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Microbiological water quality along Vaal Gamagara's potable water distribution system

Abstract

Safe drinking water is essential to all life forms. Thus analysis for microbiological parameters is critical as this assists in declaring the fitness of potable water for human consumption, among other sustainable and "green uses". The aim of this paper is to investigate the microbiological quality of potable water along Vaal Gamagara Water Treatment Plant's (VGWTP) distribution system. A total of 10 samples were collected weekly along the system. The samples were collected from January to December 2013 in order to analyze for *Escherichia coli* (*E.coli)*, total coliforms (TC) and Heterotrophic plate counts (HPC). The results showed that only 0.1% and 0.4% of samples analyzed were positive for *E. coli* and total coliforms, respectively. However, HPC results showed that 40% of the samples analyzed from June to December 2013 had higher counts than the recommended standard limit. The chlorine residual showed an increase from June to December 2013.

An assessment of the results indicated that the integrity of the system was compromised for the research period. Water quality failures in a distribution system are unacceptable because they threaten human health and sometimes result in loss of life. Thus the assessment called for an urgent need to boost chlorine residual especially at points further away from the treatment plant. This was envisaged to provide a safety net for microbial compliance while the system was critically and continuously monitored, and further investigations were performed. Studies on chlorine decay were recommended as a priority in order to optimize disinfection and maintain good quality drinking water throughout the system.

Keywords: *Escherichia coli*, chlorine residual, Heterotrophic plate Counts, microbiological parameters, total coliforms.
JEL Classification: Q53, Q56, Q57.

Introduction

Access to potable water is a worldwide challenge because the raw water sources are impacted to various degrees, resulting in variable cost inputs towards treating the raw water to acceptable standards. This has an economic implication which, going forward, has an impact on the global economy down to local context. Nhamo and Nhamo (2014) noted that the term "green economy", which is also used interchangeably with "green growth", gained prominence in 2008 after the world suffered a financial collapse. For example, in the Southern African Development Community (SADC), more sustainable ways to exploit natural resources have since been called for amid a backdrop of poverty and hunger.

SADC advocates for policies and processes to support and promote sustainable production and consumption of resources, the major of which is water. Thus the region inevitably also subscribes to the green economy drive in order to promote local production, consumption, and efficient use of water (Letsoalo, 2013), among other natural resources. Sustainable use of water in terms of its quality and quantity assures availability for current and future generations.

Since water is a basic component of sustainable living and socio-economic development, practices that help to conserve its quality and quantity thus also promote green development in the various sectors where it is used. Water plays an important role towards sustaining development and eliminating poverty and it also subsidizes 60% towards agriculture and irrigation in the South African economy (Government, 2015). "Investment in safe drinking water and sanitation is a path to economic growth" (htttp://www.unep.org/greeneconomy).

The supply of chemically and microbiologically safe potable water to communities is of major and significant importance. Compromised microbiological quality of potable water poses a health risk to all life forms and is a cost to water utilities (Abdolmajid, 2014; Dzwairo, 2005; WHO, 2011; DWAF, 1996; Dzwairo et al., 2010). In South Africa there is a challenge of deterioration of potable water quality during transportation through the distribution system and also during storage. Usually the final quality of drinking water cannot be secured after the water has been distributed to the storage facilities and consumers (Momba et al., 2000). Quality of drinking water that complies with the South African National Standard (SANS) 241 (SABS, 2011) is considered fit for human consumption and is not expected to pose any health risks to the consumers. According to this standard the recommended limits for TC is 10 counts/100 mL, for HPC is 1000 counts/100 mL and *E. coli* should not be detected.

