Microbial contamination of environmental, food and treated water samples in 
Nakuru North Sub-county, Kenya

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ABSTRACT

Nakuru North sub-county is located 160 Km Northwest of Nairobi at an altitude of 1859 m above sea level. It has an area of 593 Km² with a population density of 25.3 per Km². The residents often suffer from diarrhoeal diseases which could possibly be due to intake of contaminated foods. The study was aimed at determining the microbial levels of raw cow’s milk, animal intestinal wastes, fruits and vegetable salads, waste water and drinking water. A total of 896 samples; raw cow’s milk (112), animal intestinal waste (112), fruits and vegetable salads (112), waste water (112) and boiled (112), chlorinated (112), filtered (112) and solar disinfected (112) waters were collected and analyzed between May 2012 and April 2013. The microorganisms isolated were confirmed using biochemical tests. Out of the eight hundred and ninety six (896) samples examined 28.1 % (252/896) were positive for all the microbial isolates. The prevalence of total coliforms was 100 %, Salmonella (33 %) and E. coli 32.1 %. Total coliforms showed the highest mean resistance (26.0 %) followed by Salmonella (16.9 %) while E. coli showed the least mean resistance (15.5 %). However, there was no significant deference (p = 0.98) in resistance among total coliforms, Salmonella and E. coli at 0.05 level of significant. Foods, environmental and treated water samples are highly contaminated with microorganisms hence they are a great public health problem in the area. We recommend prudent waste disposal in order to control cross contamination in curbing this problem.

Key words: Antimicrobial resistance, Isolation, Microbial contamination, Nakuru.
INTRODUCTION

Diarrhoeal diseases due to enteric bacteria are on the increase with the increasing human population in Nakuru North sub-county. This creates a need for determining the cause of this menace before it escalates to a serious outbreak that will result in massive loss of lives (23). The major source of contamination in foods, environmental samples and treated water is human and animal faeces. Previous studies indicate that 2.4 billion people lack facilities for safe waste disposal (27). Fecal bacteria are brought into the environments mainly through treated waste water (47). In addition, untreated wastewater release, surface runoffs and soil leaching are other sources of contamination (21). Raw cow’s milk is a highly nutritious and valuable human food and is consumed on daily basis by many people in Nakuru North (32). It contains most of the nutrients such as carbohydrates, proteins, fats, vitamins and minerals required for the growth of microorganisms, combined with high water activity. Raw milk contains microorganisms capable of causing diseases (18). In the livestock sector, different types of farm animals carry a large number of pathogens that are capable of causing disease in humans. In Nakuru north majority of animals slaughtered come from villages with low levels of basic hygiene. These areas also lack veterinary services that could significantly reduce the spread of the diseases (49). In most cases Livestock act as carriers of disease causing microorganisms (11).

In Nakuru North, over seventy five households use animal wastes as manure in their farms without treatment (23). With the high levels of pathogens in animal wastes, these manure act as contaminants of fruits and vegetables in the farm. Further contamination of fruits and vegetables occur when they are on transit to the market. The situation is worsened by the absence of sewerage systems for safe waste water disposal (30). The recycling of waste water in Nakuru North increases the occurrence of pathogens in the environment. This is evidenced by the isolation of Salmonella from bottled and waste water (9). Previous studies have also isolated Vibrio and Salmonella in waste and drinking waters (27). Access to safe drinking water is essential for healthy living. Studies by Kenya Food Security Steering Group (KFSSG) indicate that 60 % of people living in Nakuru North Sub-county are aware of reduced microbial infection when drinking water is treated (23). Despite this, cases of enteric diseases are on the increase. This made it important to determine the physico-chemical properties and analyze the microbial content of water that had been treated and stored in the study area.

One of the methods that is commonly used in water treatment world over is boiling. Boiling kills all microorganisms in water when the temperature reaches 100 degrees Celsius (12). For this method of water treatment to be effective, it is recommended that water be allowed to boil for up to a minimum of 1 minute (36). For every 1000 feet above sea level, one minute of boiling should be added to the initial 1 minute (10). However, the method requires fuel which is expensive to get for most residents of Nakuru North (42). Chlorination is the most widely used chemical method in Nakuru North Sub-county for water disinfection because it is simple in application and it does not require the use of fire wood which has become scarce in the recent past (48). In this method, gaseous chlorine (Cl₂) or liquid sodium hypochlorite bleach, (NaOCl) is added to, and reacts with water to form hypochlorous acid. The acid forms strong oxidizing agents in water which react with a wide variety of microorganisms (41).

