Freshwater Quality and its Biotic Communities in Selected Sources in the Western Region of Fiji[1]

Kushaal Raj
Sanjay Singh
Priyatma Singh
Dhrishna Charan

Abstract

In this study, several factors such as biological, chemical and the physical parameters were analyzed to study the quality of freshwater sources and the biotic environment that exist in the Western region of Fiji. Most of the sources analyzed were deemed unfit for human consumption or use unless treated well. These are thought to be a public health issue.

Introduction

Fresh water is irrefutably the most essential resource in this world and is an integral aspect of the sustainability framework. It is the foundation of the three pillars of sustainable development – social, economic, and ecological. The quality of fresh water is directly linked to the ecosystem services and environmental public health (Simione *et al.,* 2008). A number of factors including agricultural production, sewage discharge, mining, logging, industrial effluents and power generation can negatively affect the quality of freshwater and threaten environmental and economic integrity and community health (Michael *et al.,* 2003). The increasing levels of pollution in water and the deteriorating water quality over the years pose multiple concerns for public health in relation to food and water security (Cimino *et al*., 2002). Pollutants in water usually exist in the forms of toxins, increased concentrations of chemicals, salt, nutrients and

[1] The authors acknowledge the University of Fiji for the research grant that enabled this study to be carried out. The support of Ms. Vishesni Chandra and Mr. Roneel Prasad in this project is also acknowledged.

acidity. One of the major water quality issues transpire from nutrient enrichment and run-offs from land.

Water quality also deteriorates due to natural phenomena. Fiji has a year-round warm tropical climate, flow of south east trade winds and high humidity content, and is prone to natural hazards such as flooding and tropical cyclones. These have considerable impacts on the quality of water. Tropical cyclones and the series of flash floods continue to compromise the sanitation of local water sources in Fiji, particularly in Western Viti Levu (Tagicakibau, 2016). In February 2016, Fiji experienced one of the worst category five cyclones in its history. A month later, Fiji was impacted by a category three cyclone and a series of flash floods. In February 2017, heavy and unremitting rain triggered flash floods in many low-lying areas in Western Viti Levu.

Water-borne diseases continue to be a persistent health problem globally, and more so in developing countries. These are further aggravated by the occurrence of natural hazards and subsequent contamination of freshwater through wastage intrusion (Mosley *et al.,* 2004). In Fiji, while most households are supplied with municipal water, many local communities still make use of springs; bore hole, shallow-well, rivers, creeks and streams for daily household uses (Lee, 2013). Consequently, incidences of common waterborne related illnesses are higher among rural communities (Tabua, 2013). Water systems within the Water Authority of Fiji reticulated network are treated, and meet national drinking water standards (Valema, 2014).

Measuring Water Quality

Physical, chemical and biological indicators are the major parameters involved in measuring and assessing fresh water quality. There are various factors which can influence biological assemblages. Benthic micro invertebrates as bio monitors is considered to be the largest database for sensitive bio monitoring of running water to assess ecological water quality and physical habitat in relation to certain environmental variables (Maraia *et al.,* 2011). Young *et al.* (2014) illustrated that benthic invertebrates find it quite difficult to colonize the benthic habitat in comparison to fish and other organisms, if the water quality deteriorates. Despite a possibility of increase in abundance of certain species, the overall species richness decreases. By evaluating the benthic macroinvertebrate indicator species, it is possible to assess water quality. Additionally, the bio-indicators of the two fish species *Salmo trutta* and *Barbus balcanicus* are also effective in assessing water quality. In their study of Tripotamos

River, Maraia *et al*., (2011) show that macro invertebrates responded better to local stressors than fish reflecting changes in habitat quality. *Barbus balcanicus* had relatively very low numbers at the sites where human disturbances were significantly intense. Maraia *et al*. (2011) found that there has been a significant difference in the measured mean values of hydromological and physiochemical parameters during autumn and spring, with higher mean nutrient values recorded in spring. Downstream sites of autumn sampling recorded the highest values of TSS (57.7 and 54 mg/l respectively) while spring sampling at the same site recorded the highest values of NO_2-N (0.002 and 0.025 mg/l), NO_3-N (0.90 and 0.91 mg/l), NH_4-N (1.66 and 1.58 mg/l), PO_4-P (0.137 and 0.057 mg/l), and B.O.D (7.8 and 8.9 mg/l) (Maraia *et al*., 2009). Moreover, high values of NH_4-N concentrations were observed during spring at sites 2 (0.047 mg/l), 6 (0.082 mg/l), and 8 (0.473 mg/l) with maximum values of conductivity (487 and 516 µS/cm for autumn and spring respectively), pH (8.25 and 8.19), and hardness (300 and 312 mg $CaCO_3$/l) measured at site 7).