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It is very important to test for *E. coli* in potable water since it is an indication of faecal contamination (Abdolmajid, 2014; WHO, 2011; Lewis et al., 1980; Graham and Polizzotto, 2013; Dzwairo et al., 2006). Literature indicates that HPC is used as an indicator for monitoring of potable water for microbiological quality, in the distribution system (Pavlon et al., 2004; Francisque et al., 2009; Chowdhury, 2012). Other studies have shown that HPC measurements are used to assess effectiveness of the water treatment processes (Bartram et al., 2004; Chowdhury, 2012), specifically performance of the final water disinfection process (Francisque et al., 2009; Chowdhury, 2012).

Worldwide, countries utilize the HPC method to monitor the microbiological quality of potable water along the distribution system (Siebel et al., 2008). "It is very important to control HPC bacteria in a water distribution systems in order to minimise human exposure to pathogenic microorganisms" (Chowdhury, 2012). If the water leaving the water treatment plant after the treatment process has high HPC above the recommended limit, it means that the distribution system has high levels of HPC. If potable water from the water treatment plant is distributed with acceptable levels of HPC but the levels increased in the distribution system, this shows that there was/is recontamination in the distribution system (Robertson, W. and Brooks, T., 2003). High HPC levels indicate a deterioration of microbiological potable water quality, bacterial regrowth and potential formation of biofilms (Bartram et al., 2002).

The microbiological quality of portable water depends on factors such as chlorine residual. Chlorination is a popular disinfection method that is used in some developed and most developing countries. The chlorine residual is used to reduce regrowth of microorganisms and to maintain microbiological quality in the distribution system. Water distribution systems that are not protected enough may result in breakdown due to waterborne diseases (WHO, 2011). It is reported that about 3.4 million people died every year due to water borne diseases (Chowdhury, 2012) while a large number of these deaths were as a result of drinking faecallycontaminated water (Dzwairo et al., 2006).

Thus this study looked at the temporal and spatial variation of the aforementioned parameters with the view of concluding on trends of microbiological quality of potable water in the VGWT system for the year 2013. The results were meant to contribute towards an in-depth assessment of the integrity of the distribution system.

1. Study area

The VGWTP is operated by Sedibeng Water Board and is situated at Delportshoop in the Northern Cape Province. Fig. 1 shows the Northern Cape Province in South Africa.

The study area covers Delportshoop near Barkly West (VG02 in Fig. 2) to Black Rock, with a total pipeline length of approximately 370 km. The furthest point in the distribution system is at Blackrock (VG13) (Fig. 2).

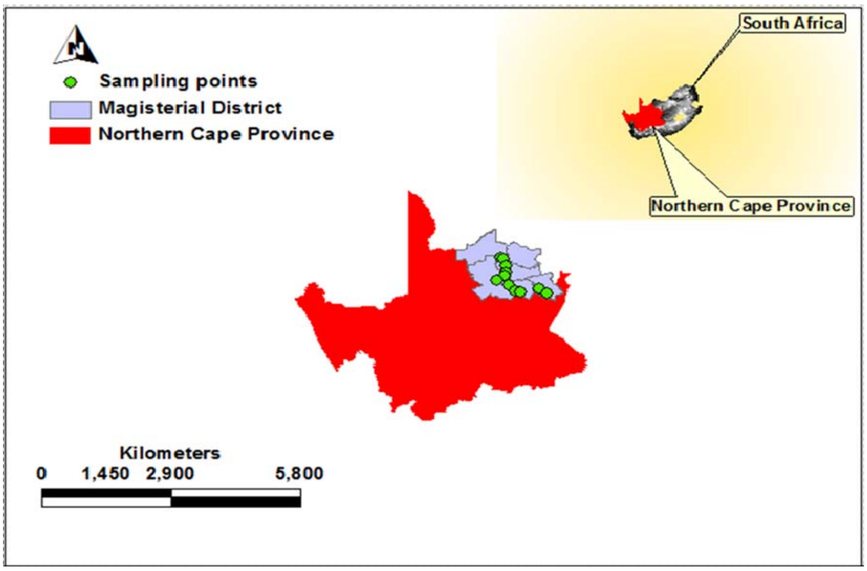

Fig. 1. Map showing Northern Cape Province

Disinfection occurs at the treatment works (VG02) and at Beeshoek (VG05) near Postmansburg that is located 150 km away from the water treatment works.