Among the various water filtration methods in use in Nakuru North, the most widely used is ceramic water filtration, which employs the use of candle-filters (25). Microorganisms are removed from water as it passes through the filter from the top compartment to the lower compartment which stores the water up to when it is used. To enhance the effectiveness of filtration, the filters...
are impregnated with silver nitrate or colloidal silver which are bacteriostatic (33). Previous studies have shown that design of the filters, method of filter production and quality vary from one manufacturer to another which may lead to variation in effectiveness of the method in water treatment (19). Although solar disinfection (SODIS) has gained a lot of popularity elsewhere in the world, the method is not used in Nakuru North (43). This was the reason for setting up an SODIS experiment to verify whether the method could work in the study area. However, unlike other methods of water treatment which require capital investment, this method involves recycling of Poly Ethylene Terephthalate (PET) bottles which could be an environmental hazard if left lying in the environment (46). In this method, disinfection is carried out by the action of ultra violet rays and temperature on the cell membranes of the microorganisms (37).

The presence of pathogenic enteric micro-organisms in foods, the environment and treated water are a source of diseases when ingested. This becomes worse when the microorganisms are antibiotic resistant because the diseases are hard to treat (22). In addition, such microorganism may transmit the resistance to other bacteria present in the same environment. This occurs through transfer of resistant genes by plasmids (47). Fecal indicator organisms such as total coliforms and E. coli are used to determine the presence or absence of groups of pathogens associated with foods and environmental samples (44). Such bacteria mostly occur in the faeces and intestines of warm blooded mammals. Although the organisms may not be pathogenic themselves they give an indication of the level of contamination in foods, environmental samples and treated water (12). The main objective of this study was to determine the abundance of total coliforms and E. coli as indicators of contamination and to also isolate Salmonella in raw cow’s milk, animal intestinal wastes, fruits and vegetable salads, waste water and in treated water. The study also aimed at determining the antimicrobial resistance of the isolates.

**METHODOLOGY**

**Sample Collection**

A total of 896 samples, 112 samples each of vegetables and fruits salads, raw milk from milk kiosks, intestinal wastes from butcheries, waste water samples from the surrounding environment and treated drinking water by the households which had been interviewed on methods of water treatment that they use and from solar disinfection (SODIS) experiment that was set up in the study area were collected. The study population was selected using random sampling. Samples were collected using sterile specimen bottles, the temperature and pH were determined from milk, fruits and vegetable salads, intestinal wastes, and waste water at the point of collection. The samples were transported to Rift valley regional water testing laboratories in Nakuru town. They were stored at 4°C until processing.

**Isolation of Microorganisms from Solid Samples**

Briefly, 25 g of fruit and vegetable salads and intestinal wastes were each taken and placed in different sterile stomacher bags containing 225 ml of buffered peptone water (Sifin, Germany) and homogenized using a laboratory blender (Stomacher 400, Seward, England) for 2 min. Serial dilution to 10^-6 was carried out. For isolation of Salmonella, 0.1 ml aliquot of the pre-enrichment broths using peptone water was transferred aseptically into 10 ml of selenite F broth for 24 h at 37°C (15). The samples were separately streaked on xylose lexine desoxycholate and Salmonella Shigella agar. One ml of each homogenate was separately transferred to 9 ml of normal saline in isolating total coliforms. For pour plating 1 ml of each sample was pipetted on in separate petri dishes before addition of MacConkey agar, swirled and incubated at 45°C following serial dilution.
to 10-6. After 1 h, the microorganisms were sub cultured in 15 ml of Violet red bile agar kept at 45°C in separate Petri dishes. The dishes were inverted and incubated at 37 °C for 24 h. For confirmation, colonies were inoculated in to brilliant green bile broth and incubated at 37 °C for 48 h and production of gas and turbidity was observed [24]. For isolation of *E. coli*, the filters were placed on Eosine methylene blue (EMB) agar for 24 h at 37 °C. Blue-black colonies having a greenish metallic sheen were streaked onto blood agar plates and incubated for 24 h at 37 °C. All the microbial isolates were confirmed using biochemical tests.

