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## Escherichia Coli: Levels Found in Suva Water and the Implications to Fijians: A Case Study of the Vatuwaqa River

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**ESCHERICHIA COLI: LEVELS FOUND IN SUVA WATER AND THE  
IMPLICATIONS TO FIJIANS:  
A CASE STUDY OF THE VATUWAQA RIVER**

**by**

**Hesper D. Kohler**

**Thesis submitted in partial fulfillment  
of the requirements for the degree**

**of**

**HONORS IN UNIVERSITY STUDIES  
WITH DEPARTMENTAL HONORS**

**in**

**Environmental Studies  
in the Department Environment and Society**

**Approved:**

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## **Abstract**

Urban migration is causing a high increase in the population of Suva, Fiji, and the population is growing at a rate that exceeds development planning and infrastructure. Several squatter settlements are established within the city limits where raw sewage, containing infectious pathogens and diseases, is released into the waterways. This study focuses on the area accumulation of the pathogenic bacteria from fecal contamination in the form of *E. coli* down the Vatuwaga River. *E. coli* is used as a water quality indicator because, if it is present, other possible pathogens and viruses such as cholera and salmonella could be present. The European Union accepts anything under 200 colonies of *E. coli* per 100 ml of seawater as safe to eat raw shell fish. Water samples were strategically taken from six sites at areas of surface run off to find the highest source of *E. coli*. The levels of *E. coli* colonies found in the Vatuwaga River ranged between 2,500-50,333 colonies per 100/ml. Though the results showed that the *E. coli* levels did not accumulate downstream, there was a significant change in *E. coli* levels after the mangrove forests due to their filtrating root system.

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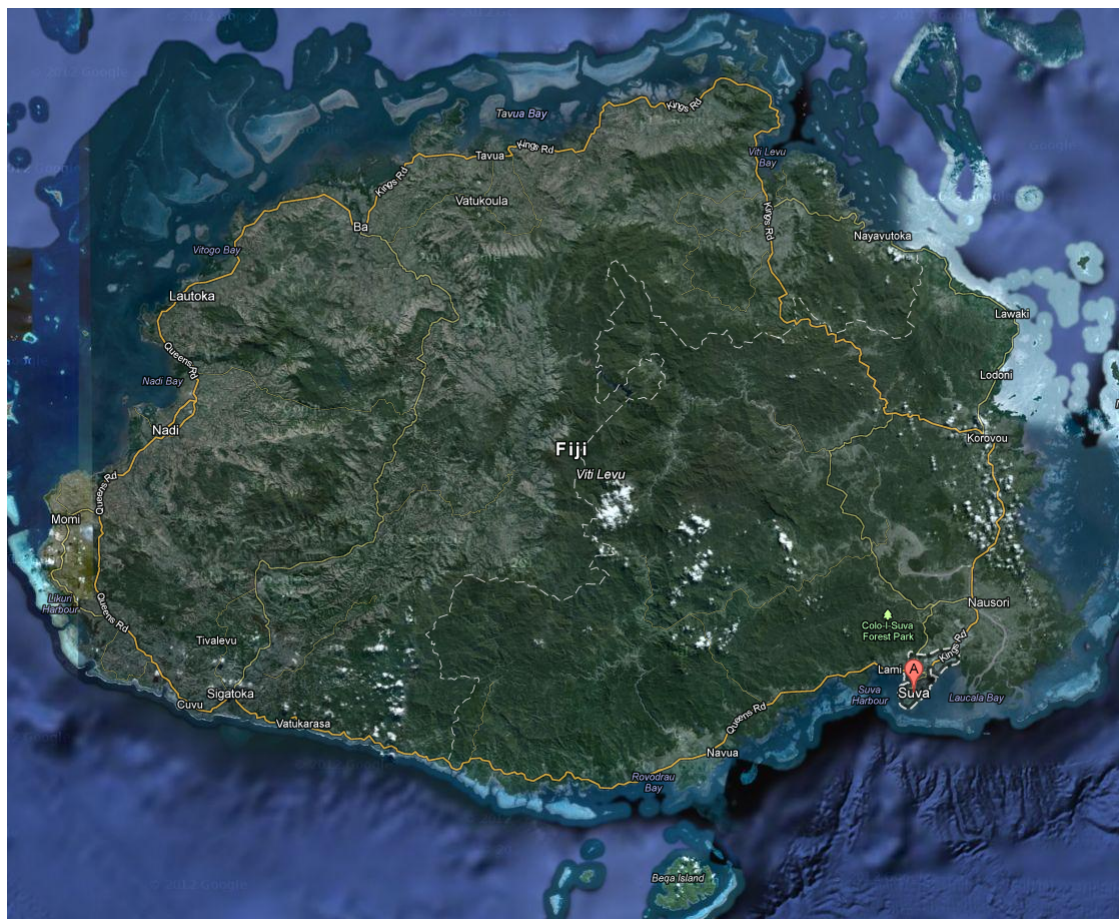
## **Introduction**

