

Microbial Analysis of Drinking Water from Nadi to Lautoka Area in Viti Levu Fiji

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Abstract

Introduction: Access to sufficient and safe drinking water is essential for human health and welfare. Countries in the Pacific Region like Fiji frequently face issues with access to safe drinking water and supply problems. Fluctuations in water resource availability, often untreated water and faulty treatment facilities, pollution, lack of proper water management frameworks and most importantly lack of water monitoring resources are all factors that influence Pacific Island Countries. Apart from this, Pacific Islands and their water supplies are susceptible to climate hazards such as floods, cyclones and drought. The Western Division of Fiji Islands is highly prone to adverse climatic conditions; therefore regular monitoring of the various drinking water sources is essential to ensure safety of people. This study was conducted in the Lautoka to Nadi corridor where 25 sites were randomly selected for water analysis processing from January to February 2019.

Method: Physio-chemical analysis, such as measuring pH and turbidity as well as simple microbial analysis, was conducted on the water samples. Specific growth media was used to determine the different types of bacteria (*Coliform*, *Escherichia coli* and *Salmonella enterica*) present in the water samples; Lauryl Tryptose Broth, Eosin Methylene Blue Agar, Xylose Lysine Deoxycholate was used. Turbidity was measured using a digital turbidity meter and pH value was determined employing a digital meter.

Results and Discussion: From the analysis it was determined that overall the pH levels of samples (6.02-8.30) falls within the permissible limits; whereas turbidity was generally higher in untreated water sources with ranges from 3 to 8 nephelometric turbidity units. Microbial content was higher in untreated water samples. Other sources such as springs and creeks recorded the most significant number of *Coliforms* when compared to other sources and some samples indicated the presence of *Escherichia coli* and *Salmonella enterica*.

Conclusion: From the study it can be concluded that all the water samples tested positive for bacterial contamination particularly *Coliforms* and it was higher in untreated water. Water from the Municipality had almost all physio-chemical and bacteria parameters within the World Health Organization limits, except for turbidity which was generally above 1NTU. However, this was not the case for untreated water which in some samples contained high levels of harmful bacteria. Monitoring needs to be carried out to better understand water quality and implement counter measures.

Keywords: Drinking water, bacteria, water contamination, Fiji.

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Introduction

Water is the key to survival of humans and many living organisms. Its unavailability or scarcity is arguably amongst one of the world's most serious issues with around 80% of all diseases related to water scarcity and water related problems such as inadequate sanitation and consumption of contaminated water (Solomon et al., 2011). In recognition of the importance of clean and safe drinking water for the good health of people, the United Nations has declared access to clean water an essential human right. However, in many countries across the globe including the Pacific Islands where drinking water is obtained either from surface or groundwater sources, attaining this basic human right has become relatively difficult (Mosley, Singh, & Aalbersberg, 2005). A number of residents in Viti Levu, Fiji, obtain their drinking water from unfiltered and untreated wells, springs, rainwater locations, rivers and creeks (Lee, 2007). In these communities there is an increased susceptibility to water borne diseases. Approximately 45% of Fiji's inhabitants dwell in the rural and coastal areas and about 70% of these people consume untreated water (Government of Fiji, 2013). Some of these water sources have become contaminated and pose a risk to health and the economic status of a small developing nation (Amin, Ali, Anwar, Khattak, 2012).

Poor management of human and livestock waste and the release of industrial waste into water-ways has introduced contaminants such as heavy metals, harmful bacteria, viruses and nitrates (G. Lee & Brodie, 1982; McAllister & Topp, 2012; Wardrop, Hill, Dzodzomenyo, Aryeetey, & Wright, 2018). Thus, altering the chemistry of our water systems. For example, an increase in levels of nutrients such as Nitrogen and Phosphorous not only leads to increased turbidity but also leads to the amplified growth of organisms such as algae and other microbes otherwise termed as eutrophication (Amin et al, 2012).

