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Household Drinking Water Contamination by Escherichia Coli and Prevalence of Diarrhoea in Children Under Five Years in Baringo County, Kenya

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Abstract

Escherichia Coli (E. Coli) is widely used as an indicator of microbial water quality. Normally domiciled in human intestines, contamination of drinking water by this bacteria occurs through inappropriate sanitation and poor water handling practices. While some strains of E. Coli are harmless, others are pathogenic and can lead to diarrhoea of varying severity both in children and adults, characterised by abdominal cramps, vomiting, bloody diarrhoea. Diarrhoea remains a major cause of death among children below 5 years. This study evaluated the extent of household drinking water contamination by E. Coli and its relationship to diarrhoea incidences in children <5 years in Mogotio and Marigat sub-counties of the largely semi-arid Baringo county in Kenya. A cross-sectional survey was used to randomly select 178 households with children below 5 years and information sought on water sources and diarrheal occurrence. Water samples were collected at the point of use and analysed using the field based Compartment Bag Test (CBT). Findings show a significant relationship between E. Coli presence and diarrhoea in under-fives. Water samples from households using water from surface water sources were more likely to have a higher E. Coli MPN/100ml count compared to those from protected sources. There is need provide improved sources of water in the community and sensitise it on treatment and safe handling of water at point of use.

Keywords: Drinking Water; E. Coli; Diarrhoea; children; Kenya.

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1. Introduction

Diarrheal diseases in children under 5 years is largely associated with poor hygiene and oral exposure to contaminated water and food. *Escherichia Coli (E. Coli)* has been recognised as an important pathogen for most diarrhoeal illnesses in developing countries, and a chief cause of child mortality [1]. This has been linked to inadequate or lack of safe, clean water for consumption and hygiene, coupled with poor sanitation practices. Globally, diarrhoea is the second leading cause of death in children below five years old [2] with a mortality rate of above 525 000 children every year. Access to sanitation and safe water is globally still a challenge, more so in developing nations [3]. According to [4], 2.4 billion people on the globe lack improved sanitation facilities with seven out of ten people live in rural area with no improved sanitation facilities [1], and nine out of ten people still practice open defecation. This increase the level of microbial contamination of water sources, directly as well as through runoff into water bodies. Although most strains of *E. Coli* bacteria are harmless and exist in the intestines of people and other animals, some enteropathogenic strains are known to cause acute diarrhoea that ranges from mild and non-bloody to highly bloody [5], and this these include enterohaemorrhagic *E. Coli* (EHEC), enterotoxigenic *E. Coli* (ETEC), and enteropathogenic *E. Coli* (EPEC). While waterborne transmission of *E. Coli* is well understood, causal factors for pathogenic contamination of drinking water varies from place to place and between households. Many remote communities have no access to modern water treatment technologies and often use water as fetched from source without further treatment. Even with provision of safe water sources, contamination commonly occur between point of source and point of use [6]. Inadequate water and sanitation are normally associated with considerable risks of diarrhoeal disease [7]. Baringo County which forms the study area, largely falls in the semi-arid regions of Kenya, and is classified as a water-stressed county. Drinking water is a significant concern in the County which encounters extreme weather events fluctuating between severe drought in the predominant dry season, to severe flooding in wet seasons. Water at household level is needed for drinking, cooking and for personal hygiene. The Baringo County Integrated Development Plan [8] has documented the gastrointestinal illnesses as being the second most prevalent in the county after malarial fever, with child morbidity (≤59 months) showing those sick with watery diarrhoea disease at 18.9%, and bloody diarrhoea and fever at 1.7%. The main sources of water include dams, lakes, water pans, streams, protected shallow wells, springs, swamps, boreholes and traditional river wells [8]. The changing seasonal patterns and extremities of climate in the region invariably affects both the quality and quantity of water sources. The vastness of Baringo county, its largely hostile climate of and rural setting, makes access to safe water to be among the greatest challenges projected in the next few years. Reference [9] observed that the impact of drought on water security is an increasing concern which does not always receive the necessary attention, more so in communities that dependent on traditional rural water supplies. Further, improvements in water and sanitation do not automatically result in improvements in health. The addition of hygiene education is often required to see health impacts materialize. In light of the above factors, this study set out to undertake a rapid documentation of the extent of *E. Coli* contamination in drinking water, with the "point of use" as the main reference point, and how this corresponds to diarrhoeal cases in households with children under five years.