Urban migration is causing a large increase in the population of Suva, Fiji, and the population is growing at a rate that exceeds development planning and infrastructure. Several squatter settlements are established within the city limits where raw sewage, potentially containing infectious pathogens and diseases, is released into the waterways. This study focuses on the area accumulation of pathogenic bacteria from fecal contamination in the form of *Escherichia coli* (*E. coli*) down the Vatuwaga River. *E. coli* is used as a water quality indicator because it is present in the waste of humans and other mammals. In the USA, the EPA's (Environmental Protection Agency) standard of fecal coliform levels in recreation water is less than 200 colonies/100 ml. *E. coli*'s presence in a water sample suggests that it has been contaminated by human feces, which may also contain, other bacteria and viruses such as cholera and salmonella. The data from this study is used as a reference for the water quality of the river, and potential health risks to urban Fijians.

## **Background**

Urban migration is causing a large increase in the population of the capitol city of Fiji, Suva, located along the southeastern coast of the main island Viti Levu (see Figure 1 below) (Stabile, 2000). In Fiji, 52% of the population is found in cities, with an immigration rate of 1.3% every year (*Australia-Oceania: Fiji*, 2013). Over 90% of the urban populations are found along the coast (Lal, 1984). Unfortunately like many large cities in developing countries, the population is increasing faster than planning and infrastructure development (Whitman and Flick, 1995). This has created a lack of essential infrastructure, such as adequate sewage collection systems or wastewater treatment plants. The current primary wastewater treatment plant in Suva, Kinoya, was built for a population of 80,000, which Suva surpassed in the early 2000s. The plant

discharges treated waste into the Rewa River, but when it rains, stormwater overflow results in discharge of excess untreated wastewater into the Luacala Bay around Suva. (USP, 2004).



**Figure 1: The main island of Fiji, Viti Levu. The capitol city of Suva is on the peninsula in the southwest corner. Source: Google Maps.**

Besides sewage from Kinoya, waterways in Suva are also carrying raw sewage from squatter settlements that have grown throughout the city. Cities provide more jobs than in the rural communities; however affordable housing is hard to find for many rural people moving to the cities. In 2012 it was estimated that 140,000 people in urban Fiji were living in 190 informal housing settlements (Bryant-Tokalau, 2012). The majority of these squatter settlements are created on cheap and undesirable areas such as near mangrove forests (USP, 2004). The mangrove forests are used as trash dumps, or are cut down for land reclamation or fuel (USP,

2004). With the constant rate of urbanization happening, it is expected that another 30,000 new houses will be built in urban squatter settlements in the next fifteen years, further aggravating the pressures on the mangrove forest (Bryant-Tokalau, 2012). This will lead to more tree removal, and more raw sewage released into the freshwater-ways of the area, ultimately discharge into the coastal waters of the country.

