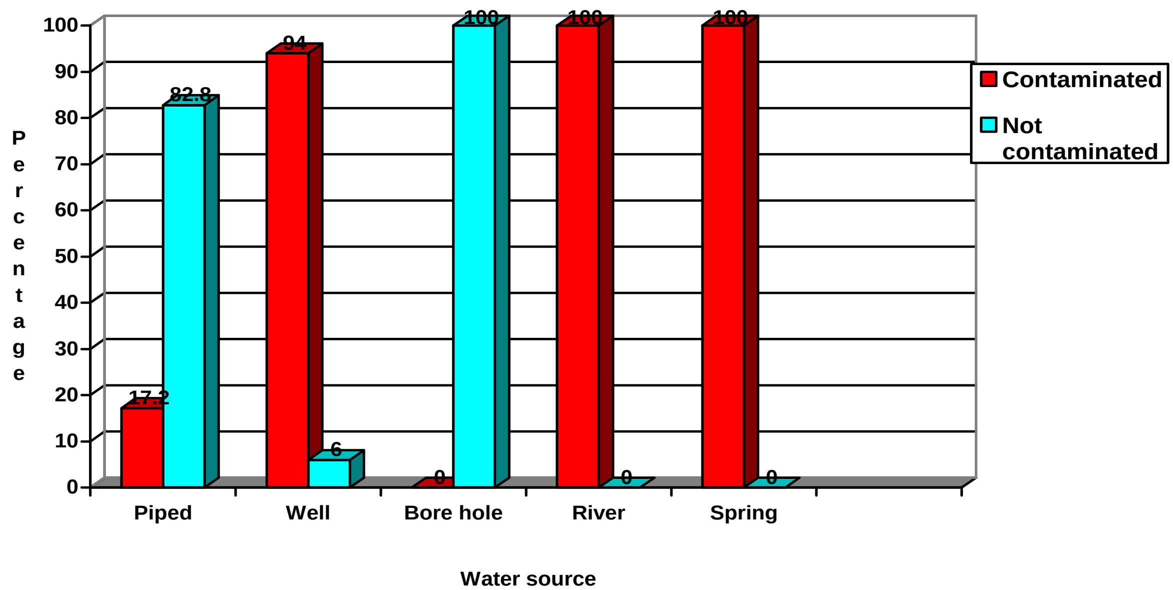
	Value	Df	**Assym. Sig (2 sided)**
Pearson chi Square	23.514	2	.000
Likelihood ratio	20.6.7	2	.000
Linear by linear Association	21.104	1	.000
No. of valid cases	125		

The results in the table indicate a direct relationship between distance from a potential contaminating source such as pit latrine and the level of contamination as indicated by total coliform counts (TTC). Chi square test showed a significant relationship, ($p < 0.05$). We noted that contaminants of water sources are carried through hands and feet of handlers who draw water after visiting the latrines. These contaminants are removed gradually as the individual walks farther away from the contaminating source and hence the low counts recorded with increasing distance from contaminating source. Residents that maintained good personal hygiene through hand washing before handling any water collection apparatus recorded low bacterial counts.

Relationship between type of water source and bacterial contamination

A comparison of the different water sources in relation to bacterial contamination indicated that surface waters such as rivers and springs had the highest levels (100%), while deep wells had low levels and boreholes had none. Bacterial densities were noted to be related to the type of water supply, with drilled wells containing fewer faecal coliforms, total coliforms and faecal streptococci than dug wells or springs. This agrees previous findings that water supplies that were that were shallower, older and lacking adequate casing were characteristically more heavily contaminated with sanitary indicator bacteria than supplies that were deeper or of more recent construction and with sufficient casing.(WHO, 1985).

Figure 1: Relationship between type of water source and bacterial contamination



Relationship between depth of well/borehole and bacterial contamination.

The results reveal that bacterial contamination was highest, 60% in wells of depth ranging from 21-40ft and 39% in wells of depth ranging from 41-60ft. No contamination was seen at depths above 60ft. These findings indicate that bacteria can thrive luxuriantly in wells between depths of 0-20ft and decrease with depth. However, above 60ft depth conditions cannot support further bacterial growth since temperatures are extremely low. In this study only one of the wells sampled had a depth of between 0-20ft. Under normal conditions shallower wells are expected to have higher levels of bacterial contamination due to ambient temperatures. This is clearly indicated in the graph, which shows a sharp decline in the level of contamination as the depth increases. Mineral content is also known to increase with depth thus providing rather unfavorable conditions due to variations in P_H . The possible reason for high level of bacterial contamination in shallow water sources was the very lukewarm temperatures of water due to residual volcanic influences, high mineral content and presence of organic waste (Shivoga, A.W, 2003).

