

Bacteriological Quality of Potable Water Supply at the National University of Samoa

¹Faainuseiamalie Latu, ²Patila Amosa, ³Taema Imo

¹Department of Science, National University of Samoa, Samoa

²Faculty of Science, National University of Samoa, P.O Box 1622, Apia, Samoa

³Department of Science, National University of Samoa, Samoa

Abstract - The purpose of this study was to determine the sanitary quality of potable water by estimating the concentration of total coliform (TC) and faecal coliform (FC) bacteria as pollution indicators. All samples from the all sites were found contaminated with total coliform and faecal coliform bacteria and the counts were higher than the maximum microbial contaminant level established by the World Health Organization (WHO). The results imply that the reticulated water supply was heavily polluted by bacteria of faecal origin suggesting that this water supply was a potential source of health hazards which is important from a public health perspective.

Keywords: Drinking water, faecal coliforms, contamination, water quality, health, Samoa.

I. INTRODUCTION

Water is essential to sustain life. Safe and accessible supply must be available to all. It is well known that the quality and safety of the drinking water continues to be an important public health [1],[2] because its contamination has been frequently described as responsible for the transmission of infectious diseases that have caused serious illnesses and associated mortality worldwide [3]. Clearly, point-of-use water quality is a critical public health indicator [4]. The severity of the typhoid problem in Samoa has been reiterated by a representative of the World Health Organisation (WHO) to the local media [4]. The National University of Samoa (NUS) is the only national university of Samoa established in 1984 by an act of parliament. Since the opening of the National University of Samoa (NUS) Campus, water quality has been taken for granted to safe for drinking and washing hands. Since then, no study has attempted to confirm the microbiological quality of water on NUS campus. The NUS drinking water is intermittently supplied by the Samoa Water Authority (SWA) which is also responsible for monitoring of water quality. Although there have been known cases of intestinal infections within the staff and student population of NUS no study has been conducted to determine its source and since SWA is reluctant to release information on water quality (microbiological), it pertinent that this study undertakes this

exercise to establish the microbiological quality of water used for drinking and hand washing. To determine the microbiological quality of water consumed and used for sanitary purposes on NUS campus and to create a regular monitoring scheme to ensure that water supplies for consumption and sanitary use meets the national water quality standards. The main objective of this study is to determine the absence/presence of Heterotrophic, total and faecal coliforms in drinking and hand washing water supplies at Building A block, on NUS campus and compare to National Drinking Water Standards to create a microbiological testing regime for regular monitoring of water supplies.

II. METHODOLOGY

2.1 Site Selection

The National University of Samoa campus (Figure 1, Figure 2, Figure 3), has more than 100 faucets and taps from which potable water can be obtained. Considering the amount of materials and man hours required to sample each it was decided that since they all fed by a common water line a selection of faucets and taps would be sufficient for our investigative purpose. The West Wing of Building A (on IHE campus) together with the Biology and Chemistry Laboratories were selected. Faucets from the boiler room and the left most faucet of the toilet block (both bottom and upper floor) were selected. After the second week of investigation, heavy bacterial growth suggested contamination and to identify the source of contamination the SWA water inlet and the NUS above ground reservoir tank were included as sampling sites. This gave a total of 10 water sampling sites (labelled A-J) (Table 1).

2.2 Sampling

Samples of drinking water and water used for hand washing will be collected from the East Wing of Building A faucets (A-Toilets (female), B-Boiler room (female), C-Toilets (male), D-Boiler room (male), E-Biology lab Preparation room, F-Biology lab, G-Chemistry lab Preparation room, H-Chemistry lab, I-SWA supplier and J-Water tank above ground reservoir). A 500mL Triplicate samples of each faucet

will be collected on each sampling date to ensure statistical significance. Due to the work involved in the culture media

preparation, samples were taken twice a week of a period of ten weeks.