In the greater Suva area there are multiple estuaries where rivers empty into the coastal areas (see Fig. 2 below). The main rivers are the Rewa, Vatuwaga, Samabula, Tamavua, and Navesi (Sugrim, 2011). As these rivers drain the land, they receive all the pollution that had accumulated along the rivers' paths and within their watersheds. These pollutants include heavy metals, oil, phosphates and nitrogen, fertilizers, pesticides, pathogens, and effluents from factories containing industrial chemicals, and sewage waste from humans, pigs and cattle (Stabile, 2000). Vatuwaqa River is known to have high sewage waste accumulation due to the Reiwasa Squatter Settlement that is built along side. The squatter settlement empties their raw sewage directly into the river, containing infectious pathogens and diseases (Stabile, 2000).



**Figure 2: Suva city and the surrounding area bays and estuaries. Source: Google Maps.**

The two main concerns with sewage waste are the diseases caused by pathogenic bacteria found in human and animal feces, and the ecologically destructive algal blooms caused by the additional nutrients added to the receiving waters (Stabile, 2000). The concern of potential infectious disease outbreaks is highest in developing countries in highly populated areas, such as Suva, Fiji (WHO, 2009).

*Escherichia coli* (*E. coli*) is one of many coliforms found in sewage (WHO, 2009; Hamzah, Kipli, Ismail, Una, Sarmani, 2011). *E. coli* is a bacteria that is commonly found in the intestines of warm blooded organisms, where it is harmless. However, if ingested, or introduced through wounds, eye exposure or other mechanisms it can cause serious health issues especially if it is the Enterohaemorrhagic strain (World Health Organization, 2011). Gastrointestinal illnesses such as vomiting and diarrhea, urinary tract infections, pneumonia, rashes, eye infections, ear

aches, and hepatitis A are all common health issues related to consuming *E. coli* contaminated water or sea food (Sugrim, 2011). It is rare to die from a health issue relate to a strain of *E. coli*, 2-7% cases (WHO, 2011). However infants are more in danger from *E. coli* pathogenic strains, often causing infantile diarrhea, which is the highest cause infant mortality (Sugrim, 2011).

*E. coli* is used as a water quality indicator because if it is present, there are other possible pathogens and viruses in the water that are connect with sewage waste, such as cholera and salmonella. In the USA, the EPA's (Environmental Protection Agency) standard of fecal coliform levels in recreation water is less than 200 colonies/100 ml using a thirty-day geometric mean (Hamzah et al. 2011). This standard is based on the World Health Organizations water quality guidelines for healthy drinking and recreation waters (Rees et al., 2010).

The goal of this project was to characterize *E. coli* concentrations along a stretch of the Vatuwaqa River and to identify potential source areas. Measured concentrations were compared to the input into the EPA standard for safe recreational water because this is the lowest level safe enough for people to spend time in the water, and the Vatuwaqa River is used for recreation, bathing, washing, and for harvesting of food. The specific objectives were to: 1. compare and contrast the fecal coliform concentration from each of the six sites sampled on three different days; and 2. use this assessment to inform management decisions along the waterway that will protect the coastal community from infectious disease outbreaks, and protect the coast from unnaturally high levels of nutrients.

## **Methodology and Methods**

### *Sites and Sampling*

The Vatuwaqa River was chosen for this monitoring program due to its short length and easy access. Six sampling stations were located along a 3.6 km stretch of this river as it moved

through Eastern Suva. Sites were located at the following locations: 1) Fletcher Road Bridge (Appendix A), 2) Fletcher Road River Bend (Appendix B), 3) Carpenter Street Nasese Bus Garage (Appendix C), 4) Reiwasa Squatter Settlement (Appendix D), 5) Karsanji Street Bridge (appendix E) and 6) Namena Road Bridge (Appendix F) (see Figure 3). The sites were strategically selected at areas with a high amount of runoff and where *E. coli* levels could possibly vary due to different types of human use. At each site samples were collected subsurface with three replications, each one a meter apart following protocol mentioned below. The river was monitored three times: Day 1) 05 May 2012, 21 May 2012, and 23 May 2012. Time was not equally spaced between monitoring days to account for the difference in times of falling tides and the schedule of the assisting lab attendant of the university. Each sample was taken during the morning falling tide when the river had the least amount of salt water diluting the samples. The average rainfall, temperature and wind speed were recorded the day before sampling to compare the days, and account for the amount of runoff in the water.

