A Comparison of the Bacteriological Quality of Drinking Water for the City of Johannesburg in the Wet and Dry Season

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Abstract

The mandate of Johannesburg Water’s supply distribution system is to deliver safe potable water, sufficient in quantity and acceptable organoleptically to 3.8 million residents of Johannesburg. The study, aims at assessing the bacteriological quality of the drinking water during the wet and dry seasons and to determine if the quality is affected by the supply type, namely reservoir, tower and direct feed.

A total of 48 reservoirs, 8 towers and 4 direct feeds were chosen. The samples were taken between October 2010-March 2011 (wet season) and April 2011-September 2011 (dry season), with 767 dry season and 976 wet season samples from reservoirs, 96 dry season and 102 wet season from towers and 46 dry season and 50 wet season from direct feeds respectively.

No *E. coli* was present in any of the samples studied. The Heterotrophic Plate Count (HPC) of 5000 CFU per mL was exceeded once (0.13%) from the zones served by reservoirs during the dry season, although the resample had an HPC <1.

During the dry season, the reservoir zones had 8 (1.04%) positive results for total coliforms, while tower zones had 1 (1.04%) positive result and none from direct feeds respectively. During the wet season there were 15 (1.88%) positive total coliform results from reservoirs, 1 (0.98%) from tower samples and 2 (4%) from direct feed samples respectively. The positive samples were re-sampled and analysed using the quantitative method and all had 0 total coliforms, except three samples during wet season which had 2, 3 and 4 coliforms respectively, thus meeting the acceptance requirement for drinking water.

The findings of the current study demonstrate that wet season can harbor substantial total coliforms in potable distribution water. Foregoing studies have associated the occurrence with water temperature and rainfall. Additional treatment during wet season may be needed.
1. Introduction

Water is important and indispensable in the maintenance of life on earth, thus all sources of water that are intended for human consumption must be free from pollution. Polluted water increases the risk of disease transmission to consumers. The most common and widespread health risk associated with water is microbial contamination [7]. Pathogenic microorganisms that are transmitted by water to humans include bacteria, viruses, and protozoa and most of these microorganisms grow in the human intestinal tract and are transmitted via faeces [6]. It is estimated by World Health Organization that up to 80% of all sicknesses and diseases in the world are caused by inadequate sanitation, polluted water or the unavailability of water [4].

The presence of *E. coli* in drinking water is traditionally seen as an indicator of faecal contamination through inadequate treatment, cross connections or the inability to maintain a disinfectant residual in the water distribution system [1]. *Escherichia*, *Klebsiella*, *Enterobater* and *Citrobacter* are regarded as genera of coliforms and are useful for monitoring the microbial quality of treated piped water supplies [3]. The organisms are known to ferment lactose with the production of acid and gas within a 48 hour incubation period. Results are calculated using the most-probable-number multiple-tube fermentation test [6].

The availability of safe and clean water seems not be a problem in towns and cities, where consumers generally receive a constant supply of water of high quality. The mandate of Johannesburg Water is to supply safe potable water which is sufficient in quantity and acceptable organoleptically to 3.8 million residents of the City of Johannesburg. In South Africa, data on quality of water sources and associated health problems is available. However few studies have been conducted in assessing water quality in the urban areas of South Africa using such data sources. Thus the aim of this study was to assess the bacteriological quality of the drinking water during the wet and dry seasons supplied by Johannesburg Water Reservoirs, Towers and Direct Feeds using existing data sources.

2. Material and Methods

2.1. Data collections and selected study areas

The study was conducted on data obtained from the Laboratory Information System of Johannesburg water. The data selected was for two different seasons (wet and dry). The wet season selected was from October 2010-March 2010, while the dry season was from April 2011-September 2011. The data selected was for three different sampling point types namely Reservoirs, Towers and Direct Feeds. The study was conducted on 48 Reservoir sample points, 8 Tower sample points and 4 Direct Feed sample points. Figure 1 shows the selected study areas and locations around the City of Johannesburg.

2.2. Sample collection.

A total of 796 samples were taken from the 48 Reservoirs, 102 from the 8 Towers and 50 from 4 Direct Feeds during the wet season, while during the dry season, 767, 96 and 46 samples were taken from Reservoirs, Towers and Direct feeds respectively. Each sampling point was sampled twice a month. If the sample is out of specification for any microbiological parameter, then the
sample point was re-sampled the following day. The method of sample collection at each source was based on the World Health Organization (WHO) guidelines for drinking water [2].