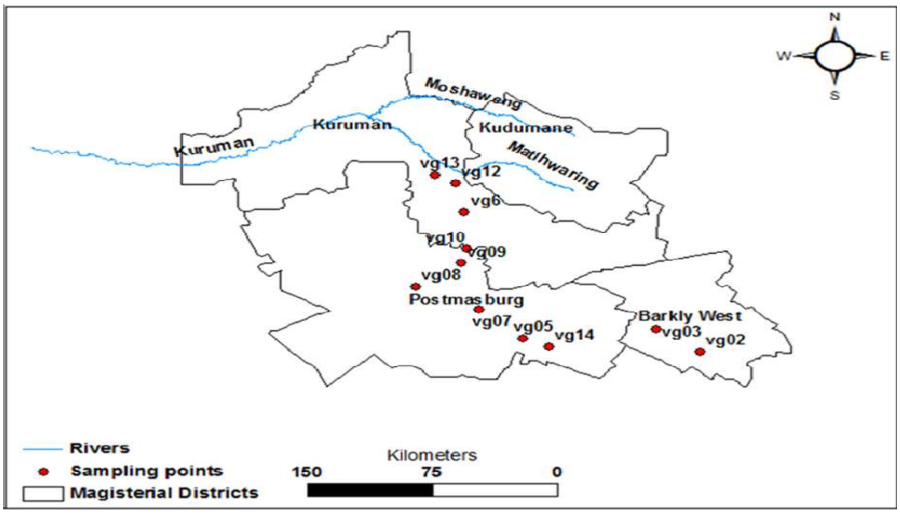

Fig. 2. Vaal Gamagara Sedibeng Water Board sampling points

2. Methods and materials

2.1. Sampling. A total of 10 distribution samples were collected from Vaal Gamagara distribution system. The samples were collected on a weekly basis from January to December 2013 for the analyses of microbiological parameters: *E.coli*, TC and HPC. The samples were collected using 500 mL sterile bottles. The sampling procedure was followed as described in the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

2.2. Analytical measurements. The DPD Colorimetric method (4500-CI G) was used to measure free residual chlorine on site during sampling (APHA, 2012). A sample cell was filled with 10 mL of potable water. The DPD chlorine reagent was added to the sample and the chlorine residual was measured using HACH Pocket Colorimeter II. The pour plate method 9215B was used in the laboratory for the analyses of HPC (APHA, 2012). Some 1 mL of a sample was pipetted into a petri dish and the yeast extract agar was added to the sample. Duplicate plates were incubated for 44 to 48 hours at 36 ± 1°C. The results were expressed in CFU/mL.

The TC and *E. coli* were analyzed using IDEXX Quanti-Tray Standard Method of 1994. A 100 mL volume of water was measured into a bottle and the dehydrated media was added to it. After the powder dissolved, the sample containing the media was dispensed into a multi-well sachet (Quanti-Tray), which was heat-sealed using a Quanti Tray sealer. Following incubation at 36°C (± 1°C) for 18-22 hours, the number of yellow wells and the number of wells that fluoresced were counted. The results were expressed as counts/100 mL.