**Isolation of Microorganisms from Liquid Samples**

Milk and waste water were first serially diluted to 10^-6. Following this, 100 ml each of milk, waste water, boiled, chlorinated, filtered and water that had been treated using SODIS were filtered using 0.22 μm cellulose nitrate membranes (Whatman GmbH, Germany). For isolation and enumeration of *Salmonella* species, petri-dishes containing *Salmonella-Shigella* agar were inoculated and incubated at 37 °C for 24 h [31]. Total coliforms were isolated by placing the filters aseptically on MacConkey agar in separate petri dishes. The dishes were inverted and incubated at 37 °C for 24 h. For isolation of *E. coli*, the filters were placed on Eosine methylene blue (EMB) agar for 24 h at 37 °C. Blue-black colonies having a greenish metallic sheen were streaked onto blood agar plates and incubated for 24 h at 37 °C. Isolated colonies were confirmed as *E. coli* using biochemical tests.

**Solar Disinfection Experiment**

An experimental design adopted from (34) was used in order to investigate the effectiveness of the method in the study area. Three sets labeled A, B and C each having 6 bottles were used. Set A had water that had been treated by boiling and found to be infected with microorganisms, B had water inoculated with previously isolated total coliforms and commercially obtained *E. coli* (ATCC 25922) and *Salmonella* (ATCC 6539) while C was a control with contaminated water. Set A and B were exposed to sunlight for 5 h while set C was kept in the dark. *Salmonella* analysis was carried out on hourly basis. Exposure to sunlight was carried out for five continuous hours starting at 10 a.m each day for 90 sunny days (21).

**Antimicrobial Sensitivity Testing**

The antimicrobial susceptibility testing was carried out by the use of Kirby Bauer disk diffusion method as described by the Clinical and Laboratory Standards Institute (CLSI) (7). The zones of inhibition were measured in millimeters and graded according to sensitive, intermediate or resistant (6).

**Data Analysis**

Statistical package for social sciences software version 17.0 was used in statistical analysis. Spearman’s rank correlation test was used to establish the relationship between the number of microbial isolates and the parameters under study. ANOVA was used to compare the means of physico-chemical parameters and microbial isolates between the various sampling regions while Tukey’s Honest significance was used to separate the means at a significance level of 5 %.
RESULTS

Temperature and PH

The milk temperature ranged from 18.4 °C in Bahati to 16.0 °C in Kabatini. In intestinal wastes, the temperature varied from 21.1 °C in Bahati to 17.6 °C in Bahati. The temperature in fruits and vegetable salads varied from 21.6 °C in Bahati to 17.8 °C in Kabatini while in waste water, the range was 21.1 °C in Maili 5 to 17.6 °C in Kabatini. The pH varied from 7.4 in Kabatini to 6.8 in Bahati in raw milk. The highest pH was 5.8 in Maili 5 while the lowest was 4.8 in Kabatini in intestinal wastes. In fruits and vegetable salads, the pH ranged from 5.6 in Maili 5 to 4.3 in Kabatini. The pH in waste water ranged from 5.3 in Kabatini to 4.7 in Bahati and Kabatini. There was no significant difference in mean temperature (p > 0.05) and pH (p > 0.05) between Maili 5, Bahati and Kabatini. A correlation study between the isolated microorganisms to temperature and pH indicated no significant relationship (Table 1).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Microbial type</th>
<th>No. of microorganisms</th>
<th>Temp (°C)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Maili 5</td>
<td>Bahati</td>
<td>Kabatini</td>
</tr>
<tr>
<td>Milk</td>
<td>Salmonella</td>
<td>1.0 x10⁴</td>
<td>1.0x10³</td>
<td>1.0x10³</td>
</tr>
<tr>
<td></td>
<td>T. coliforms</td>
<td>2.4x10⁴</td>
<td>3.2x10⁴</td>
<td>1.5x10⁴</td>
</tr>
<tr>
<td></td>
<td>E. coli</td>
<td>3.2x10⁴</td>
<td>4.1x10⁴</td>
<td>3.0x10⁴</td>
</tr>
<tr>
<td>Int. wastes</td>
<td>Salmonella</td>
<td>3.2x10⁴</td>
<td>2.6x10⁴</td>
<td>2.5x10⁴</td>
</tr>
<tr>
<td></td>
<td>T. coliforms</td>
<td>3.2x10⁴</td>
<td>2.2x10⁴</td>
<td>1.8x10⁴</td>
</tr>
<tr>
<td></td>
<td>E. coli</td>
<td>4.1x10⁴</td>
<td>3.3x10⁴</td>
<td>4.0x10⁴</td>
</tr>
<tr>
<td>FV salads</td>
<td>Salmonella</td>
<td>1.5x10⁴</td>
<td>2.4x10⁴</td>
<td>1.8x10⁴</td>
</tr>
<tr>
<td></td>
<td>T. coliforms</td>
<td>4.6x10⁴</td>
<td>4.4x10⁴</td>
<td>4.3x10⁴</td>
</tr>
<tr>
<td></td>
<td>E. coli</td>
<td>5.1x10⁴</td>
<td>4.7x10⁴</td>
<td>4.8x10⁴</td>
</tr>
<tr>
<td>W. water</td>
<td>Salmonella</td>
<td>2.3x10⁵</td>
<td>1.2x10⁵</td>
<td>1.4x10⁵</td>
</tr>
<tr>
<td></td>
<td>T. coliforms</td>
<td>3.9x10⁵</td>
<td>3.3x10⁵</td>
<td>4.0x10⁵</td>
</tr>
<tr>
<td></td>
<td>E. coli</td>
<td>3.4x10⁵</td>
<td>4.3x10⁵</td>
<td>3.6x10⁵</td>
</tr>
</tbody>
</table>