Sample collection and processing followed protocol's similar to EPA's Method 1604 (EPA, 2002). At bridge sites, samples were collected using a bucket on a rope. The bucket was rinsed between samples. Water was distributed from the bucket into three 250 ml Duran® glass sampling bottles. For samples taken from land, an extendable steel arm was used to hold sample bottles, which were plunged in neck first then tilted upward, facing upstream to collect the sample. A bottle was filled with sterilized distilled water at site 6 and analyzed as a field blank. The samples were stored in an icebox at four degrees Celsius until all samples were collected. Further processing of samples was done upon returning to the University of the South Pacific (USP) within eight hours of sampling, as indicated in Method 1604.



**Table 1: Weather the Day before Sampling.**

	Average Rainfall (cm)	Average Temperature (°C)	Average Wind Speed (kph)
Day 1: 5 May 2012	0.4	22.7	6.4
Day 2 : 21 May 2012	1.4	23.0	8.0
Day 3: 23 May 2012	0.0	23.0	6.4



**Figure 3: Map of the 6 sites for sampling up the Vatuwaqa River, Suva, Fiji. Source: Google Maps.**



**Table 2: Distance Upstream from Site 1 in kilometers**

Site 1	0
Site 2	0.5
Site 3	1.2
Site 4	2.5
Site 5	3.0
Site 6	3.6

### *Measurements of Water Parameters*

Water temperature, dissolved oxygen, and salinity were measured at site before collecting the water samples. These physical parameters were used to help identify any differences in the general water properties of each site. All three properties were measured using Yellow Springs Instrument Co. Inc. (YSL) electric meter, which was calibrated on site.

### *Coliform Analysis*

The analysis of *E. coli* was done using the Membrane Filtration Method from the Marine Science 312 Water Pollution course. A sterile filtering apparatus, a large trap for filtered water, and a secondary trap were arranged in series and connected to a vacuum pump with adjustable suction pressure (Figure 4 -USP, no date). Serial dilutions with distilled water were prepared in sterilized glass 25ml flasks, using 1ml and 10 ml pipettes, resulting in 0.01%, 1%, and 10% dilutions of the original sample. The dilutions were done to provide at least one plate with identifiable number of count colonies. The bacteria were plated out on new, disposable 50 mm plastic Petri dishes containing 2 ml of sterile growth medium, MH broth. The MH broth was made one day before sample collections by mixing 3.7g MFC powder with 100 ml distilled water in a beaker and

heating it on a heating pad. 1 ml Rosolic acid solution was added before the solution boiled. After cooling slightly, 2 ml of broth was added into each sterile Petri dish with an absorbent pad. The Petri dishes were refrigerated until use, and then returned to room temperature before placing the filters containing the colonies.

Each dilution was filtered with the apparatus rinsed with sterilized distilled water between each dilution. Filters were transferred to the Petri dishes using sterilized forceps that were dipped in ethanol and flamed with an alcohol burner between each transfer (see Figure 4). The dishes were then incubated at 35°C for one hour, then transferred to 44.5°C to continue incubation for a further 20-24 hours as done in Method 1604 (EPA, 2002). After incubation, the number of blue colonies (*E. coli*) on each plate was counted and recorded (USP).



**Figure 4: Filtering apparatus and forceps sterilization equipment used when analyzing samples.**

### *Data Analysis*

In this study, the dilution with the highest count of distinct colonies was used. Bacterial counts are typically expressed as number of colonies per 100 ml. This is calculated as:

