

Original Research Article

CHARACTERIZATION AND DISTRIBUTION OF PATHOGENIC MICROORGANISMS ALONG KABIANGA RIVER WATER BETWEEN JANUARY AND MARCH 2016 IN KERICHO COUNTY, KENYA.

ABSTRACT

The quality of water in Kabianga river water assessed to ascertain whether it meets local and international microbiological standards for safe human consumption. Standard bacteriological techniques were used to describe bacteria content from water samples collected during different seasons. Water were highly contaminated with human pathogenic bacteria. The most dominant bacteria in both seasons was *Escherichia coli*, *salmonella*, *shigella*, *proteus*, *pseudomonas aeruginosa*. Microbiological quality of the surface water was high above the compliance level of National standards, and the World Health Organization (WHO) guidelines for drinking water. The water from this river is not potable, and poses a health risk to communities that rely on the river as the primary source of domestic use. These findings in water scarce region of the world underline the challenges a number of developing countries are facing currently and in long-term into the future. Lessons learnt from this study would suggest appropriate measures are necessary to control pollution of similar rivers in Kericho County in particular and in developing countries in general to ensure availability of clean water supplies to large population like the learning institutions and town and cities. Regular monitoring of the water microbiological quality, and public health education to avoid consumption of untreated water from this river is vital to ensure the reduced water borne disease burden in low-income regions in Kenya and developing countries.

Key words: Pathogenic, Microbiological, Coliforms, Contamination,

INTRODUCTION

Pollution of river waters with deleterious microbes, including bacteria, viruses, parasites as well as fungi has been in a steady increase in the recent past. The major source of microbes in water is feces from human and other animals. Entry of pathogens into rivers can occur either from a point source, non-point source or both. Non-point source microbial pollution of rivers occurs from rainwater surface run-offs, storm sewer spillages or over flow, while point source pollution comes from discharge of untreated or partially treated effluents from waste water treatment plants. The impact of river pollution on human depends mainly on the water use, as well as the concentration of pathogen in water. In order to reduce water borne disease outbreaks, World Health Organization (WHO) develops microbiological quality guide lines based on intended water uses. The guidelines stipulate, that fecal coliforms (FC) should not exceed 103 per 100 mL of water to be used in irrigation of crops that are eaten uncooked, sports fields and public parks in unrestricted regions (WHO, 2004). Environmental Protection Agency (EPA) is stricter and requires zero (0) FC/100 mL of water to be used in irrigation of crops not commercially processed including crops eaten raw. Kenya standard of drinking water quality states that no *Escherichia coli*, *Shigellae*, *pseudomonas aeruginosa* or coliforms should be detectable in 250 mL of drinking water. Microbial risk assessment and management of water quality is an important concern and focus of governmental regulation and scientific inquiry (WHO, 2004).

Microorganisms (bacteria, protozoa and viruses) are ubiquitous in aquatic environments. While most microorganisms are benign and serve essential ecosystem functions, some can be (or produce substances that are) harmful to ecosystem and human health. Microbially-contaminated drinking water has long been implicated in human illness and historically, attention has focused on finished (endproduct or tap) water quality. However, these strategies are increasingly regarded as insufficient to prevent disease outbreaks and more attention has been paid to preventing illness from source-to-tap (Byleveld et al., 2008; Summerscales and McBean, 2011). Furthermore, it has been increasingly noted that poor microbialwater quality can be harmful to aquatic organisms and ecosystem function (Gozlan et al., 2006; Miller et al., 2002, 2011; Weitz and Wilhelm, 2012). Human health and ecosystemhealth are implicitly related, particularlywhen considering microbial risk along the source-to-tap spectrum (Serveiss and Ohlson, 2007; Davies and Mazumder, 2003).

A comprehensive understanding of the risks (both existing and potential) to water quality can be achieved through evaluation of the entire water supply system. This concept is known as ‘source-to-tap’, whereby a high quality source, in combination with effective treatment and safe distribution, supported by legislation and ongoingwater quality testing,will yield water that is safe for human consumption. As a cornerstone of drinking water quality risk assessment (Hrudey, 2011; Krewski et al., 2002), the source-to-tap framework has, to date, been mobilized with a focus on human health. Comprehensive risk assessment and management approaches that include the entire source-to-tap gradient are more likely to successfully address not only point-source pollution but also the more complex impact of non-point sources of water contaminants within a given watershed (Phillips, 1988). Sound risk assessment and management is crucial for both drinking water provision (Byleveld et al., 2008; Hamilton et al., 2006; Jayarante, 2008) as well as broader ecosystem protection (Serveiss and Ohlson, 2007). Indeed, riskmanagement in a source to tap framework is thought to be critical given the recognition that hazards are innumerable and resources to deal with them are limited (Dominguez-Chicas and Scrimshaw, 2010; Gelting, 2009; Hamilton et al., 2006; Hrudey, 2004, 2009).