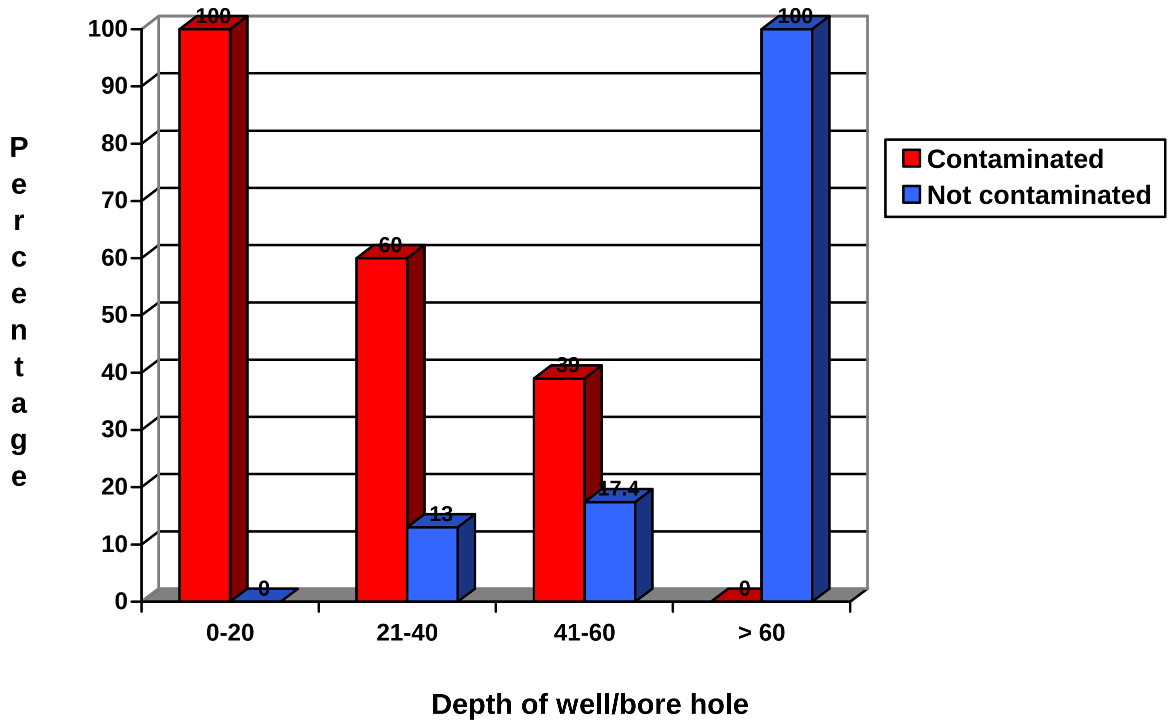


Figure 2: Relationship between type of water source and bacterial contamination

Poor housing and sanitation

The study revealed that some of the residents lived in dilapidated slum dwellings with no proper housing characterised by shacks made of plastic bags with no sanitation facilities. These crowded and poor unhygienic conditions in the surrounding environment were noted to contribute to gross contamination of river water as seen in Kipsongo slum. The main water source was a river on the extreme right of the slum. A faecal coliform count on all samples taken at various points along the river was 100%. An interview with some of the residents indicated that most of them constantly suffered from typhoid and other gastrointestinal infections. However, residential areas occupied by high income groups were served with piped water facilities and in some cases drilled boreholes, to supplement water shortage during drought conditions. Faceal colifrm counts were extremely low or nil. Chi square test revealed a significant difference in level of faecal contamination between these two extremes based on differences in socioeconomic status, ($p<0.05$).

Delay in repair of burst pipes and leaking sewers.

Major complaints by some of the residents served by piped water facilities, especially in the residential estates cited this as one of them. It has been noted that when such a problem is not addressed promptly it frequently become a source of contamination of treated water as noted in some areas within the study sites. Conditions such as those seen in the file photo below are common in many urban settings and can frequently, be a possible risk due to back- siphonage, leaking service connections and contamination of treated water with sewage. The water collected by the children in this photograph is likely to be highly contaminated.