Table 1: Microbial counts of foods and environmental samples, temperature and pH from Kabatini Maili 5, Bahati and Kabatini in Nakuru North Sub-county from May 2012 to April 2013

Int. wastes, intestinal wastes; FV salads, fruits and vegetable salads; W. water, waste water; T. coliforms, total coliforms, Ap counts, aerobic plate count; Temp, temperature.

Microbial Load of Milk, Intestinal Wastes, Fruit and Vegetable Salads and Waste Water

Raw milk from Maili 5, Bahati and Kabatini was assessed for the presence of microorganisms. The average Salmonella load from Maili 5 was 1.3 x 10⁴ cfu/100 ml which was higher than that in Bahati and Kabatini (1.0x10⁴). Bahati registered the highest average total coliforms (3.2x10⁴) in milk than Maili 5 (2.4x10⁴) and Kabatini (1.5x10⁴). The E. coli were 4.1x10⁴ in Bahati which was
higher than in Maili 5 ($3.2 \times 10^4$) and Kabatini ($3.0 \times 10^4$) (Table 1). The difference in microbial means obtained from raw cow’s milk in the three sampling sites were not statistically significant ($P > 0.05$).

The mean *Salmonella* isolates from animal intestinal wastes in Maili 5 was $3.2 \times 10^4$ which was higher than in Bahati ($2.6 \times 10^4$) and Kabatini ($2.5 \times 10^4$). The average total coliforms were $3.2 \times 10^4$ in Maili 5 which was higher than in Bahati ($2.2 \times 10^4$) and Kabatini ($1.8 \times 10^4$). The *E. coli* were highest in Maili 5 ($4.1 \times 10^4$), followed by Kabatini ($4.0 \times 10^4$) while the least was in Bahati ($3.3 \times 10^4$) (Table 1). The microbial mean differences obtained from intestinal wastes in Maili 5, Bahati and Kabatini were not statistically significant ($P > 0.05$).

The results of *Salmonella* isolation from fruit and vegetable salads indicated that Bahati had $2.4 \times 10^4$ isolates which was higher than in Maili 5 ($1.5 \times 10^4$) and in Kabatini ($1.8 \times 10^4$). The average total coliforms in Maili 5 was $4.6 \times 10^4$ which was higher than in Bahati ($4.4 \times 10^4$) and also in Kabatini ($4.3 \times 10^4$). Maili 5 also registered the highest *E. coli* followed by Kabatini ($4.8 \times 10^4$) while the least was in Bahati ($4.1 \times 10^4$) (Table 1). The difference in mean microbial counts in the three sampling site was not statistically significant ($P > 0.05$).