Abbreviations: MPN: Most Probable, EMB: Eosin Methylene Blue, XLD: Xylose Lysine Deoxy cholate.

METHOD AND MATERIALS

Sample Collection

Samples were collected from Kabianga River Kericho West sub- county Kenya, and were analyzed at university of Kabianga microbiology laboratory. The study site had an increased number of people living around and this river is the major source of water.

Study Design

Three sample points were identified guided by the river flow direction. The first site was some 50 meters upstream before the bridge the second site was at University pump point at the river after the bridge and the third site was down the river 100 m just after university of Kabianga sewage treatment plant. The study included laboratory analysis of samples and observation noting the various ways of waste disposal in and around the river. The specimen were drawn at

an interval of two weeks for three months. The samples of water were drawn aseptically then analyzed for coliform contamination.

Collection of water samples

Water samples to be analyzed were collected in sterilized 250 mL plastic bottles pre-cleaned and rinsed in distilled water. The samples were unfiltered and unpreserved before analysis. Samples were aseptically removed the cap of the sterile sample bottle and faced the mouth of the bottle upstream. The neck was Plunged downwards about 30 cm below the water surface, and then tilted slightly upwards to let it fill completely before carefully replacing the cap ,Labeled the sample with the sample code number , location of collection , date and time of collection. Immediately after collection, sample were placed in a black polythene bag for transport to the testing laboratory. Water samples were examined within 24hours of collection and was kept at 4°C, refrigerator.

Isolation of Microorganisms

The number of coliforms in water were determined by statistical estimation. Most probable number (MPN) This test involves a multiple series of Durham fermentation tubes and is divided into three parts: The presumptive, Confirmed and Completed test.

Presumptive Test

In presumptive test, dilution from the water samples were added to lactose broth fermentation tubes. Each tube received a water volume of 10 mL in double strength lactose broth, 1 mL or 0.1mL in single strength lactose broth. The tubes were incubated at 35°C and observed after 24 hours and 48 hours for evidence of gas production.

Confirmed Test

In the confirmed test one transfers material from the highest dilution of those lactose broth tubes that showed growth and gas production were streaked onto Eosin methylene blue (EMB) agar plates. EMB prevents growth of Gram-positive organisms. Coliforms which are Gram-negative produce acid; under acidic conditions the Eosin and methylene blue dyes are absorbed by the organisms of a colony.

Completed Test

In the completed test, the colonies formed were inoculated into lactose broth and agar slants. The production of acid and gas in the lactose broth and microscopic identification of Gram-negative, on-spore-forming rods from slants constitute a positive completed test.

Isolation and Identification of Coliforms using Eosin Methylene Blue Agar (EMB)

The media was prepared aseptically following manufacturer's instructions, sterilized and dispensed in the plates. Samples from the positive completed test were cultured on the EMB,

117 observing all aseptic techniques. The colonies that grew on EMB appeared pink mucoid and
118 entire. Green metallic sheen. Pink colonies with dark center and pink/white colonies. This
119 appeared in all samples collected during rainy season and dry season except for samples
120 collected during dry season that appeared pink mucoid and white colonies there was no E.coli.
121 The colonies from EMB were further sub-cultured in MacConkey, salmonella shigella media and
122 Xylose Lysine Deoxycholate agar (XLD)

123 **Isolation using MacConkey**

124 The colonies that grew in EMB were further sub-cultured in MacConkey as follows. Colonies
125 that appeared white in EMB plate, were pink colonies in MacConkey, while others were white
126 colonies. Pink dark centered in EMB plate, appeared pink/white colonies that were mucoid,
127 which appeared moist and showed two characteristics that is small and large pink colonies. The
128 pink colonies in EMB plate, appeared small mucoid pink colonies while others were rough dry
129 pink colonies. These colonies were further sub-cultured in salmonella shigella media.