Cimino *et al*. (2002) established that varying the number of water samples from different sites in Sicily (Italy) showed significant differences in the values of pH, conductivity, total dissolved solids, sulphates and nitrates. Groundwell water has shown high nitrate concentration (about 70 mg L^{-1} as N), TOC values up to 10 mg L^{-1}, poor levels of dissolved oxygen, presence of detergents and enteric bacteria (Cimino *et al*;. 2002). However, very little difference was seen in the concentration of dissolved oxygen measured at different sites for surface freshwater. There was significant difference in the concentration of total dissolved soil, total phosphorus, and nitrates.

Seasonal variation in water quality of the Gandak, Ghaghra, and Sone River in India were observed by Nipunika *et al*. (2010). Gandak River was evaluated by seven parameters—turbidity, sulfate, pH, phosphate, water temperature, total alkalinity, and sodium. Tests showed that the upstream site of Gandak River variables such as temperature, turbidity, and dissolved oxygen, total dissolved solid and total suspended solid differed significantly from downstream sites in a particular season (Nipunika *et al*., 2010). Nipunika *et al*. (2010) also found that Gandak River has significantly high pH due to bicarbonate leaching and carbonate weathering in catchment area, while total alkalinity and water temperature caused seasonal discrimination in water quality of Ghaghra. In addition, Sone River showed vast differences in water quality variables at the two sites at different seasons. A study by Young *et al.* (2014) based on Tanshui River in Taiwan further revealed that mostly the suspended solids were due to anthropogenic sources. However, the amount of suspended solids in Tanshui River increases largely due to heavy rain during the typhoon season. Thus, water qualities of studied rivers are influenced by anthropogenic activities and different seasons.

It is well established that fresh water quality is crucial to society in order to protect human health, aquatic ecosystems and preserve adequate water quality. The assessment of Alqueva reservoir in Portugal showed that that some parameters such as chemical oxygen demand, bio chemical oxygen demand, and NH_4^+–N had mean values above the limit levels. The poor quality of reservoir surface water correlated with wastewater discharge, containing organic matter, nutrients, and faecal bacteria in high concentrations (Palma et al., 2010). These wash downs contaminate water bodies adjacent to them.

Fiji lacks analytical data on water quality, particularly in rural western regions of Viti Levu. Data collected by government organizations and researchers become part of discrete reports and papers which is difficult to access. There is no publicly available scientific publication on water quality assessment in Fiji. This study is one of the first on water quality which will be publicly available. The results are anticipated to add to the scientific knowledge base and serve as a baseline for future research. The study will engage quantitative and qualitative data collection and laboratory analysis of water samples (Biotic, Chemical and Physical) from various sources to examine the health of some of the common water bodies surrounding the communities in the western Viti Levu. The paper concludes by emphasizing the need for greater freshwater protection, implementation of integrated water resource management and increasing public awareness in regards to environmental public health.

Methodology

Viti Levu is Fiji's largest island and home to approximately 70% of the population. Viti Levu has several river systems, including the Tavua, Ba, Lautoka, Nadi and Sigatoka systems. All of these rivers originate from the island's central mountains. The core methodological considerations are given below.

Samples: For the study, samples were collected from six different river sources in western Viti Levu. These are: Nadi River, Votualevu River, Sabeto River, Lomaloma Creek (Saweni), Veitari Stream (Lautoka) and Vanuakula in Tavua. Samples were collected in sampling bottles from the littoral zone of the river at a time of 6.00 - 7.00 am. A total of three (3) samples were analyzed from each source. Analysis required in situ Physico-chemical measurements and biological quality analysis.

Physical Parameters: Physical parameters (stream flow rate (qualitative), substrate type and bank erosion) were determined at each site.

Chemical Parameters**:** The water quality parameters using chemicals tests (pH, dissolved oxygen (DO), temperature, and conductivity, nitrates, chloride and calcium) were measured in situ in triplicates using the appropriate sensors and meters.

Biotic Filtering**:** Invertebrate samples was taken using a kick net method (Cummins and Merritt, 1996) to determine the presence of major benthic organism to measure the biotic index. Sampling was carried at each identified site.[2] All the samples were brought back to the lab for sorting and identification under an optical microscope.