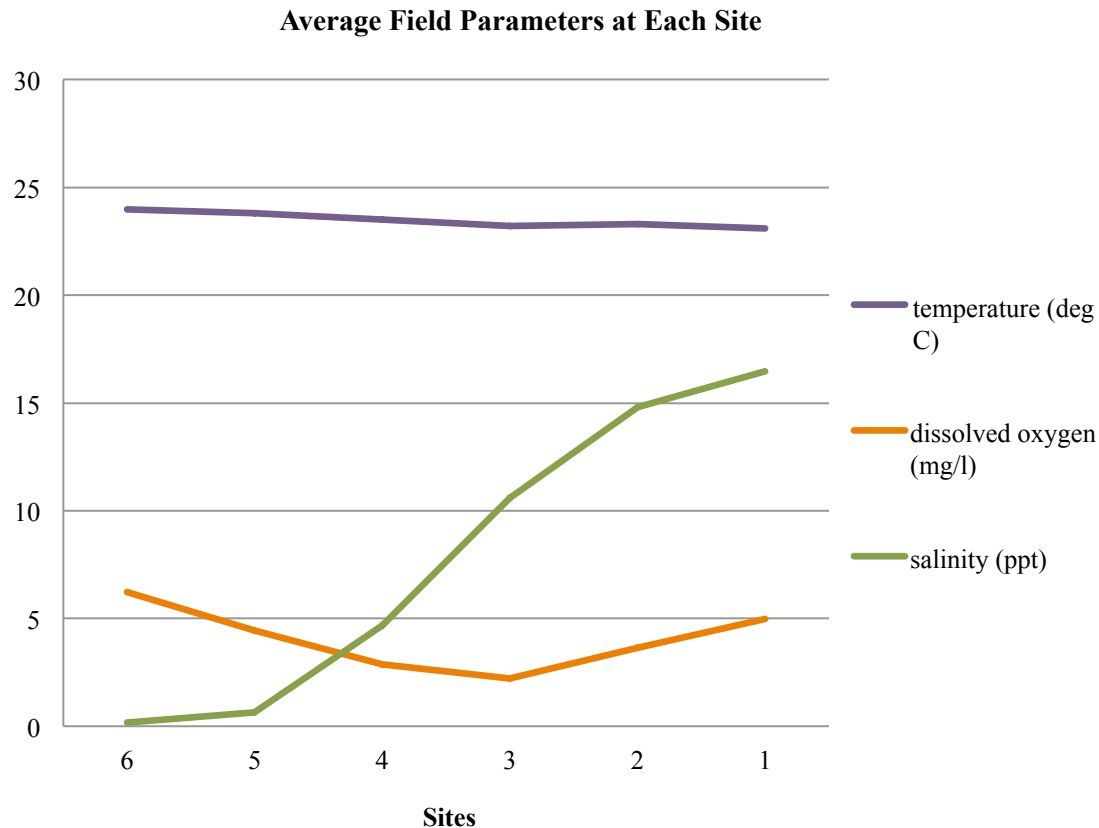
$$\text{colonies/100 ml} = (\text{colonies} * 100\text{ml}) / (\text{volume filtered in ml})$$

Arithmetic and geometric means for total blue (*E. coli*) colonies were counted for each site on each day using Microsoft Excel. Arithmetic means of salinity, dissolved oxygen, pH, and *E. coli* colonies were also calculated for each site ( see Appendix G), and each sample date. To view the overall difference between sites and the days sampled, a line graph was created.

## **Results**

### *Water Characteristics*

There was no significant difference between the water temperatures of each site, staying between 23-24°C. The site with the lowest dissolved oxygen level (DO) was site 4, Reiwasa Settlement. The site with the highest DO level was site 6, Namena Road Bridge, which is the farthest upstream. Dissolved oxygen concentrations are affected by the water's salinity and temperature. Depth and current at a site affect contact with the surface, which drives the reoxygenation rate (Hamzah et al. 2011). Salinity was highest at Site 1, nearest the ocean, and decreased upstream. Salinity in coastal environments fluctuates due to tides and the relation of the river water to the ocean. Salinity levels also change during weather events and tides (Fig. 5).



**Figure 5: Arithmetic averages of field parameters found at each site going downstream, from all three days of sampling.**

### *E. coli* Count

*E. coli* concentrations at a given site, and the relationships between sites varied according to sampling day. The lowest counts of *E. coli* were found at site 3, the Nasese Bus Garage, with a range between 2500-5700 colonies per 100ml water. The site with the highest *E. coli* count was site 6, Namena Road Bridge, with a range between 23333 -50333 colonies (see Figure 6 and Appendix G). All other sites were also above the USEPA standards for safe recreational water, <200 colonies per 100 mL. On Day 3 there was a large increase in *E. coli* found in sites 4, 5 and 6 compared to the other days (Fig. 6). *E. coli* concentration can depend on the water depth, temperature and salinity levels, and the source of input into the waterway.