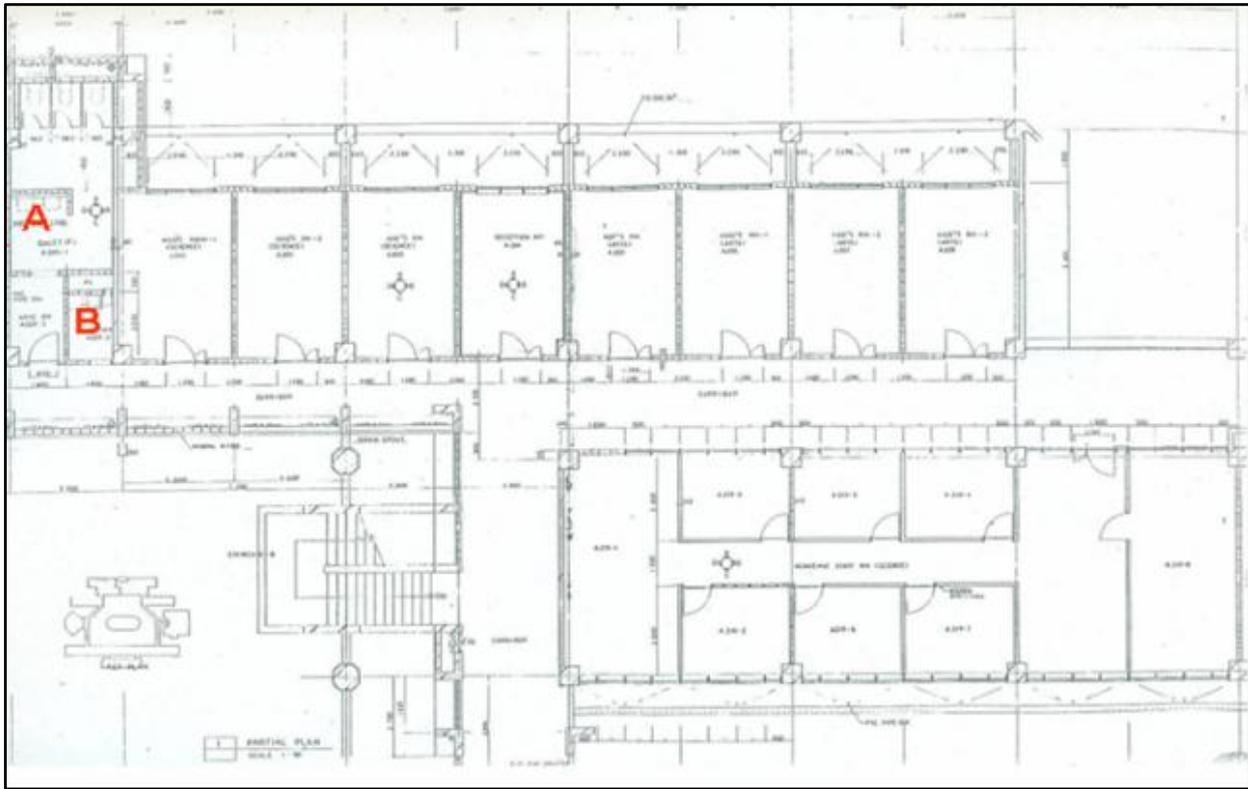


Figure 1: Floor Plan – Sampling locations (A, B)