Results and Discussion

Table 1.0 provides results of visual observations that were made on the study site. Signs of pollution were noticed in the Nadi River and Veitari stream. These two sources also had relatively higher conductivity, higher chloride and calcium content in the sample (Table 2). Other water samples did not show much anthropogenic activity except for wood logs and eroded banks which are results of flooding and weathering as part of the natural hydrological cycle.

The normal pH value of river water is around 7.4 (Crooked River Project, 1997). While the Nadi River had a pH close to the mean value result, Votualevu, Sabeto and the Lomaloma creek had slightly elevated levels. This could be due to higher carbonates in the system. The three rivers also had the highest calcium content (1850.1, 1854.2 and 1860.3 mg/L respectively; Table 2). This may also explain the high pH levels. Calcium is sourced from minerals and rocks and is dependent on the geographical availability of this mineral around the rivers.

Veitari stream and the Vanuakula sample had relatively low pH values (6.9 and 6.6 respectively). Low pH levels indicate an acidic environment in the aqueous body. According to the Fondriest Environmental Inc. (2016), low pH has a detrimental effect on aquatic life. Low pH not only reduces the solubility of calcium in the water and stress marine species but it also increases the solubility of heavy metal ions. This was also

[2] The kick net was plunged downstream to the post the sampler was standing. One foot was than dislodged in order for the subtrates to mix up towards the net. An average of three kicks (30 seconds each) was used for the collection of the invertebrates and the subtrates.

observed for the reduced calcium levels in comparison to the pH of the water sample in this study (Table 2).

Table 1: Qualitative observation of the physical parameters at the study site

Location	Stream Flow (Qualitative)	Substrate type	Bank Erosion
Nadi River	Almost Stagnant	Debris, Plastic matter, Wood logs, Cans and Bottles	None
Votualevu River	Free flowing	Wood logs	Major erosion due to extreme flooding
Sabeto River	Fast flowing	Wood logs	Major erosion due to extreme flooding
Lomaloma Creek (Saweni)	Free flowing	Wood logs	None
Veitari Stream (Lautoka)	Almost stagnant	Debris, Plastic matter, Wood logs, Cans and Bottles, Rags and Clothes and Metal pieces	None
Vanuakula, Tavua	Almost stagnant	Wood logs	None

Table 2: Chemical Parameters analyzed in situ for all the study sites

Location	pH (±0.3)	TDO (mg/L)	Nitrates (mg/L)	Chloride (mg/L)	Conductivity (µS/cm)	Calcium (mg/L)
Nadi River	7.6	5.3	4.4	32.0	225.6	1754.0
Votualevu River	7.8	6.0	4.8	5.8	211.3	1850.1
Sabeto River	7.8	5.7	4.6	6.2	212.0	1854.2
Lomaloma Creek	8.0	4.1	2.2	16.5	205.5	1860.3
Veitari Stream	6.9	4.7	24.0	1049.9	261.8	1722.0
Vanuakula, Tavua	6.6	4.5	26.8	605.8	272.1	1701.0

Chlorides are generally supposed to be low in river water. Our study, however, shows Veitari and the Vanuakula had very high levels of chlorides. This may be due to large volume wash down from bleaching agents found in cleaning compounds such as hypochlorous compounds like detergents, washing powders, disinfectants and toilet cleaners. Hypochlorous and chloride compounds react in aqueous media to form hypochlorous acid, lowering the pH of the water bodies.

Interestingly, the nitrate level of these two streams is relatively high as well. The European Commission established threshold limit (Eurostat

Statistics Explained, 2016) is 25mg/L. Vanuakula site nitrate was above the threshold while Veitari levels were close to the threshold. Nitrates are sourced from run-offs and anthropogenic activities, especially wash offs from fertilizers and pesticides which are used by agricultural communities in Fiji. Nitrates pick up free hydrogen in aqueous media and form nitrous and nitric acid, which in turn reduces the pH levels of the water body, further explaining the trend seen above.

Table 2 also shows the relative levels of TDO in the Veitari and the Vanuakula sites. The average value is much lower than those of the other river sources indicating an anoxic environment. Nitrates in high amounts leads to eutrophication, which is a process whereby excess algal growth occurs and in turn stress's the oxygen concentration in water (European Environment Agency, 2017). For these streams, as noted above, the levels of nitrates are higher than the threshold level. This also relates to the low levels of measured TDO in these waters. However DO results in this study show that these are not at any critical level as the accepted mean concentration is about 4-5 mg/L (Water Research Centre, 2014).