The *Salmonella* isolates from waste water in Maili 5 were $2.3 \times 10^5$ which was higher than in Bahati ($1.2 \times 10^5$) and Kabatini ($1.4 \times 10^5$). In isolation of total coliforms, Kabatini had an average of $4.0 \times 10^4$ which was higher than Maili 5 ($3.9 \times 10^4$) and Bahati ($3.3 \times 10^4$). Bahati had an average of $4.3 \times 10^5$ *E. coli* from waste water which was higher than in Maili 5 ($3.4 \times 10^5$) and Cabatini ($3.6 \times 10^5$) (Table 1).

**Table 2:** Colony forming units of microbes from stored water after boiling, chlorination and filtration in Nakuru North from May 2012 to April 2013. A, rainy season; B, dry season.

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Boiling</th>
<th>Chlorination</th>
<th>Filtration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T. coli ($\times 10^4$)</td>
<td><em>E. coli</em> ($\times 10^4$)</td>
<td><em>Salmonella</em> ($\times 10^4$)</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Kabazi</td>
<td>9.0</td>
<td>8.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Kirima</td>
<td>6.0</td>
<td>8.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Solai</td>
<td>5.0</td>
<td>6.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Green</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Maili 9</td>
<td>5.0</td>
<td>7.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Murunyu</td>
<td>8.0</td>
<td>6.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Maili 7</td>
<td>7.0</td>
<td>8.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Nyandundo</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Scheme</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Workers</td>
<td>4.0</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Mean</td>
<td>4.4</td>
<td>4.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

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The difference in the microbial averages obtained from waste water in the three sampling sites were not statistically significant (P>0.05).

**Microbial Load of Treated Water**

The mean total coliform count, *E. coli* count and *Salmonella* from boiled water in the wet season were $4.4 \times 10^4$, $3.0 \times 10^4$ and $3.3 \times 10^4$ respectively while in the dry seasons the means were; total coliform ($4.9 \times 10^4$), *E. coli* ($5.3 \times 10^4$) and *Salmonella* ($4.2 \times 10^4$). In chlorinated water the means were; total coliform ($2.0 \times 10^4$), *E. coli* ($1.1 \times 10^4$) and *Salmonella* ($1.4 \times 10^4$) in the wet season.

During the dry season, the means were; total coliform ($1.3 \times 10^5$), *E. coli* ($1.3 \times 10^5$) and *Salmonella* ($0.9 \times 10^4$) in the wet season. From filtered water, the means during the wet season were; total coliform ($4.0 \times 10^4$), *E. coli* ($2.7 \times 10^4$) and *Salmonella* ($2.7 \times 10^4$). During the dry season, the means were; total coliform ($4.3 \times 10^4$), *E. coli* ($4.5 \times 10^4$) and *Salmonella* ($3.9 \times 10^4$) (Table 2). The isolation of microorganism differed significantly in the wet and dry season (p < 0.05). Likewise, the isolated microorganisms from boiled, chlorinated and filtered water were significantly different (p < 0.05).

**Microbial Load after Solar Disinfection**

The number of total coliform before exposure to sunlight were $10.7 \times 10^5$, $11 \times 10^5$ and $10.1 \times 10^5$ in set A, B and C respectively. *E. coli* were $9.8 \times 10^5$ in set A, $7.6 \times 10^5$ in set B and $8.8 \times 10^5$ in set C while *Salmonella* were $1.6 \times 10^5$ in set A, $2.9 \times 10^5$ in set B and $3.3 \times 10^5$ in set C. There was complete absence of microorganisms in set A and B after five hours of continuous exposure to sunlight. In set C, the number of microbes varied with time reaching a maximum after 5 h of exposure (Table 3). The number of microbial isolates from set A, B and C differed significantly (p< 0.05).