3. Results and discussion

Fig. 3 shows the results of *E. coli* over a period of 12 months. The results indicate that only 0.1% of samples analyzed were positive for *E. coli.*

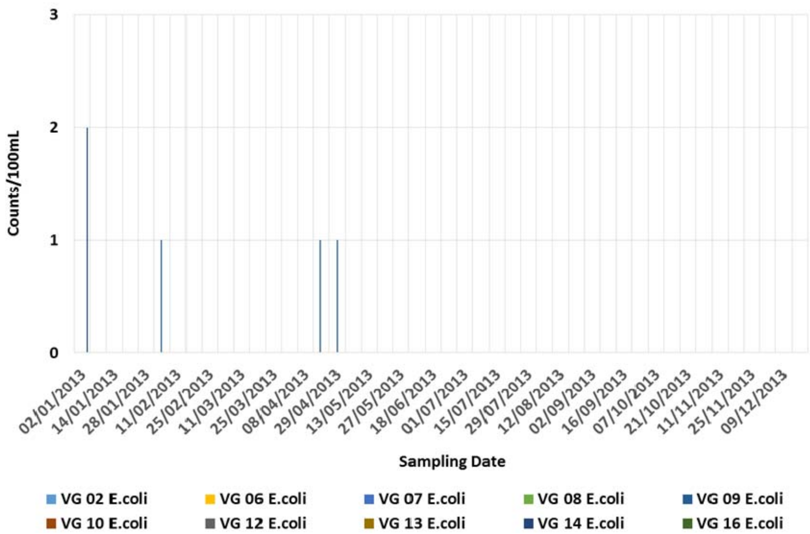

Fig. 3. ***E. coli*** **results for January to December 2013**

Figure 4 illustrates the results of TC along a period of 12 months. The results showed that the TC above recommended standard limit were detected in only 0.4% of samples analyzed.

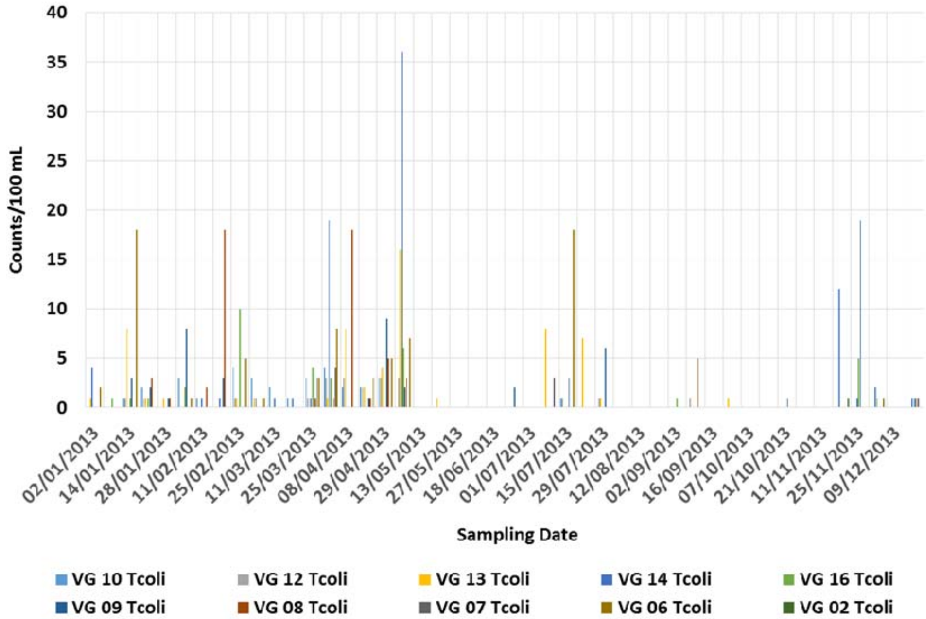

Fig. 4. Total coliform results for January to December 2013

Figure 5 shows the results of HPC for a period of 12 months. The results show that from January to May 2013, there were occasional HPC failures in the distribution. However, between June and December 2013, HPC failures (not complying with the standard limits as prescribed in SANS 241, 2011), became regular. From June to December 2013, the concentration of HPC was above 1000 CFU/mL in 40% of the samples analyzed.