Conductivity values measure the total ions that can carry charge in water. The trend in this is very much related to the trend in nitrates and the observed lower pH (high H^+ concentration). Hence it is fairly higher for the Veitari and Vanuakula source than the rest of the samples.

Biotic study results are given in Table 3. Results show that the type of speciation found in these waters was generally very similar. Except for the Sabeto River, the rest of the sites had parasitic worm, fish and shrimps which are mostly tolerant to changes in nitrates and pH levels. Sabeto River had a faster flow rate which could account for the fact that fewer invertebrates were identified.

Table 3: Invertebrate analysis using kick-net method

Location	Invertebrate Net
Nadi River	Small fish, Mosquito larvae, High tadpole population, Shrimps, Insects, Birds and Ants
Votualevu River	1 Snail (Hydrobidue sp.), 1 Worm (Oligochaeta sp.), Dragon fly larvae (Odonata sp.), Crabs, Mosquitoes, Fishes (medium size), and Dragon flies
Sabeto River	1 Snail, lots of leaves decomposing in the river
Lomaloma Creek (Saweni)	High tadpole population, Algae, Small fishes, 1 Worm (Oligochaeta sp.), Crabs
Veitari Stream(Lautoka)	High tadpole population, Algae, Shrimps, Crabs and Fish larvae
Vanuakula, Tavua	Aquatic worm, Snail, Fish (medium in size)

Michael *et al*. (2003) state that many fish species tolerate high amounts of total dissolved solids and suspended sediments. This means that the percentage of agricultural land use is not necessarily directly associated with degradation of fish community at broad geographic scales. This has been due to riparian enhancement in agricultural and urban basins to restore fish communities. However, the impact of row crop agriculture and altered riparian vegetation destructed habitat through combination of channelization and tile drainage through scarring, sedimentation, habitat and homogenization (Thomas *et al*., 2007). Channelization is the most common of habitat modification which contributes to the poorest physical habitat quality and reduced biodiversity due to reduction in niche potential. Better physical habitat quality is associated with lower nutrient concentrations in stream (Thomas *et al*., 2007).

Implications

The key to maintaining safe water for all stems from the actions of communities. It is, thus, extremely important to increase public awareness in the following key areas:

- Water pollution from anthropogenic causes;
- Water conservation;
- Freshwater quality and its impact on human health
- Proper waste disposal practices
- Integrated water resource management

In a number of countries, there are national plans on water, air and environment quality.[3] Fiji has no such plan. Data on water and river quality is also negligible. A comprehensive study over a period of time is needed for ground water, surface water and water quality monitoring. Fresh water quality monitoring and evaluation measures are the foundation of water quality management (Nipunika *et al.*, 2003). Additionally, a common online database portal is important to disseminate and evaluate water quality information in a meaningful and dynamic way. A participatory and cross sectoral intervention is also necessary for embracing a holistic approach to natural resource and water quality management.

---

[3] An example is Thailand. The National Environmental Quality Plan of Thailand (2007-2011) emphasized rehabilitation of natural resources and environment through strengthening environmental management and increasing local and community participation (Boonsoon *et al.*, 2010). Rehabilitation of water quality policies aims to reduce and control water pollution originating from domestic, industrial and agricultural activities. Thailand aims to achieve good quality fresh water for all users by 2025.

Conclusion

This paper is based on a limited study of rivers and streams in western Viti Levu. It was able to quantify some of the important chemical factors in determining the health of water bodies. Results showed that there were over the threshold limits in these samples. However, on the basis of previous studies, one can suppose that most aquatic organisms found in these areas would be tolerant of the conditions of the water bodies. Nonetheless, the Veitari and the Vanuakula samples reported a stressing environmental condition and showed signs of advanced anthropogenic activity in the area. The river water samples were found to be of poor quality with reference to the European Union guidelines. A more comprehensive water quality analysis is necessary. So is the need for sustained research interest in monitoring water quality of Fiji's rivers and streams.

References

Boonsatien, B., S. Narumon, T. B. Michael, and S. Wijarn (2010) 'An Implementation Plan for Using Biological Indicators to Improve Assessment of Water Quality in Thailand'. *Environ Monit Assess* 165: 205-215.