2. Materials and methods

2.1 Description of study site

Baringo County lies between longitudes 35° 30’ and 36° 30’ East and between latitudes 0° 10’ and 1° 40’ South (Figure 1). The study was carried out in two sub-counties (Marigat Sub-county and Mogotio Sub-County), which lie to the east of the county.

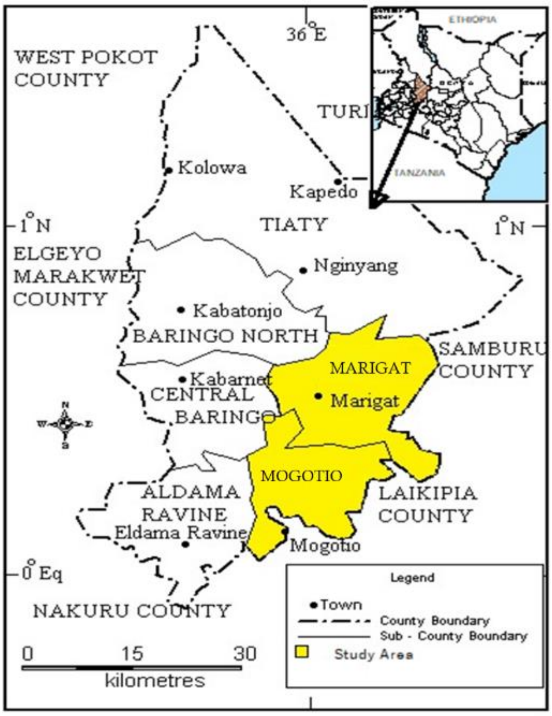

Figure 1: Map showing Marigat and Mogotio sub counties in in Baringo, Kenya

Marigat Sub-county has a population of 19,658 households while Mogotio Sub-county has 18,169 households. The two sub-counties lie in the relatively semi-arid part of the county, with annual rainfall of about 600mm per year, and temperatures between 10°C and 38°C [8]. The study was cross sectional, and collected information on diarrhoeal incidences in children under 5 years in the previous two weeks preceding the study. The sample size (n) was calculated using Cochran formula, $n = (Z^2pq)/e^2$, where *p* was based on the prevalence of diarrhoea among children under 5 years, at 18% [8]; Z =1.96, and *e*=0.05. A total of 230 households were randomly selected through stratified proportional sampling in the two sub-counties, the main inclusion criteria being the presence of at least one child under the age of 60 months.

2.2 Water sample collection and analysis

Samples of drinking water were collected within households at the point of use, i.e. when the water is fetched from container or conveying vessel for drinking. Aseptic sampling techniques were applied, and a blank (using distilled water) was included after every 20 households, for quality control. The *E. Coli* were enumerated based on MPN using the Compartment Bag Test (CBT) method. The CBT has been found to be simple, portable, rapid and validated method for measuring *E. Coli* in field environments, and is adaptable to situations where normal laboratory incubation is not easily accessible [10,11]. It can be used for rapid assessment of *E. Coli* as part of water quality monitoring programmes [12], and is able to detect and quantify the most probable number (MPN) of *E. Coli* ranging from undetectable to > 100 *E. Coli*/100 ml. Collected samples were mixed bacterial growth media (Aquagenx) to promote bacterial growth, then each transferred into a compartment bag (with 5 compartments (of 10ml, 30ml, 56ml, 3ml and 1ml respectively). The samples and blanks in compartment bags were immediately stored under ice packs, and transferred to a central location where they were incubated for 30-40 hours in a secure place at ambient room temperatures of 24°C - 36°C. MPN of *E. Coli* per 100 mL was estimated from the combination of positive (blue colour) and negative (no blue/green colour) compartments in the Compartment Bag. Changes in colour were evaluated against the *Aquagenx* Most Probable Number (MPN) Table to determine the MPN/100ml [13] and the associated WHO health risk level.

2.3 Limitations of the study

The study was conducted in a wet season towards the end of the long rains when surface water bodies are the predominant source of water. Therefore the observed data on *E. Coli* levels and diarrhoeal prevalence may not be representative of likely observations in the dry season, which is characterised by a severe scarcity of water.

3. Results and discussion

3.1 Distribution of E. Coli in drinking water

A total of 178 samples were collected and analysed for *E. Coli*, alongside 9 blanks. Of the nine blanks, none tested positive for *E. Coli*. Results indicate that 32.6% of households used safe water without any detectable *E. Coli*. Cumulatively, 43.6% households (HH) used water which was of either low or intermediate risk (Table 2), with less than 5 MPN/100ml with confidence intervals below 22/100ml.