2.3. Sample processing

All samples were analysed for total coliforms, *E. coli* and HPC in Johannesburg Water’s microbiology laboratory. The Colilert 18® method was used to test for the presence of total coliforms and *E. coli* while the heterotrophic plate count method was used for the total bacterial count. The first test used for total coliforms and *E. coli* was a qualitative (presence or absence) method. If a sample tested positive, then the sample point was re-sampled and analysed using a quantitative method.

2.3.1. The qualitative method was conducted as follows: 100mL of sample was added to a sterile Schott® bottle followed by the addition of the contents of a Colilert 18® sachet. The Colilert18® medium was allowed to dissolve and the mixture was incubated at 37°C for 18-22 hours.

2.3.2. The quantitative method was conducted as follows: the sample / Colilert 18® mixture was added to a Quanti-tray® and sealed using quanti-tray sealer then incubated at 37°C for 18-22 hours.

2.3.3. In determining HPC, 1mL of the sample was pipetted into a petri dish and a Plate Count Agar was added and allowed to gel. The petri dish was then incubated at 35 °C for 48 hours.
3. Results

All the results were compared to SANS 241 [11] standard for drinking water. The results of heterotrophic plate count analyses and qualitative method results for total coliforms and *E. coli* from different water distributions during the wet season is displayed in Table 1 below. None of the wet season samples tested from reservoirs, towers and direct feeds distribution contained *E. coli*. Total coliforms were detected in 1.88%, 0.98% and 4% from all the samples collected from reservoirs, towers and direct feeds respectively. None of the samples collected during the wet season had HPC bacteria exceeding 5000 Colony Forming Unit/mL (CFU/mL).

Figure 2 shows the results for total coliforms during the wet season. None of the sampling points had been out of specification more than three times. However 7 reservoirs, 1 tower and 2 direct feeds had been out of specification once during the wet season. Only three reservoirs were out of specification more than once during the evaluation period.
Table 1: Heterotrophic plate count results and qualitative method results of total coliforms and *E.coli* from different water sampling point types during the wet season

<table>
<thead>
<tr>
<th></th>
<th>Reservoir (no=48)</th>
<th>Tower (no=8)</th>
<th>direct feeds (no=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total coliform /100mL</strong></td>
<td>15(1.88%)</td>
<td>1(0.98%)</td>
<td>2(4%)</td>
</tr>
<tr>
<td><strong>E.Coli /100mL</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>HPC &gt;5000 CFU/mL</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total no. of samples</strong></td>
<td>796</td>
<td>102</td>
<td>50</td>
</tr>
</tbody>
</table>

Figure 2: Map showing areas which had samples that were out of specification for total coliforms through qualitative analysis during the wet season.

The results of the heterotrophic plate count analyses and qualitative method results for total coliforms and *E.coli* from different water sampling point types during the dry season is displayed in Table 2 below. None of the dry season samples tested from reservoirs, towers and direct feeds
contained *E. coli*. Total coliforms were detected in 1.04% from all the samples collected from reservoirs and towers respectively. The direct feed samples were free from any bacteria detected through the different test methods used during the dry season. HPC bacteria only exceeded 5000 CFU 0.13% in samples tested from reservoirs. Figure 3 shows the result for total coliforms during the dry season. None of the sampling points had been out of specification more than once; however 8 reservoirs and 1 tower had been out of specification once during dry season.

Table 2: Heterotrophic plate count results and qualitative method results for total coliforms and *E.coli* from different water sampling point types during the dry season

<table>
<thead>
<tr>
<th></th>
<th>Reservoirs (no=48)</th>
<th>Towers (no=8)</th>
<th>Direct feeds (no=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliform /100mL</td>
<td>8(1.04%)</td>
<td>1(1.04%)</td>
<td>0</td>
</tr>
<tr>
<td><em>E.Coli</em> /100mL</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HPC &gt;5000 CFU/mL</td>
<td>1(0.13%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total no. of samples</td>
<td>767</td>
<td>96</td>
<td>46</td>
</tr>
</tbody>
</table>

Figure 3: Map showing areas which had samples that were out of specification for total coliforms using qualitative analysis during the dry season.
Samples that had shown the presence of total coliforms using qualitative methods for both wet and dry seasons were re-sampled. Three of the wet season samples were positive for total coliforms when the quantitative method was used, while the dry season samples that were re-sampled for quantitative analyses had zero (0) count/mL of total coliforms. The three wet season samples, as shown in table 3, had 2, 3 and 4 counts/100mL respectively. None of the resampled samples had shown the presence of *E. coli* for both seasons.