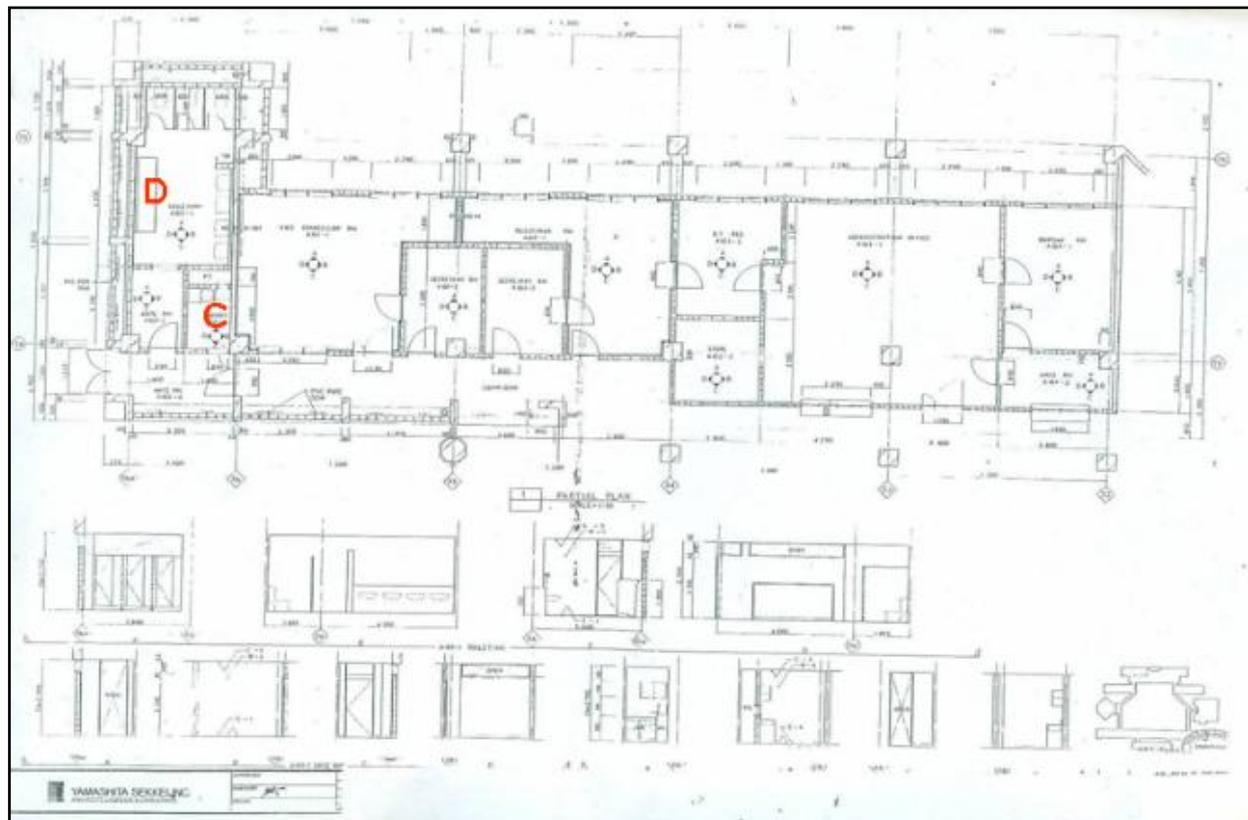


Figure 2: Floor Plan – Sampling locations (C, D)

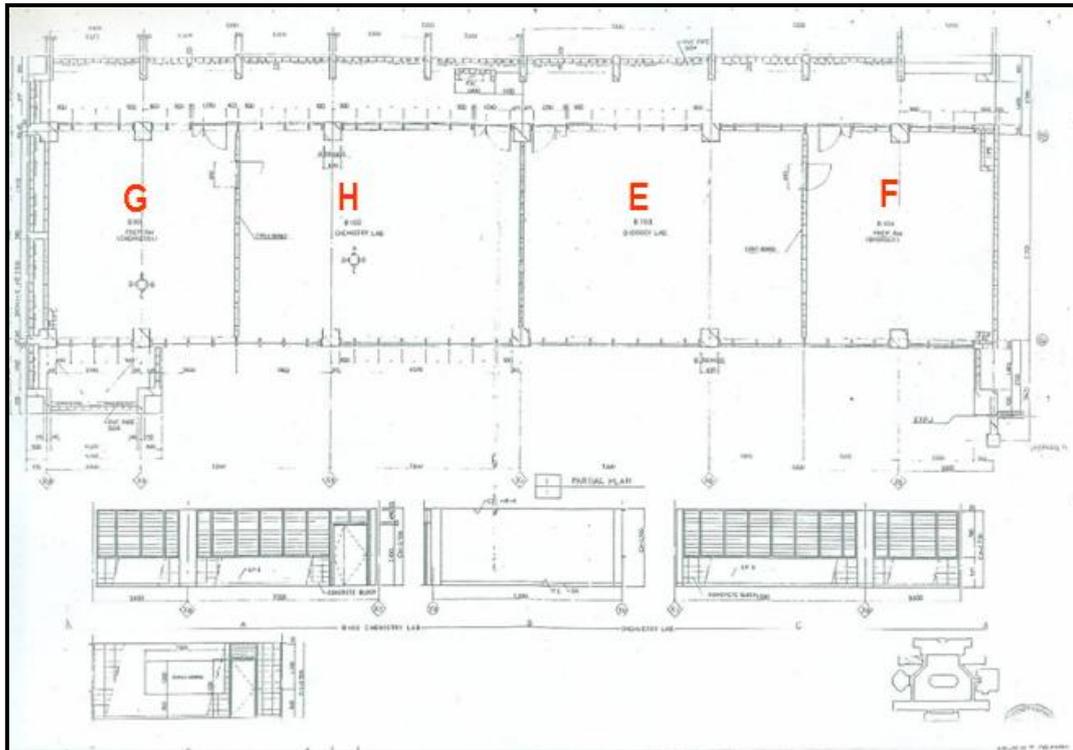


Figure 3: Floor Plan – Sampling locations (E, F, G H)

2.3 Culture Media Performance

The use of mFC agar (DIFCO) for the detection of faecal coliform bacteria and the enumeration of total coliforms on mEndo LES agar (DIFCO) has been cited in several studies [5],[6],[7],[8]. The *E.coli* was inoculated on plates of both mEndo and mFC culture media and incubated at 37°C and 44.5°C respectively to ensure performance of each prepared batch.