<table>
<thead>
<tr>
<th>Exposure Time (h)</th>
<th>Set A</th>
<th>Set B</th>
<th>Set C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T. coliform Cfu/100ml x10^5</td>
<td>E. coli Cfu/100ml x10^5</td>
<td>Salmonella Cfu/100ml x10^5</td>
</tr>
<tr>
<td>0</td>
<td>10.7</td>
<td>9.8</td>
<td>1.6</td>
</tr>
<tr>
<td>1</td>
<td>12.4</td>
<td>10.2</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>6.1</td>
<td>8.2</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>1.4</td>
<td>3.0</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>1.2</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 3: Mean microbial (cfu/100 ml) after solar disinfection in Nakuru North from May 2012 to April 2013

T. coliform, total coliform; Cfu, colony forming units; h, hours
Antibiotic Resistance Patterns

The pure microbial isolates were tested against seven different antibiotics to establish their levels of resistance. The mean resistance in total coliform was 32.0 %, E. coli (15.4 %), Salmonella (16.6 %). Total coliform (11.7 %), E. coli (10.8 %) and Salmonella (5.6 %) were intermediate resistant to the tested antibiotics. In addition, 63.1 % of total coliform, 73.9 % of E. coli and 77.0 % of Salmonella were resistant (Table 4). There was no significant difference (p > 0.05) in resistance between total coliforms, E. coli and Salmonella.

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Total coliform (n=98)</th>
<th>E. coli (61)</th>
<th>Salmonella (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>I</td>
<td>S</td>
</tr>
<tr>
<td>CL30</td>
<td>60.2</td>
<td>0.0</td>
<td>39.8</td>
</tr>
<tr>
<td>NA30</td>
<td>63.8</td>
<td>28.2</td>
<td>8.0</td>
</tr>
<tr>
<td>C30</td>
<td>5.3</td>
<td>1.9</td>
<td>92.8</td>
</tr>
<tr>
<td>CIP5</td>
<td>4.0</td>
<td>23.0</td>
<td>73.0</td>
</tr>
<tr>
<td>CN10</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>AML10</td>
<td>29.7</td>
<td>19.3</td>
<td>51.0</td>
</tr>
<tr>
<td>SXT25</td>
<td>13.1</td>
<td>9.6</td>
<td>77.3</td>
</tr>
<tr>
<td>Mean</td>
<td>32.0</td>
<td>11.7</td>
<td>63.1</td>
</tr>
</tbody>
</table>

Table 4: Antimicrobial sensitivity test (%) results for the seven antimicrobials in Nakuru North from May 2012 to April 2013

CL30, Cephallexin; NA30, Nalidixic Acid; C30,Chloramphenicol; CIP5, Ciprofloxacin, CN10, Gentamicin; AML10, Amoxycillin; SXT25, Sulfa-trimethoprim.

DISCUSSION

We assessed the microbial contamination of foods, environmental samples and treated water in Nakuru North sub-county in Kenya. The collected samples were found to be highly contaminated with microorganisms (Table 1). Many countries, Kenya included have responded by putting in place measures to curb the menace. However, pathogenic microorganisms remain problematic world over. The mean temperature values obtained from animal intestinal wastes, fruit and vegetable salads and waste water were higher than in milk (Table 1). In addition, the mean temperatures for samples obtained from Kabatini were low compared to Maili 5 and Bahati.

The location of Kabatini next to the prominent Bahati forest which lowers the ambient temperature of the region could be the most probable reason (22). The mean pH values obtained from milk samples was higher than in intestinal wastes, fruits and vegetable salads and waste water, probably because the milk did not have acid producing microorganisms (3). However, temperature and pH did not significantly influence the number of microbial isolates. The possible reasons could be that the factors were determined in their natural environment without treatments. In addition, the factors...
did not rise to levels that could influence microbial growth (32). However, the temperatures values obtained from Kabatini were lower because this study area is located next to the former Bahati forest.

Comparatively, the prevalence of *Salmonella* in milk was lower than in intestinal wastes, fruits and vegetable salads and waste water. This is because *Salmonella* is not secreted in milk. Its presence in milk arises from contamination from the environment (3). However, high microbial load were isolated in milk (Table 1) compared to those obtained from previous studies in Kenya in bovine milk (31). The findings in the current study were similar to those obtained in South Africa (23). Poor hygiene practices especially milking by use of bare hand, poor farm management practices, watering the animals using waste water, lack of animal feed monitoring and presence of rodents and animals in animal dwelling places could have contributed to detected pathogens in milk (17).