130 **Xylose Lysine Deoxycholate (XLD) Agar**

131 The colonies from EMB plate that appeared pink dark centered, appeared white mucoid with
132 entire margin, white mucoid pulvinate with an entire margin. The media turned yellow. This is a
133 selective media for isolation of salmonella and shigella species. It is also used to isolate other
134 enter bacteria. Microorganisms like *Pseudomonas aeruginosa* colonies have similar characteristics
135 with salmonella. Therefore need to subculture in salmonella Shigella media.

136 **Isolation using Salmonella Shigella Agar**

137 The colonies from XLD plate that appeared white were transparent large and entire colonies in
138 SS media. Dark centered pink colonies in XLD plate were transparent/ white mucoid colonies
139 .The pink colonies in XLD plate were pink and dry. The colonies that appeared pink in EMB,
140 turned back raised mucoid colonies indicating presence of salmonella and the pink colonies
141 indicate presence of shigella, and the pink colonies in EMB turned black raised mucoid colonies
142 indicating that the colonies were salmonella .The colonies in MacConkey were pink with a
143 characteristic smell.

144 **Motility**

145 The colonies from EMB, were picked and stabbed into the media. Non -motile colonies only
146 grew on the stab. The motile grew along the stab and swum out away from the stabbed area.

147 **Morphological and Biochemical Tests**

148 Microorganisms displayed diversity of cell arrangements. Microorganisms' morphologies were
149 classified by direct examination with the light microscope and the staining characteristics by
150 gram stain, which classified microorganisms into gram negative and morphologically as bacilli.

151 **Triple Sugar Ion Test**

152 The media was prepared according to manufacturer's instructions, dispensed into bacteriological
153 tubes and sterilized in an autoclave. Then it was cooled in a slanting position to make a slant.
154 Colonies from salmonella shigella plate and XLD plate were inoculated unto the tubes and
155 incubated for 48 hours. After which the results were read.

156 **Simmons Citrate Tests**

157 The media was prepared according to manufacturer's instructions, dispensed into bacteriological
158 tubes and sterilized in an autoclave. Then it was cooled in a slanting position to make a slant.
159 Colonies from salmonella shigella and XLD were inoculated unto the tubes and incubated for 48
160 hours. After which the results were read.

161 **Oxidase Test**

162 Oxidise discs were moistened using distilled water then a colony was picked from EMB plate
163 those that were appearing pink dry and from MacConkey plate that appeared pink and those
164 from XLD plate were smeared on the discs. After 3min an observation was done.

165 **RESULTS AND DISCUSSION**

166 **Isolation of Microorganisms**

167 Multiple tube fermentation test (MTFT)

168 **Presumptive Test**

169 In presumptive test, dilution from the water samples were added to lactose broth fermentation
170 tubes. Each tube received a water volume of 10 mL in double strength lactose broth, 1mL or 0.1
171 mL in single strength lactose broth. The tubes were incubated at 35 °C and observed after 24
172 hours and 48 hours for evidence of gas production as in Table 1.

173 **Table 1: Presumptive Test dry season**

Sample points	Number of positive tubes	3 tubes BSLB 10 mL	3 tubes SSLB 1 mL	3 tubes SSLB0.1ML	MPN
Sample1	T1	3	3	1	460
	T2	3	3	1	460
	T3	3	2	1	150
Sample 2	T1	3	3	0	240
	T2	3	2	0	93
	T3	3	2	1	150
Sample 3	3	3	3	1	460

	3	3	3	1	460
	3	3	2	1	150

174 **Table 2: Presumptive test Rainy season**

Sample points	Number of positive tubes	3 tubes BSLB 10ml	3 tubes SSLB 1ml	3 tubes SSLB0.1ML	MPN
Sample1	T1	3	2	2	210
	T2	3	3	2	1100
	T3	3	2	2	150
Sample 2	T1	3	3	2	1100
	T2	3	2	0	93
	T3	3	2	2	210
Sample 3	3	3	3	2	1100
	3	3	3	2	1100
	3	3	3	2	1100

175 **Confirmed Test**

176 In the confirmed test one transfers material from the highest dilution of those lactose broth tubes
177 that showed growth and gas production were streaked onto Eosin methylene blue (EMB) agar
178 plates. EMB prevents growth of Gram-positive organisms. Coliforms which are Gram- negative
179 produce acid; under acidic conditions the Eosin and methylene blue dyes are absorbed by the
180 organisms of a colony.

181 **Completed Test**

182 In the completed test, the colonies formed were inoculated into lactose broth and agar slants. The
183 production of acid and gas in the lactose broth and microscopic indicated the presence of Gram -
184 negative, non-spore-forming rods from slants constitute a positive completed test.