Table 1: Distribution of MPN/100ml for household drinking water and associated risk category

MPN/100ml	No. of Households	Upper 95% Confidence Interval/100ml)	Percent	Compartment Bag Test (CBT) Health Risk Category
0	58	2.87	32.6%	Low risk/safe
1.2	4	5.64	2.2%	Intermediate risk/Probably safe
1.5	2	7.81	1.1%	
2.4	4	8.12	2.2%	
3.2	2	9.70	1.1%	
3.7	2	11.82	1.1%	Intermediate risk/Possibly safe
4.7	4	21.19	2.2%	
8.4	2	22.75	1.1%	
13.6	6	83.06	3.4%	High risk/Possibly unsafe
32.6	2	145.55	1.1%	
48.3	20	351.91	11.2%	High risk/Probably unsafe
≥100.0	72	9435.10	40.4%	Unsafe
Total	**178**		**100.0%**	

The study also revealed that 40.4% (72 HH) use water that considered unsafe, and cumulatively 56.1% (100

HH) use water considered to be outright unsafe or of high risk. Thus a relatively higher proportion of households were consuming water considered unsafe or of high risk for infection.

A higher proportion (44.9%) of the households fetch their drinking water from surface water bodies (Table 2) such as streams, ponds, shallow pans and rivers compared to other sources. These sources are likely to be contaminated by animal and human faeces [14]. Communities in the study sites are predominantly pastoralists and commonly share open water sources with domestic and wild animals. From field observations, only a handful of dams and waterpans were fenced off, and the fences were not robust enough to prevent entry of animals into such water sources. [5, 19] has established that *E. coli* normally resides in animal intestines, and is passed out the environment through excreta. This leads to contamination of water resources with the bacteria. Another likely source of contamination accounting for higher *E. coli* levels in surface water is the lack of proper sanitation in the County, with an average of only 49.8% of the population having access to some type of sanitary facilities [8] for disposal of excreta (pit and VIP latrines, flush/semi-flush toilets, etc). This means that a significant number (approximately 50.2%) use unsafe excreta disposal means including open defaecation. During rains, runoff can wash up both human and animal excreta into surface water bodies [15], consequently leading to elevated *E. Coli* levels this source of water.

Table 2: WHO health risk category based on drinking water source

Primary water Source	Households per WHO's Health Risk Category						Total
	Low risk	Intermediate risk		High risk		Unsafe	
	Safe	Probably safe	Possibly safe	Possibly unsafe	Probably unsafe	Unsafe	
Rainwater	4(2.2%)	-	-	-	-	-	4(2.2%)
Unprotected spring	-	-	-	-	-	6(3.4%)	6(3.4%)
Protected dug well	6(3.4%)	-	-	21.1%)	-	-	8(4.5%)
House/ yard tap	2(1.1%)	2(1.1%)	-	-	2(1.1%)	6(3.4%)	12(6.7%)
Water-vendors	6(3.4%)	-	-	2(1.1%)	2(1.1%)	4(2.2%)	14(7.9%)
Borehole (pumped)	10(5.6%)	-	-	-	2(1.1%)	8(4.5%)	20(11.2%)
Public tap	12(6.7%)	-	4(2.2%)	-	4(2.2%)	14(7.9%)	34(19.1%)
Surface water (pond/river/stream)	18(10.1%)	10(5.6%)	4(2.2%)	2(1.1%)	12(6.7%)	34(19.1%)	80(44.9%)
Total	58(32.6%)	12(6.7%)	8(4.5%)	6(3.4%)	22(12.4%)	72(40.4%)	178(100.0%)

A chi-square test showed a significant difference in health risk/safety between the various sources ($X^2_{(40,\ N = 178)} = 80.67$, p=0.011) implying that the type of water source could be the primary factor associated with contamination of drinking water. This however does not rule out other sources of contamination between point of collection at source to usage, since *E. Coli* was also detected in a few households that were using presumably safer water sources such as boreholes and public taps. Water treatment chemicals such as chlorine and other modern methods of making water safer are not readily available in the rural settings of communities [8] including the study sites. It has previously been demonstrated by [16] that some methods of water treatment may have low or poor acceptability to local community due to various reasons. In the study area, it was observed that some community members shun simple treatment methods such as boiling, which is claimed to interfere with taste associated to production of smoke from firewood, which is predominantly used for cooking and heating.