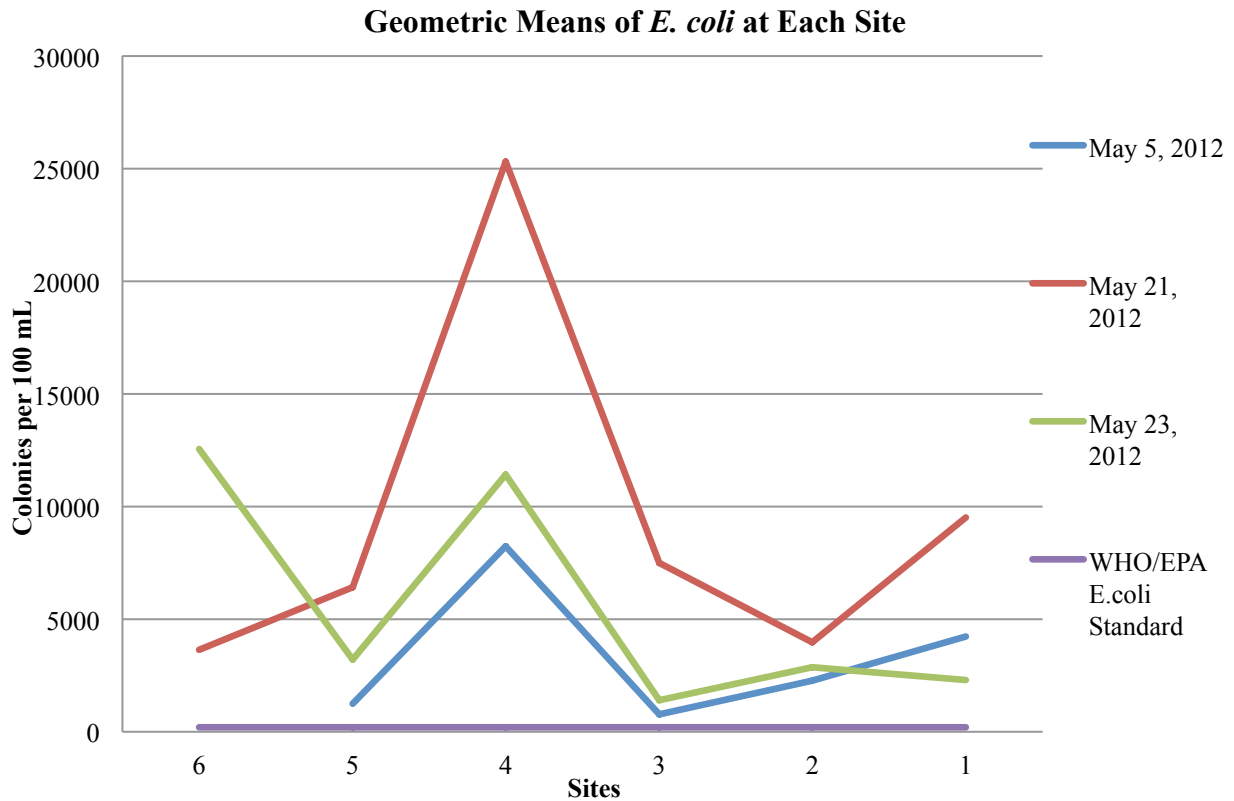


Figure 6: The geometric mean of *E. coli* colonies found at each site on Day 1, Day 2, Day 3. Averages are of the dilutions done at each site going upstream.

## Implications

Physical parameters were measured for a general assessment of the water quality of the river.