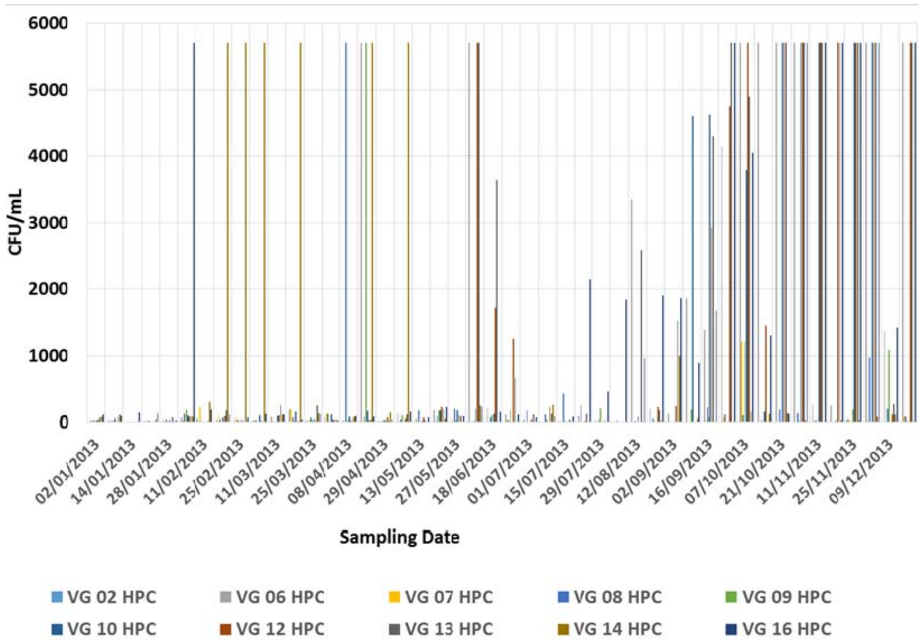

Fig. 5. Heterotrophic plate count results for January to December 2013

Figure 6 shows the results of residual chlorine for a period of 12 months. The results show that from January to May 2013, the chlorine residual was < 0.1 mg/L for most of the sampling points except for the initial treated water at VG02. From June to December 2013, the chlorine residuals increased but the HPC still failed. The results indicate that inefficient disinfection is one of the factors that contribute to high HPC in the distribution system, but in this case other factors would require further investigation.

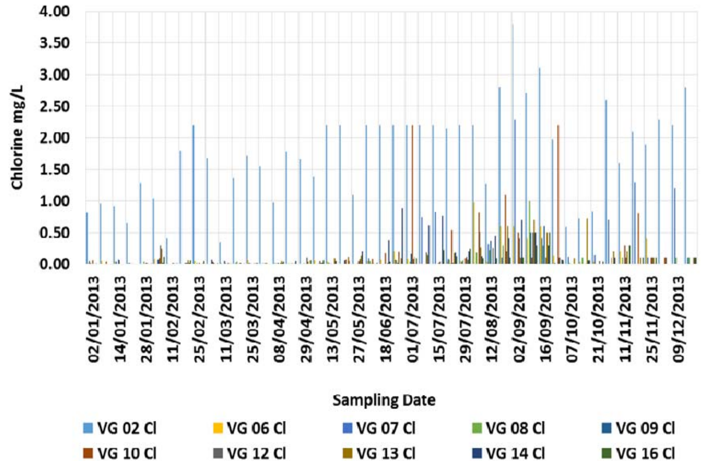

Fig. 6. Residual chlorine results for January to December 2013

Figure 7 shows the results of HPC versus chlorine for VG02 (which is the initial sampling point at the plant, for final treated water). The results show good residual chlorine throughout the year and HPC was not detected in most cases. The highest HPC result detected was 50 CFU/mL with chlorine residual of <1.0 mg/L.