185 **Eosin Methylene Blue Agar (EMB)**

186 There was growth of different colonies in the media .The colonies were pink with dark center
187 (Figure 1), mucoid and entire margin, and greenish with metallic sheen and pink mucoid with
188 entire margin. Since EMB is a selective media for gram negative bacteria ,The bacteria which
189 fermented lactose in the medium formed colored colonies ,while those that did not ferment
190 glucose appeared as colorless colonies .EMB agar is used to distinguish coliforms and fecal
191 coliforms that signal the possible pathogenic microorganism contamination in water samples.
192 EMB is also used to differentiate in the colon-typhoid -dysentery group: Escherichia coli
193 colonies grow with metallic sheen, with dark Centre and non-lactose fermenting gram negative
194 bacteria appear pink.



Figure 1: Growth of different media

Using MacConkey Results

The colonies that were transferred from EMB were grayish small mucoid with entire margin, pink large mucoid with entire margin, dry rough pink colonies, however in another plate the pink colonies were small and large with the same characteristics, and since MacConkey is a selective media for isolating gram-negative bacteria and other enteric bacilli, The agar distinguishes those gram negative bacteria that can ferment glucose from those that cannot ferment glucose. Lac ⁺bacteria such as *Escherichia coli* and *klebsiella* produced acid which lowered the PH of the agar to 6.8 and result in appearance of pink colonies. Lac-Non-lactose fermenting bacteria such as salmonella, *proteus* species, *pseudomonas aeruginosa* and shigella cannot utilize lactose and used peptone water instead. This forms ammonia, which raises the PH of the agar and leads to formation of white/colorless colonies on the plate. Some organisms, especially *klebsiella* produced mucoid colonies

Xylose Lysine Deoxycholate Results

The pink dark centered colonies from EMB plate, appeared white mucoid with entire margin, white mucoid pulvinate with an entire margin. The media turned yellow. XLD is a selective medium used in the isolation of salmonella and shigella species in water .It has a PH of 7.4 leaving it with a bright pink or red appearance due to the indicator phenol red, sugar fermentation lowers the PH and the indicator registers this by changing to yellow. Salmonella ferment the sugar xylose to produce acid shigella colonies cannot do this and therefore remain red. Salmonella metabolize thiosulphate to produce hydrogen sulphide which lead to the formation of colonies with black centers and allows them to be differentiated from similarly colored shigella colonies. Salmonella species- Red colonies some with black centers the agar itself will turn red. Shigella species - Red colonies, *pseudomonas aeruginosa*- Pink flat, rough colonies.



Figure 2: Colonies growth on different media.

Salmonella Shigella Results

The colonies from XLD plate that appeared white were transparent large and entire colonies in SS media. Dark centered pink colonies in XLD plate were transparent/ white mucoid colonies. The pink colonies in XLD plate were pink and dry.



Figure 3: Salmonella Shigella plates showing growth of microorganisms.

The colonies that appeared pink in EMB, turned black raised mucoid colonies indicating presence of salmonella and the pink colonies indicated the presence of shigella. The colonies in MacConkey were pink with a characteristic smell. Salmonella Shigella agar is selective and differential media widely used to isolate salmonella and shigella. Inhibition of gram positive microorganisms is obtained by bile salt mixture. The bile salts select for gram negative bacteria the other components differentiate among gram negative bacteria coliform bacteria such as E.coli fermented the lactose in media resulting in bacterial growth with a pink color. Members of the genus salmonella did not ferment lactose but produced hydrogen sulphide gas. The resulting bacteria colonies appeared colorless with black centers. Shigella do not ferment lactose or produce hydrogen sulphide gas the resulting colonies were colorless (Figure 4).



239

240 **Figure 4: Plates with growth of *Salmonella***

241 Sulphide and some pink colonies in the first plate from left indicate presence of *Shigella*, they do
242 not produce hydrogen sulphide.

243 **Motility**

244 The samples positive samples from presumptive test, were cultured in motility media .The
245 samples from sample point 1 and 3 showed positive results for motility. Motile organisms extend
246 from the stab line and produced turbidity throughout the media. Non-motile organism from
247 sample point 2 grew only along the stab line and leave the surrounding media clear. The two
248 samples that showed presence of motile organisms were from sample point 1 and 3 during rainy
249 season. This was attributed to the fact that more runoffs enter the river at these points and that
250 the population around these point are high compared to sample point 2. The isolated organism
251 was *proteus* spp.