### Table 3: Quantitative method results for total coliforms from the re-sampled water of all the sampling point types during wet & dry season

<table>
<thead>
<tr>
<th>Seasons</th>
<th>Wet season</th>
<th>Dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of +ve samples</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Counts/100mL</td>
<td>sample 1-(2 counts/100mL) sample 2-(3 counts/100mL) sample 3-(4 counts/100mL)</td>
<td>0</td>
</tr>
</tbody>
</table>

### 4. Discussion

Water contamination has been traditionally confirmed by the detection or enumeration of total and faecal coliforms. These should not be detected in treated water supplies and if they are it would indicate that a need for further survey, investigation and examination of drinking water sources, including excessive nutrients, is needed. Inadequate water treatment and the inability of maintaining an effective disinfectant residual in the water distribution system should also be considered [3 and 6].

The use of certain bacteria as indicators of the potential presence of pathogenic microorganisms in treated waters is the standard means of assessing the microbiological quality of water. The catchment area of a water supply can be a source of disease if it is unprotected. However this study was conducted on urban areas where water used is stored and distributed from protected facilities. Protected water connection systems are expected to produce water free of any form of harmful bacteria. This study was conducted on microbial water quality data through tests done on *E. coli*, total coliforms and HPC. The physiochemical analysis was not considered for this study. The study showed an *E. coli* content of zero (0) per 100mL in all the samples tested for both seasons. However a few samples, as indicated in Tables 1 & 2 had shown the presence of total coliforms. The samples were re-sampled and analysed using a quantitative method and the results obtained, as shown in Table 3, were within the required compliance of <10 counts/100mL [11]. The majority of the samples were from the wet season including the three samples that had total coliforms after quantitative testing. These findings indicate that the wet season can harbor increased total coliform counts in potable water distribution systems. Previous studies have linked these occurrences with water temperature changes [13] and rainfall events [1 and 12]. According to the authors, water temperature influences microbial growth, lag phase, and cell yield. Their findings had shown that *Escherichia coli* and *Enterobacter aerogenes* growth was very slow below 20°C. They have also proved that the lag in the growth phase of *Pseudomonas*
*Pseudomonas putida* was within 3 days at 7.5°C but only 10 hours at 17.5°C. According to the authors, rainfall can be a mechanism that introduces coliform bacteria into a system through leaks and cross-connections. However, according to the findings of this study, rainfall was suspected to be the cause of contamination at sampling points during the sampling event. According to the sampling personnel, they do encounter problems when sampling during rainfall events, which could lead to sampling errors (such as rainwater ingress to the sample bottle) being introduced. However a more extensive study would be needed to determine the influence of rainfall on the contamination of a drinking water sample during the sampling event.

In comparison with the study conducted in Uganda 2002 and Sudan Darfur 2011[8 and 9] which indicated a higher percentage exceeded the WHO guidelines [3], the findings of this study were that all samples met the required limit. This study showed that adequate protection of water distribution sources, leads to the maintaining of the microbial quality of said water supply. This correlates with the study conducted in Lesotho Highlands [10].

HPC bacteria as a group do not present a risk to water consumers [3]. However a high plate count numbers in a distribution system may indicate water-related quality problems [3 and 5]. One sample taken during the dry season had a HPC bacteria count exceeding 5000 CFU/mL. It was suspected that this was due to laboratory contamination or a sampling error, as no colonies were present after re-sampling.

5. **Conclusion**

The consumer has a right to expect that the water supplied leaves the treatment plant meeting the bacteriological standard required for drinking water. The reason for the presence of total coliforms reported in this study remains unclear, thus a more extensive study would be required to determine the factors that influence the occurrence of total coliforms in finished drinking water systems. Extra supervision with regard to the taking of samples is also required to obtain water free of microorganisms. However, the findings of this study indicate that Johannesburg Water supplies good quality water for the community of the City of Johannesburg, water that is acceptable and meets the standard required by the Department of Water Affairs.

6. **References**