The water temperature found in the river is normal for a river of its size in a tropical climate,

between 20 and 30 degrees Celsius (Hamzah et al. 2011). Dissolved oxygen (DO) changed

throughout the sites based on the change in salinity, water temperature, water movement, and

river depth, which was expected. The results show levels of DO that can maintain life in the river

on the surface however the vertical profile is not known since depth and flow of the river was not

sampled. As the salinity levels decreased going up the river, the types of organisms changed too

(Hamzah et al. 2011). The lower reach of the river flows through mangrove forests, while reeds

and cassava were found upriver. The change in salinity appears to drive the change in elevation along the river.

In regards to the *E. coli* counts along the river, the mangrove forest found between sites 3 and 4 may explain the *E. coli* levels found from Site 3 on down the river. At site 3 the water is only accessible through the mangrove roots. Mangroves are known for their filtering ability of water. Sediment is trapped in the root system and the nutrients and bacteria (like *E. coli*) in the water are filtered through the roots or taken up by the roots (Duke and Allen, 2006). The highest levels of *E. coli* (Site 6) can be explained by the river's size, and land use around the river. Site 6 is the most accessible site at the beginning of the Vatuwaqa River. At this site the river has the lowest flow. It is shallow and less than a meter wide. This portion of the river runs through a residential area where people have thrown rubbish into the river, and there are groups of stray dogs. The combination of river size and the potential waste from dogs and humans can explain why this part of the river would have the highest *E. coli* count. The river gets wider and deeper downstream. Also, salt has the potential to kill a small portion of the coliform as the fresh water mixes with the salt water (Hamzah, et al. 2011).

Throughout the river residents have used the waterway for waste disposal. Site 4, with the highest measured concentrations on two of the three days, is located at the squatter settlements which had no sewage management. Waste at this site goes directly into the water. Trash and garbage disposal was also common at sites 3-5, although there was no evidence of human waste, which may explain the lower *E. coli* concentrations. At site 3, the bus garage threw all bus waste into the mangroves, including seats, tires, oil canisters, rusting pieces of metal, and food containers. At sites 5 and 6, residents had their rubbish piles in the river. At all other sites, trash was found floating throughout the river. The combination of these factors increases the *E. coli*

level in the river. However the reason for such high counts of *E. coli*, even from the beginning of the river, might be explained by the feral packs of dogs in the area, or other animals.

### **Conclusion/Recommendations**

When sampling, people were seen fishing, swimming and bathing from the river and its estuary. It is recommended that the city of Suva creates a warning system for *E. coli* levels in the water systems. This can be done with signs along the river systems and coastal areas. Signs can inform locals, and tourists, who come to the area of the potential hazards in the water. By warning people of the health hazards they can avoid the possibility of getting sick. Also people who are already sick might be able to realize what caused them to get sick, and find a remedy. The later reason can be especially important in areas such as Reiwasa Settlement where health risks are high due to lack of infrastructure.

It is also recommended that Suva creates a water quality management policy, under either the Ministry of Health or Ministry of Environment, for the water sources that run through the urban areas. Fiji does have a waste water treatment plant, a safe drinking water policy (Stabile, 2000) and has just created a rural water and sanitation policy to manage water quality, but the water that just flows through the city also needs to be managed and cleaned. The policy should include water quality standards, and a plan for improving water sources that do not meet the standards, for *E. coli*, and other pollutants such as heavy metals, nitrates, phosphates and oil found in the water of the river systems and the coastal environment. These pollutants are the most harmful to human and ecosystem health (Naqasima, 1996).

Suva should also create a mangrove management plan in order to conserve their urban mangrove forests. As seen in this project results, the filtering root system of the mangrove forest found on

the Vatuwaqa River likely trapped a large portion of the *E. coli* that entered the river upstream.

With a strong management plan, Suva can use mangroves as a natural cleanser to help them improve the water quality of the freshwater before it empties into the coastal waters.