3.2 E. Coli contamination and prevalence of diarrhoea

As indicated in Table 3, 32.3% of 130 the households reported one or more of their children under five years having suffered from diarrhoea in the two weeks preceding the study. This was considered high, but assumed to have been exacerbated by contamination of open sources by runoff, since the study was carried out in the month of July 2018, towards the end of the rain season. It is also important to note that over 50% of the population have no toilets and many still practice open defaecation [8]. A Pearson Chi-Square test of independence showed a weak but significant association ($X^2_{(5,\ N=130)}$ =17.37; *p*= .041) between *E. Coli* contamination levels (Health risk) and diarrhoea occurrence.

Table 3: Drinking water microbial risk Category and diarrhoeal prevalence in households

	Diarrhoea in Households with children under 5 years		Total
	Present F (%)	None F (%)	
Safe *(0MPN/100ml; 95%CI ≤2.87)*	10(7.7%)	40 (30.8%)	50(38.5%)
Probably safe *(1.0-3.7MPN/100ml; 95%CI≤9.70)*	8(6.2%)	4(3.1%)	12(9.2%)
Possibly safe *(3.1-9.6MPN/100ml; 95%CI ≤37.68)*	2(1.5%)	2(1.5%)	4(3.1%)
Possibly unsafe *(13.6 -17.10 MPN/100ml; 95%CI =65-83)*	2(1.5%)	0	2(1.5%)
Probably unsafe *(32.6 – 48.3MPN/100ml; 95%CI=145.5-351.9)*	2(1.5%)	12(9.2%)	14(10.8%)
Unsafe *(>100MPN/100ml; 95%CI ≥9435.1)*	18(13.8%)	30(23.1%)	48(36.9%)
Total	42(32.3%)	88(67.7%)	130(100.0%)

Observations in Table 3 demonstrate that households whose water samples had unsafe levels of *E. Coli* (>100MPN/100ml) were slightly at higher risk of having a child with diarrhoea than those drawing water from safe sources. This observation provides further evidence on the relationship linking diarrhoeal occurrence to microbial water quality by [17], who demonstrated that children whose household drinking water samples were contaminated with progressively higher concentration had higher diarrhoea prevalence. Majority of households were using surface waters due to its affordability compared to borehole and piped water, thus are more at risk of exposure to contaminated water. It can therefore be surmised that the amount of *E. Coli* in drinking water has an influence on observed diarrhoea incidences in the study area. According to Baringo county fact sheet [8], 58.5% of the population live in absolute poverty, thus affording alternative water sources is impracticable. Poverty has been associated with poor health outcomes, as it denies access to basic sanitation by the affected communities and households. It is however, similarly important to note that in this study the association between *E. Coli* presence in drinking water and diarrhoea prevalence is positive but weak (*p*=0.041). Apparently, there was a substantial number of diarrhoeal cases occurring among children in households where drinking water had considerably "safe levels" of *E. Coli* at points of use (i.e. those using protected or pre-treated sources such as boreholes and tap water). This infers that there may be other hygiene-related factors not directly related to the inherent drinking water quality, contributing to observed diarrhoeal prevalence. This observation is supported by the findings of a similar study in Peru [18] which showed that despite over 90% of households using improved water sources, 43% of stored water samples were contaminated with *E. coli.* While such factors are numerous, field observations revealed that some of the containers for storage and drawing water at point of use were unclean and storage vessels were not always covered, and no specific efforts were made to clean hands before fetching the water. Such poor handling practices may significantly contribute to inconsistencies observed in this study. This further indicates the general lack of knowledge on ways to keep the water safe, and is reinforced by the documented low levels of literacy in the communities within the study area, at 34.5% [8].

4. Conclusion and recommendations

The results confirm that indeed *E. Coli* presence in drinking water has a significant contribution to the diarrhoeal disease burden in Mogotio and Marigat Sub counties, and hence support the use of *Escherichia Coli* as a faecal indicator for household drinking water. Children in households with unsafe *E. Coli* levels were at an increased risk of contracting diarrhoea. Surface water bodies had a consequent high level of *E. Coli* at point of use, implying little or poor treatment to make the water safer before consumption. Improved and "safer" sources are few, but some were found to have traces of *E. Coli* at point of use. It is therefore important that more improved and protected sources be developed and expanded within the communities to minimise contamination of water sources, and consequent diarrhoeal outbreaks. There is need to sensitise households on proper handling of water, especially, storage, treatment and cleanliness of any vessels or containers used in handling water.

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