History has indicated the significant role that water plays in the dispersion of various protozoans, bacterial and viral diseases (Cunningham & Cunningham, 2005). Water that has been contaminated with fecal matter can spread a broad variety of dangerous diseases such as dysentery, hepatitis, typhoid and diarrhoea (Amin et al, 2012). Fiji's Ministry of Health records diarrhoea as the second most frequently reported disease between 2017 to 2018 (Ministry of Health, Fiji, 2018) with *Escherichia coli* documented as one of the major causes usually contracted through untreated drinking water (Behiry, Abada, Ahmed, & Labeeb, 2011; Amin et al, 2012). *Coliform* has also

been extensively documented in water quality studies with research revealing that although *Coliform* is usually harmless, its presence can indicate the occurrence of other pathogenic microbes (Saxena, Bharagava, Kaithwas, & Raj, 2015; Solomon et al., 2011). Typhoid has been commonly linked with poor sanitation and hygiene and is associated with the presence of the pathogenic bacteria *Salmonella enterica* which is transmitted through the consumption of contaminated food or water. Typhoid fever is becoming a significant health problem in Fiji with the number of reported cases escalating in the last decade. Figures grew from less than five in every 100,000 cases in 2005 to about 44 in every 100,000 in 2011 (Thompson et al., 2014).

Oceania continues to be troubled by water woes and water borne illnesses due to increasing pollution, poor infrastructure, lack of appropriate policies and finance and accessibility to proper water resources (Naica & Ferreira, 2016). These factors are exacerbated by the effects of climate change further increasing the susceptibility of vulnerable rural and coastal communities (Government of Fiji, 2013). A developing nation such as Fiji is constantly undergoing changes to its landscape. Subsequently, the overall quality of water will alter in response to the dynamic environment. As such, tracking these changes and monitoring water quality becomes paramount so that we make progress towards cleaning polluted water bodies and that appropriate awareness and preventative methods can be employed.

Fiji lacks important water quality data especially in Western Viti Levu (Mosley et al., 2005) and there is a need to mitigate the prevalence of water- borne illness. This study was conducted as an attempt to collect data and to investigate the physical, chemical and biological qualities and parameters of drinking water in the Viti Levu's Western Division playing particular attention to the Nadi-Lautoka corridor.

Method

A total of 25 sites within the Nadi to Lautoka corridor were randomly selected for analysis. These sites comprised of both urban and rural residential areas. The drinking water sources comprised of springs, wells, boreholes, creeks, rainwater stored in tanks. The pH and turbidity were determined by American Society for Testing and Materials International method (Amin et al., 2012). Microbial analysis was carried out for *Coilforms*, *Escherichia coli* and *Salmonella enterica*. Samples were collected from January to February in 2019. Water samples for bacteriological testing was collected in 500mL sterilized Schott Duran bottles and placed in an ice box. For pH and turbidity analysis 500mL sterilized plastic bottles were used to store the water.

Sample bottles were transported to the laboratory for analysis and testing was completed within one hour of collection. This was done prevent the over growth of microorganisms which could have an effect on the total bacterial count.

pH

The balance between acid and base in drinking water was assessed by its pH value (Akter et al., 2016). The pH of the water samples was measured using a digital pH meter (Hanna Instruments, USA).

Turbidity

Turbidity is simply the measure of the clarity and transparency of water (Amin et al., 2012). Drinking water turbidity was measured using a digital turbidity meter (TB1000, USA) and the results were expressed in nephelometric turbidity units (NTU) (Mosley et al., 2005).

Bacteriological Analysis

Multi-tube fermentation and Most Probable Number techniques were employed as described by Amin et al. (2012). Selective Culture Medium was used to confirm the growth of a specific type of microbe.

Coliform

Coliform bacteria was isolated and identified using Most Probable Number (MPN) where diluted samples of Lauryl Tryptose Broth 1:10 and Brilliant Broth was used as medium for growth (Amin et al., 2012; Mosley et al., 2005). Samples were incubated for 24 hours at a temperature of 44.5°C.