Cimino, G., M. C. Puleio & G. Toscano (2002) 'Quality Assessment of Freshwater and Coastal seawater in the Ionian Area of N.E. Silicy, Italy'. *Environ Monit Assess,* 77: 61-80.

Crooked River Project (1997) 'Water Quality: pH', viewed 26 February 2017, at: https://www.grc.nasa.gov/WWW/k-12/fenlewis/Waterquality.html

Cummins, K.W. & R. W. Merritt (1996). *Ecology and Distribution of Aquatic Insects*: *An Introduction to the Aquatic Insects of North America* (3rd Edition). Dubuque, Iowa: Kendall/Hunt Publishing Company.

European Environment Agency. (2017) 'Nitrates in Rivers' viewed 26 February 2017, http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/nitrate-in-rivers

Eurostat Statistics Explained (2016) 'Agri-environmental indicator - nitrate pollution of water'. European Commission, viewed 26 February 2017 at http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_nitrate_pollution_of_water

Fondriest Environmental Inc. (2016) Fundamentals of Environmental Measurements: pH of water, viewed 26 February 2017. http://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/

Lee, C. (2013) *Help Fijians get clean drinking water*, Institute of Environmental and Sustainability, viewed 4 August 2016 at: http://www.environment.ucla.edu/

Maria, T., D. C. Cheimonopoulou, Ioannis T. Bobori, and L. Maria (2011) 'Assessing Ecological Water Quality with Macroinvertebrates and Fish: A Case Study from a Small Mediterranean River'. *Environmental Management* 47: 279-290.

Michael, R. M., M. G. Robert (2003) 'Assessing Water Quality at Large Geographic Scales: Relations Among Land Use, Water Physicochemistry, Riparian Condition, and Fish Community Structure'. *Environ Management* 31: 504-517.

Mosley, L.M., D. S. Sharp & S. Singh (2004) 'Effects of a tropical cyclone on the drinking-water quality of a remote Pacific island'. *Disasters 28*(4): 405-417.

Nipunika, R., K. S. Ravindra, P. Kriteshwar, and K. K. Dilip (2011) 'Assessment of temporal variation in water quality of some important rivers in middle Gangetic plains, India'. *Environ Monit Assess* 174: 401-415.

Palma, P., P. Alvarenga, and V. L. Palma (2010). 'Assessment of anthropogenic sources of water pollution using multivariate statistical techniques: a case study of the Alqueva's reservoir, Portugal'. *Environ Monit Assess* 165: 539.

Simione, D. R., C. Dennis, M. D. (2009) 'Comparative Analysis of Regional Water Quality in Canada Using the Water Quality Index'. *Environ Monit Assess* 156: 223-240.

Tabua, J. (2013) 'Environmental Health Issues in Fiji'. viewed 5 August 2016 at http://www.ehawa.org.au/documents/item/707

Tagicakibau**,** M. (2016). 'Water-borne diseases likely to arise'*. The Fiji Times*, viewed 27 April 2016, URL: http://www.fijitimes.com/story.aspx?id=3430711

Thomas, H., R. W. Matt, V. R. Todd, and B. D. Mark (2007). 'Relationships Between Water Quality, Habitat Quality and Macroinvertebrate Assemblages in Illinois Steams'. J. O. *Environ Quality* 6*:* 1653.

Valema, R. (2014). *Test on Water in Fiji; The Fiji Times*, viewed 27 April 2016, URL: http://www.fijitimes.com/story.aspx?id=2737266

Water Research Centre. (2014) 'Dissolved Oxygen: How dissolved oxygen affects aquatic life'. viewed 26 February 2017, at http://www.water-research.net/index.php/dissolved-oxygen-in-water

Young, S., Y. Hsi-Nan, H. Da-Ji, L. Su-Miao, H. Yueh-Han, C. Chung-Ting, L. Jin-Wei (2014). 'Using Benthic Macroinvertebrate and Fish Communities as Bioindicators of the Tanshui River Basin Around the Greater Taipei Area — Multivariate Analysis of Spatial Variation Related to Levels of Water Pollution'. *Int. J. Environ. Res. Public Health* 11: 7116-7143.

Authors:

Kushaal Raj, Sanjay Singh, Priyatma Singh and **Dhrishna Charan** are Lecturers in Chemistry at the University of Fiji. Corresponding Author: Kushaal Raj. Email: kushaalr@unifiji.ac.fj