In addition, stress due to travelling for long distances when searching for pasture, food deprivation and confinement may also have led to the high microbial load observed from milk in this study (13). The microorganisms isolated from intestinal wastes are presented in table 1. These results were in contrast with previous studies in Kenya (6.3 %), Ghana (33 %) and Nigeria (9.5 %) (2, 16, 3). Several factors have been linked to the wide variations in the microbial load from animal intestinal waste. To begin with cross contamination may occur during direct contact of animals or directly through contact with contaminated surfaces. Another possibility of contamination could be use of already contaminated knives during slaughter and the hygiene level of the abattoir (26).

The microbial load of fruits and vegetable salads indicates the microbial composition of the soil used in growing fruits and vegetables, harvesting, transport, storage and processing conditions (40). The microbial loads observed from the fruits and vegetable salads in this study (Table 1) were higher than those obtained in other parts of the world (1.0x10^3) (38, 50, 8). The results obtained in this study could be a reflection of the level of exposure and handling processes during transport or processing. The salads were seen to be opened depending on the demand posed by the customers. This could have further exposed the salads to contamination especially by flies. Moreover, continued cleaning of fruits and vegetables using the same water could have led to the high microbial load witnessed in this study (35). The dusty and unhygienic market from which fruits and vegetables are obtained coupled with contaminated cutting knives could be additional factors (32).

A recent study on isolation of microorganisms from waste water in Dakar, Senegal obtained lower microbial load than those obtained in this study (29). The results of this study (Table 1) could be due to storm runoff or waste water from washing of children’s clothes (4), discharge of kitchen waste into the environment and disposal of wastes from meat processing industries. Waste water used in cleaning of livestock housing structures in ranches could be an additional possibility if disposed off without treatment (45).

The level of microbes obtained from treated water in Green, Nyandundo and Scheme both in the wet and dry seasons were within the zero microorganisms per 100ml standard given by World Health Organization (35). The reason for this possibly lies on the location of these regions on hilly areas which are the origins of rivers which are important water sources in the region. The results may give a suggestion that the water was obtained from less contaminated sources prior to treatment (1). On the other hand, the level of microorganisms obtained in the wet season was lower than those in the dry season (Table 2). This may be associated to dilution effect during the rainy seasons (37). As opposed to the other methods of water treatment, chlorination was observed to be the most effective method of treating water. This can be explained by the residual effect chlorine
has after water has been treated (46). The number of microorganisms obtained in boiled water in
this study agrees with a previous study (29). This could be attributed to inadequate boiling coupled
with poor storage (46). On isolation of microorganisms from filtered water, the results are in
agreement with previous studies (40). Poor fabrication of the filter candles by local manufactures
could be a contributing factor, cracked candles or candles that have been overused (20).

Solar disinfection was found to be an effective method of treating water (Table 3). This is similar
to results obtained in Kajiado District in Kenya (9). However, (28) observed that water has to be
left outside for two days for effective disinfection to take place using this method. The difference
in the two studies could be attributed to the duration of sunny periods within a day and also the
season during which the method is used (5).

The microbial isolates were highly resistant to amoxicillin, cephalexin and nalidixic acid. On the
other hand, they were most sensitive to gentamicin, chloramphenicol and sulfa-trimethoprim
(Table 4). This study therefore suggests that amoxycillin, cephalexin and nalidixic acid have a low
potential of controlling the microorganisms. The results agree with a previous study by (18).
Because People in Nakuru North keep livestock, they could be using allot of antibiotics in treating
animals (19). This could be a contributing factor to the high level of resistance witnessed in the
current study (6). In addition, seepage of antibiotics into water sources and the selection pressure
posed by their increased usage in the environment could be another possibility (14, 24).

CONCLUSION

Environmental, food and drinking water samples in Nakuru North Sub-county were found to be
highly contaminated with Salmonella, total coliforms and E. coli. This gives an indication that
human and animal wastes are not properly disposed in the study area. In addition, the high levels
of microorganism obtained from treated water indicate that either drinking water is not properly
treated or storage of water after treatment is not properly carried out. There is also a likelihood of
massive misuse and abuse of antibiotics leading to antimicrobial resistance observed in this study.
We recommend health awareness strategy by the public health officers in order to sensitize people
in the study area on the need of practicing proper personal hygiene. There is also a need of creating
awareness on the efficiency of solar disinfection as a method of water treatment in the area. Prudent
usage of antibiotics is also inevitable if resistance to antibiotics is to be curbed.

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