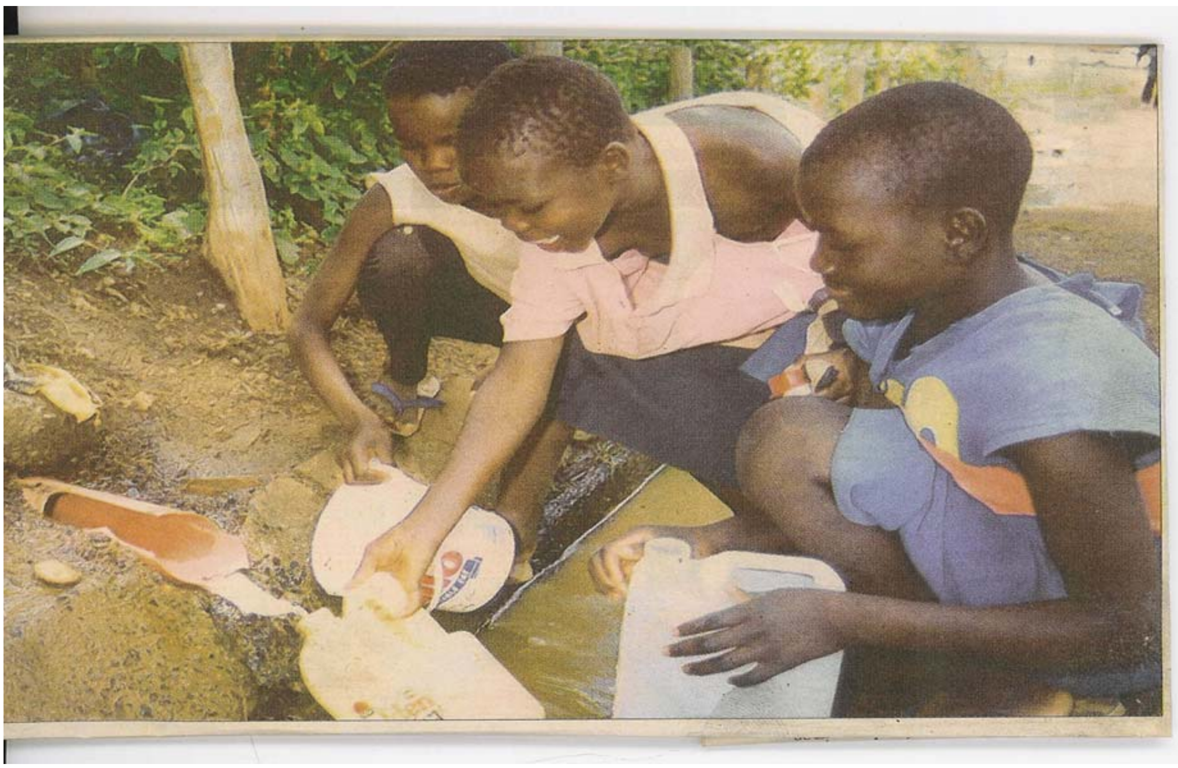


Figure 1: File photograph of children fetching water from a burst pipe in a city Estate, Nairobi, Kenya Source: Daily Nation; May 14th, 2007.

Unprotected water catchments

A survey of the surrounding environment and supporting bacteriological results seen earlier indicated that spring water had 100% bacterial contamination. This was observed in Ziwani daraja spring in Kitale Municipality. The area was noted to be lying on the rugged foothills of Mt. Elgon. It was densely populated with evidence of intensive farming even on the hillsides. Most of the residents here obtained their water from the spring. An interview with some of the women found drawing water on the quality of the water indicated that it was not safe. This was because many of the inhabitants living uphill had dug pit latrines that could possibly be a source of contamination of the spring water tapped downhill. A well downhill from a source of bacterial contamination runs a greater risk of contamination than a well on the uphill side of the pollution source. Good well location is encouraged by requiring minimum separation distances from sources of potential contamination, thus using the natural protection provided by soil, (Sharon Skipton, Paul Jasa,et al,2000)

Lack of alternative water sources

Residents also noted this factor as a possible cause of consumption of contaminated water (46%). Due to acute water shortages, some of the water vendors fetch drinking water from dams and swamps during the dry seasons to sell to unsuspecting customers in the urban centres. This becomes a possible source of waterborne diseases as these waters used by both man and animals (Daily Nation, October 5th 2006**,** Horizons). Studies in various parts of Kenya reveal that water shortages in urban settings has forced residents to resort to use of water supplied from vendors from questionable sources. Due to confounding factors of poverty, illiteracy and ignorance, some residents use any available water source for domestic use. This scenario is common in various parts of Kenya including and leads to indiscriminate use of any available water thus posing high risk waterborne diseases to consumers.

Efficiency of water treatment

The results revealed that efficiency of water treatment was rated 63.0 % by residents. High frequency of water rationing and the general quality of the water with respect to taste, color and turbidity were some of the features contributing to the ratings. The level of training of water supply operators is a very important determinant of quality service to consumers. The process of water treatment requires highly skilled manpower to undertake quality procedures involved in every step of the treatment process as well as final assessment of the quality of the product as far as physical, chemical and microbiological properties are concerned.
The availability of chemicals and accurate doses also contribute to quality water treatment. Despite clean, adequately chlorinated water and the widespread practice of boiling water for drinking, we found that contaminated water is consumed with remarkable frequency by many residents. Fecal contamination increased as we followed the water from its source to drinking water storage containers, (Checkley W, Gilman et al, 2004)

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