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## Appendix

### A. Site 1: Fletcher Road Bridge



### B. Site 2: Fletcher Road River Bend





C. Site 3: Carpenter Street Nasese Bus Garage



D. Site 4: Reiwasa Squatter Settlement

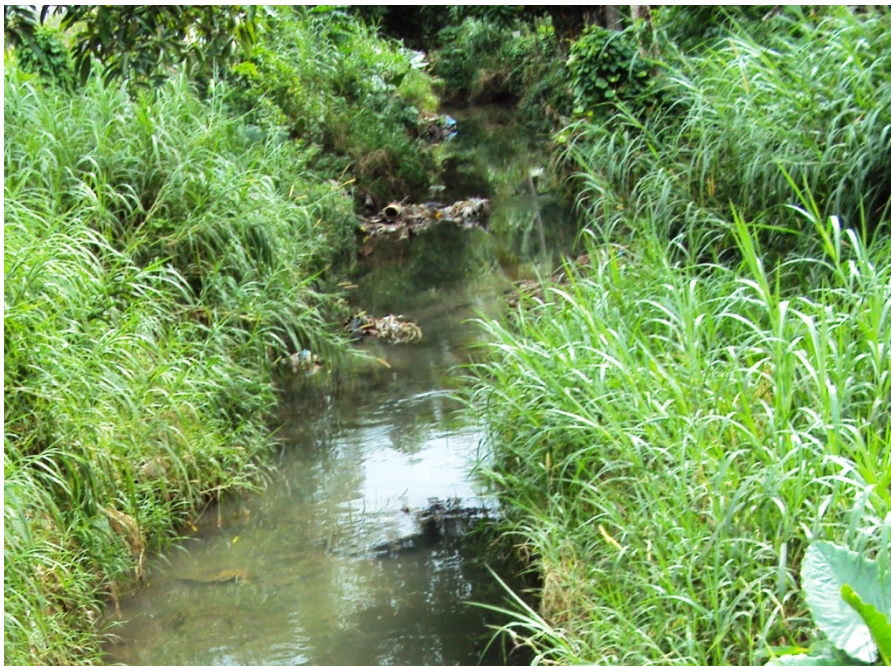




E. Site 5: Karsanji Street Bridge



F. Site 6: Namena Road Bridge



G. Arithmetic Means of Highest Distinct *E. coli* Counts per Site and Day, Going Downstream

<b>Site</b>	<b>Day 1</b>	<b>Day 2</b>	<b>Day 3</b>	<b>Mean</b>
<b>6</b>	NA	3638.0	12561.0	<b>8099.5</b>
<b>5</b>	1236.0	6409.0	3203.0	<b>3616.0</b>
<b>4</b>	8235.0	25318.0	11415.0	<b>14989.3</b>
<b>3</b>	774.0	7489.0	1401.0	<b>3221.3</b>
<b>2</b>	2276.0	3960.0	2879.0	<b>3038.3</b>
<b>1</b>	4240.0	9522.0	2295.0	<b>5352.3</b>
<b>Mean</b>	<b>3352.2</b>	<b>9389.3</b>	<b>5625.7</b>	

### **Author's Biography**

Hesper D. Kohler was raised in New Mexico, Florida and Oregon and graduated from McMinnville High School in 2009. A Quinney Scholar for the S.J. and Jesse E. Quinney College of Natural Resources, she entered Utah State University in the fall of 2009 as an Environmental Studies major. While attending school her sophomore year, she obtained an internship with the USU Water Quality Extension Office as a Program Assistant and taught students and community members throughout Utah about the importance of water quality and has since continued her interest in water resources. As an Aggie, Hesper has complemented her education by being an Honors Mentor, an Honors Teaching Fellow for their Breadth Physical Science course, and has served at different times as Vice President, President and the Environment and Society Student Representative on the Quinney College of Natural Resources Student Council. In the spring of 2012, Hesper left the cold of Logan and obtained an emphasis in Marine Studies while studying abroad in Suva, Fiji.

After she graduates in May 2013, Hesper is moving to Seattle, Washington for a summer long internship as a Fish Biologist for the International Pacific Halibut Commission. After the summer, she will probably stay in the Pacific Northwest, enjoying the outdoors, traveling, and working towards a career in Coastal Marine Management, hopefully with the National Oceanic and Atmospheric Administration.