Escherichia coli

This microbe was isolated and identified by employing streaking method (Kenneth, 2011). Streak loop inoculums from EC Broth tube which were positive on Eosin Methylene Blue Agar plates were then incubated for 48 hours at a temperature of 35°C. The colonies of *E.coli* were identified biochemically by using API 20E kit (API system France).

Salmonella

This microbe was detected using streak plate method on selective media (Kenneth, 2011). Xylose Lysine Deoxycholate (XLD) agar was used and this was then incubated for 20 hours at 37°C. The colonies of *Salmonella enterica* were identified biochemically by using API 20E kit (API system France).

Results and Discussion

pH

The pH of the samples collected ranged from 6.02 to 8.30 with an average pH of 6.91 over 25 sites. The lowest and highest pH readings were recorded from untreated water sources i.e. pH 6.02 was recorded for well water which was unprotected and pH 8.30 from a creek system. Overall (in reference to Figure 1), the pH ranges across all 25 sites fall within the permissible limits (6.5 to 8.5) as outlined by Akter et al., 2016. Variation in pH values may be due to an increase in temperature that can also inhibit the solubility of carbon dioxide (Amin et al., 2012; Mosley et al., 2005). Changes also come about due to leakages in the supply chain or seepage of waste products into these water sources (Amin et al., 2012).

Decline in pH makes water acidic in nature and can leach metals in pumps and pipes (Mosley et al., 2005). Water with a pH less than 7 will tend to have a soft mouth feel and a bitter taste however alkaline water has a pH greater than 7 and has a soda taste, feels slippery and will be hard in nature (Amin et al., 2012).

Turbidity

Turbidity is typically a reliable and affordable indicator of water quality. As a visual guide, crystal clear water would have turbidity of less than 1 NTU while readings greater than 4 NTU would have a visible cloudiness. The World Health Organization establishes that the turbidity of drinking water should

not be greater than 5 NTU and should ideally be less than 1 NTU. Results from this study reveal that while local municipal water supplies may not fulfill the ideal criteria of less than 1 NTU the average of 4 NTU was recorded from 8 municipal water supplies is within WHO's acceptable limits.

The remaining water sources, however, yielded an average of 7 NTU. Samples collected from Rainwater sources were 8 NTU while Borehole water had an average of 6 NTU. The only creek water source sampled had turbidity of 8 NTU. These relatively high turbidity levels are generally expected in untreated water sources. Due to the presence of sediments and particulate matter that would otherwise be filtered off during water treatment (World Health Organization, 2017). Water sources will tend to be murkier as well following natural disturbances such as intense rainfall or works being undertaken upstream (World Health Organization, 2017).

Table 1: Physio-chemical and Bacteriological analysis results.

Site	Source	Treated or Untreated	Coliforms (MPN per 100ml)	<i>Escherichia coli</i>	<i>Salmonella</i>	pH	Turbidly (NTU)
1	Municipal	Treated	<3	-	-	7.07	3
2	Spring	Untreated	250	+	-	6.71	7
3	Municipal	Treated	<3	-	-	7.03	4
4	Well	Untreated	≥2500	+	+	6.98	8
5	Well	Untreated	≥2300	+	-	6.64	7
6	Rain water	Untreated	1100	+	-	6.05	8
7	Municipal	Treated	<3	-	-	7.2	3
8	Municipal	Treated	<3	-	-	7.02	3
9	Municipal	Treated	<3	-	-	7.08	4
10	Well	Untreated	≥250	+	-	6.02	7
11	Spring	Untreated	≥2400	+	-	6.57	8
12	Spring	Untreated	≥2400	-	-	6.4	7
13	Rain water	Untreated	240	-	-	6.2	7
14	Well	Untreated	2400	+	-	6.03	8
15	Borehole	Untreated	11200	-	+	7.3	8
16	Borehole	Untreated	≥2000	-	+	7.22	5
17	Creek	Untreated	1100	-	+	8.3	8
18	Spring	Untreated	1100	-	+	6.63	7
19	Borehole	Untreated	<3	-	-	7.6	6