252 **Morphological and Biochemical Tests**

253 Microorganisms displayed diversity of cell arrangements. Microorganisms' morphologies were
254 classified by direct examination with the light microscope and the staining characteristics by
255 gram stain, which classified microorganisms into gram negative and morphologically as bacilli.

256 **Biochemical tests**

257 These tests, test the ability of microorganisms to ferment sugar present in the media or its ability
258 to use other components like citrate in Simmons citrate media as a source of carbon and energy.

259 **Simmons Citrate agar test**

260 The tubes which were inoculated with colonies from SS had a blue slant and a green butt same to
261 those obtained from XLD plate. The small mucoid colonies obtained from XLD plate, the part
262 that there was no fermentation of xylose sugar had a blue slant and a green butt showed that
263 citrate was utilized .The only organism that utilizes the citrate and not the sugar in TSI is
264 *pseudomonas aeruginosa*.

Simmons citrate agar test for the ability of the gram negative organisms to import citrate for use as the sole carbon source and energy source .Only bacteria that can utilize citrate as the sole carbon and energy source will be able to grow on the Simmons citrate medium, thus a citrate negative test culture will be virtually distinguishable from an uninoculated slant.

Simmons citrate -blue is a positive citrate test while green is negative/no growth (Figure 5 and 6).

The increase in PH then causes color change in the bromothymol blue indicator turning it to blue .Under neutral conditions the medium remains green color, the color change to blue is useful because the growth on Simmons citrate agar is often limited and would be hard to observe if it were not for the color change. Bacteria that develop in such media are *Salmonella* and *Providencia*



Figure 5: Positive tube

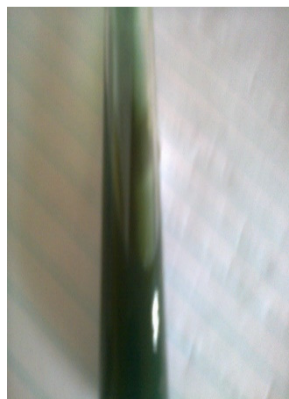
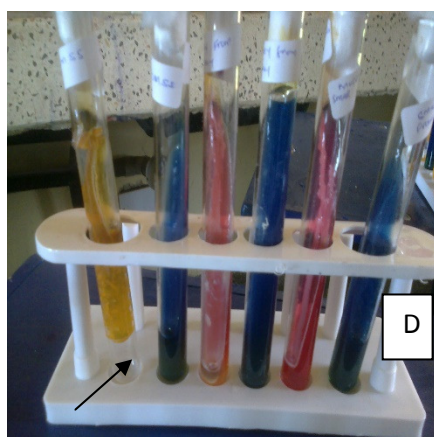
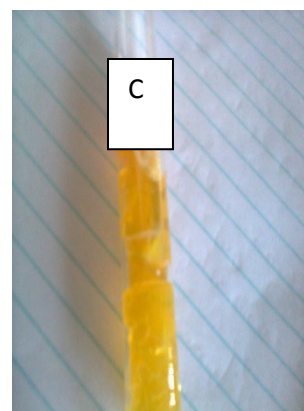
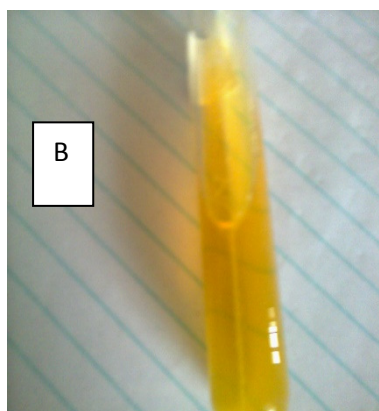
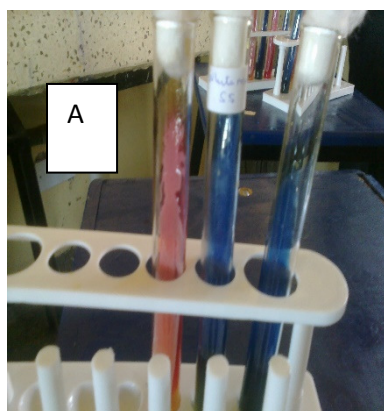