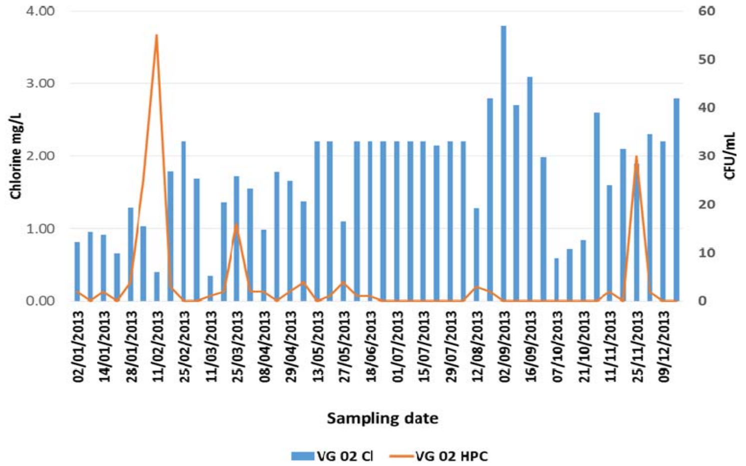

Fig. 7. Graph of chlorine and HPC for VG02

Figure 8 shows the results of residual chlorine versus HPC for VG13, which is the furthest point from the treatment plant, in the distribution system. The results show that residual chlorine from January to May 2013 was as low as 0.01 mg/L while the HPC were always below 1000 CFU/mL, which is the standard limit. Starting June 2013 to December 2013, the residual chlorine improved, but HPC was >5700 CFU/mL in most cases. The value >5700 CFU/mL was statically changed to 5701 for analysis purposes, as described in Dzwairo et al. (2011).

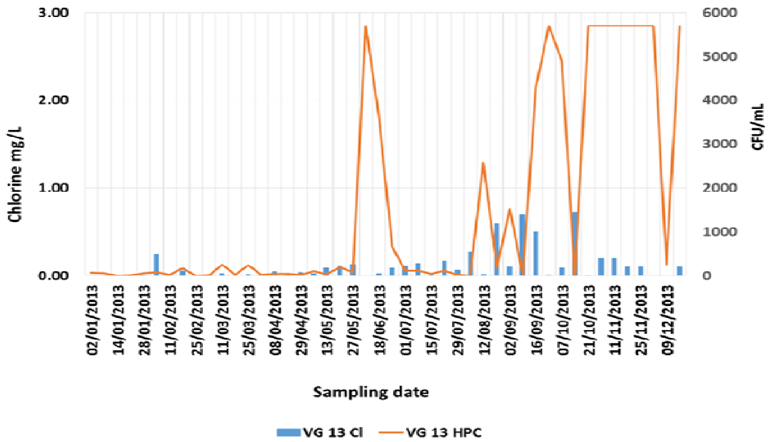

Fig. 8. Graph of chlorine and HPC for VG13

Conclusions

The *E. coli* and TC results showed very low percentages, which means that there was no fecal contamination from the samples that were collected from Vaal Gamagara distribution system.

The HPC results showed a trend of failures (Figure 5, 7) starting June 2013 to December 2013 as a result of the residual chlorine which fluctuated during that period. Further investigation is in progress in order to:

1. identify possible contributing factors for the HPC failures in a section of VGWTP's long distribution network;
2. assess the chlorine decay in a section of the water board's long distribution network;
3. investigate and test an alternative disinfection protocol that could sustain the integrity of an identified section of VGWTP's long distribution network.

An assessment of the results indicated that the integrity of the system was compromised for the research period. Water quality failures in a distribution system are unacceptable because they threaten human health and sometimes result in loss of life. Thus the assessment called for an urgent need to boost chlorine residual especially at points further away from the treatment plant. This was envisaged to provide a safety net for microbial compliance while the system was critically and continuously monitored, and further investigations were performed. Studies on chlorine decay were recommended as a priority in order to optimize disinfection and maintain good quality drinking water throughout the system, a fundamental concept of green production, distribution and use of good quality water. It is essential to supply good quality potable water in order to improve human well-being and to protect imminent re-generation of environmental risks and ecological scarcities.

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