20	Borehole	Untreated	23	-	-	7.55	6
21	Borehole	Untreated	23	-	+	7.3	7
22	Municipal	Treated	<3	-	-	7.05	4
23	Municipal	Treated	<3	-	-	7.04	3
24	Municipal	Treated	<3	-	-	7.06	4
25	Well	Untreated	≥450	+	-	6.6	7

+ indicates positive for bacteria

- indicates negative for bacteria

Microbial Content

The biological testing of the water samples comprised of microbial analysis for the presence of *Coliforms*, *Escherichia coli* and *Salmonella enterica* bacteria. All 8 municipal water samples yielded replica results of <3 MPN per 100mL for *Coliforms* and zero detection of *E.coli* and *Salmonella enterica*. Untreated water sources however revealed alarming bacterial counts. For instance, one borehole water source recorded the most significant content of *Coliforms* with a total of 11,200 MPN per 100mL and tested positive for the presence of *Salmonella enterica*. While *Coliforms* do not directly affect human health, it's often an indicator of fecal contamination due to *E. coli* or the presence of other harmful pathogens such as *Salmonella enterica*. A closer look at the data obtained from all 25 sites shows that higher MPN counts for *Coliforms* does not always necessarily indicate possible fecal contamination i.e. one Borehole source recorded *Coliforms* of 23 MPN per 100mL, was negative for *E.coli* and positive for *Salmonella enterica* while a second Borehole source recorded the same for *Coliforms* but was negative for both *E.coli* and *Salmonella enterica*. The five well water sources tested had alarming *Coliform* counts ranging from 450 - 2500 MPN per 100mL. Four out of the five well water samples tested positive for *E.coli* and one tested positive for both *E.coli* and *Salmonella enterica*. The four spring water samples also had high *Coliform* counts ranging from 250 - 2400 MPN per 100mL with 2 samples testing positive for *E.coli* and 2 tested positive for *Salmonella*. It is likely that these water sources are in close proximity to livestock and have faced fecal contamination. Also, these

drinking water sources could have been situated near human waste disposal sites which could have led to contamination (Vantarakis et al., 2016). The same is likely for rainwater and creek water samples. Samples collected from five borehole sites gave variable results with one site having almost similar microbial levels as the municipal water supply. Two sites had *Coliform* counts of 23MPN per 100mL. Both samples were negative for *E.coli* and one was positive for *Salmonella enterica*. Two borehole sites recorded >2000 and 11,200 MPN per 100mL *Coliforms* with both showing negative results for *E.coli* and positive for *Salmonella enterica* .

The observed microbial testing results confirm that Fiji's Municipal water supplies meet drinking water standards and should be the preferred source of drinking water nationwide. The reality though is that there still exists rural communities which do not have the luxury of piped water and rely on alternative sources such as borehole, spring, rainwater collected in tanks and well water. In this case, water quality monitoring and routine disinfection should be carried out in these areas to ensure that communities who depend on these water sources have access to clean and safe drinking water.

Conclusion

From this study it can be stated that most of the physio-chemical and bacteriological parameters are within the permissible limits for treated water except for turbidity which was above 1NTU for the drinking samples. Presence of *Coliforms* was discovered to exist in all the samples including for the Municipality. The primary cause of this can be leakage in pipes which may cause pollutants and waste to enter into the system. Untreated water sources contained the highest amount of bacterial contamination with indication of *E.Coli* and *Salmonella enterica*. This can be due to poorly constructed wells which may also be near farms and septic tanks near sources. The results indicate that drinking water is highly susceptible to contamination therefore it is essential that regular monitoring be done on the larger scale which includes all the areas within Fiji Islands.

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