Figure 6: Negative tubes

Triple Sugar Iron Tests

The colonies that were transferred from XLD plate which were small pink colonies, appeared red indicating that there was no utilization of the sugars and the only organism that do not utilize sugars is *pseudomonas aeurogenosa*. Other were able to utilize either glucose or sucrose appearing as red slant and yellow butt or yellow slant with yellow butt. Triple sugar iron test, tests the ability of microorganisms to ferment sugar and produce hydrogen sulfide. It is used as selective identification of enteric bacteria including salmonella and shigella. The bacteria that is non-lactose fermenter and ferments glucose alone causes red slant/ yellow butt. Blackening of the butt is due to production of hydrogen sulfide is due to utilization of glucose only. Yellow slant/yellow butt, lactose or sucrose fermentation has occurred. Red slant/red but no carbohydrate fermentation has occurred. Carbon dioxide production is recognized as bubbles of gas between the agar and the wall of the tube or within agar itself. The carbon dioxide production is sufficient to split the agar into two or more sections. The microorganisms that were isolated, none of them produced hydrogen sulphide.



KEY

A- Tube 1 from left red slant yellow butt, no gas production only glucose utilized -organisms *Salmolla and Shigella*.

B-Yellow slant yellow but no gas production all sugars utilized organism-*serratia*

C-Yellow butt red slant there was gas production only glucose utilized organism-*Escherichia, Shigella*

D-Tube 1 from left Yellow butt yellow slant gas production-organism *Enterobacter, Klebsiella*.

Tube 3and 5 from left-No sugar was utilized entire tube red that is red slant red butt-organism *Pseudomonas aeruginosa*

Oxidase Test

The small dry pink colonies from SS plate were oxidase positive. There was a color change to dark blue/purple. This means the bacterium contains cytochrome producing intracellular oxidase enzyme. This oxidase enzyme catalyzes the oxidation of cytochrome c turning reagent color to blue/purple. Organisms lacking cytochrome c as part of thir respiratory chain do not oxidize the reagent, leaving it colorless within the limit of the test, and are oxidase negative. The

309 cytochrome system is usually only present in aerobic organism which are capable of using
 310 oxygen as the final hydrogen acceptor. The end product of this metabolism is either water or
 311 hydrogen peroxide. Oxidase positive organism found was *Pseudomonas aeruginosa*

312 **Table 3: Bacterial types in Kabianga River during dry season**

Bacterial type	Upstream	Midstream	Downstream
<i>Escherichia coli</i>	6.8x $10^3 \pm 1.2 \times 10^3$	5.8x $10^3 \pm 1.2 \times 10^3$	6.8x $10^3 \pm 1.2 \times 10^3$
<i>Salmonella spp</i>	$1.3 \times 10^3 \pm 1.1 \times 10^3$	$1.3 \times 10^3 \pm 1.1 \times 10^3$	$1.3 \times 10^3 \pm 1.1 \times 10^3$
<i>Shigella spp</i>	$1.3 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$1.3 \times 10^2 \pm 1.1 \times 10^2$
<i>Pseudomona aeruginosa</i>	$1.2 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$1.2 \times 10^2 \pm 1.1 \times 10^2$
<i>Proteus mirabilis</i>	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$0.9 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$
<i>Klebsiella</i>	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$0.9 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$
<i>Enterobacter</i>	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$0.9 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$

313 **Table 4: Bacterial types in Kabianga River during Rainy season**

Bacterial type	upstream	Midstream	Downstream
<i>Escherichia</i>	9.8x $10^3 \pm 1.2 \times 10^3$	5.8x $10^3 \pm 1.2 \times 10^3$	9.8x $10^3 \pm 1.2 \times 10^3$
<i>Salmonella spp</i>	$2.3 \times 10^3 \pm 1.1 \times 10^3$	$1.3 \times 10^3 \pm 1.1 \times 10^3$	$2.3 \times 10^3 \pm 1.1 \times 10^3$
<i>Shigella spp</i>	$2.3 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$2.3 \times 10^2 \pm 1.1 \times 10^2$
<i>Pseudomona aeruginosa</i>	$2.2 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$2.2 \times 10^2 \pm 1.1 \times 10^2$
<i>Proteus mirabilis</i>	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$0.9 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$
<i>Klebsiella</i>	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$0.9 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$
<i>Enterobacter</i>	$1.1 \times 10^2 \pm 1.1 \times 10^2$	$0.9 \times 10^2 \pm 1.1 \times 10^2$	$1.1 \times 10^2 \pm 1.1 \times 10^2$

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316 CONCLUSION

317 Microbiological quality of the surface water was high above the compliance level of National
318 standards, and the World Health Organization (WHO) guidelines for drinking water. The water
319 from this river is not potable, and poses a health risk to communities that rely on the river as the
320 primary source of domestic use.

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