2.4 Data Collection

Data will be collected after 24-hour incubation period of the culture media plates. Data will in the form of colony forming units per 100mL of filtered water (cfu/100mL). They will be recorded separately as heterotrophic bacterial (HTC) counts, Total coliform counts (TC) and Fecal coliform counts (FC) for every sampling date. The data groups will then be analyzed separately.

2.5 Quality Control

This process was conducted to ensure the validity and reliability of results. Before the equipment was used for subsequent site samples, the membrane holder and holding funnel were thoroughly washed with 70% ethanol and rinsed with sterile water. A 100mL of sterilized water was membrane filtered and placed on both growth media used to ensure water sterility. An unused membrane was placed on both growth media and incubated at the appropriate temperature to ensure

membrane sterility. One unused plate of each growth media was incubated at the appropriate temperature to ensure media sterility.

2.6 Sample processing and culturing

For the detection and enumeration of total and faecal coliforms, several methods have been suggested. Membrane filter procedure which is as effective as the multiple tube fermentation procedure shows discrete bacterial colonies that may be further identified, although highly turbid water and non-coliform bacteria can interfere with the test. Although highly effective, the membrane filter procedure requires processing of several sample dilutions in order to obtain filter plates with an appropriate range of colonies to validate enumeration [9]. All 108 water samples collected from the three sites over the study period were prepared and processed in an identical manner. Prior to the beginning of this study, samples were collected and vacuum filtered to establish a baseline count of raw samples. These pre-study trials confirmed that, a ten-fold serial dilution of the raw sample was necessary to obtain a meaningful viable count due to the exceptionally high bacterial content of the original samples. From each 500 ml raw sample, a 30 ml aliquot was added to 270 ml of sterilized water to obtain a 1/10 dilution of the sample. From this dilution, 30 ml was transferred to 270 ml of sterilized water to obtain a 1/100 dilution. This was repeated until a 10⁻⁵ dilution of the original sample was obtained. In vacuum filtration, 100 ml from the highest dilution (10⁻⁵) was

vacuum filtered through a 0.45 µm nitrocellulose millipore membrane (Millipore) according to the USEPA membrane filtration method 8074¹. The membrane was then placed on mEndo agar. Another 100 ml was membrane filtered then placed on mFC agar. The holding funnel was then rinsed with 70% ethanol [10] to remove any residual bacteria. This procedure was repeated for the next highest dilution (e.g. 10⁻⁴) to reduce any cross contamination through carry over. This process was repeated for all triplicate samples from each site. For detection of faecal coliforms and total coliforms, culture media plates were incubated inverted for 24 h at 44.5°C and 37°C respectively.

2.7 Data Analysis

The validity of the data and potential relationships between the measured parameters (water source and monthly variations) were addressed by conducting comparative statistical analyses of power transformed results using the R package statistical software.

III. RESULTS AND DISCUSSION

The results revealed that there are no faecal coliform detected in sites F, G, and H. Thus, there is no need to include these sites in the analysis (Table 1). In site I, the faecal coliform was only detected in week 3. During week 3, faecal coliform were recorded quite high at sites A, B, C, D, and E. Hence, it can be considered as a random occurrence for site I. Moreover, any descriptive statistics calculated out of the present results is meaningless. Hence, site I is also dropped from the analysis. It seemed that at the beginning of the study, the NUS water supply was contaminated but after week 7, the water seems to be free of faecal coliform (except site J). This experiment needs to be repeated again to confirm this. But because the results of the last three weeks will corrupt the analysis, they are dropped off in the following analysis.

Table 1: Sites and Amount of Faecal Coliform Present

SITES & Amount of Faecal Coliform Present (% measured)										
WK	A	B	C	D	E	F	G	H	I	J
1	20	0	20	0	0	0	0	0	0	0
2	0	0	0	0	20	0	0	0	0	20
3	40	40	60	40	60	0	0	0	20	0
4	0	20	40	20	0	0	0	0	0	0
5	20	0	20	20	0	0	0	0	0	40
6	60	0	0	20	40	0	0	0	0	20
7	0	40	0	0	0	0	0	0	0	11
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	20
10	0	0	0	0	0	0	0	0	0	0

¹ Adapted from Standard Methods for Examination of Water and Wastewater, 9222 B and 9221 B

All the analyzed sites show that there is faecal Coliform present. The probability measured of the FC present is extremely high. These probabilities show both the chances of having FC in our water and the high quantity they are likely to occur in. (Table 2).

Table 2: Summary of analysed sites

	SITE STATISTICS					
	A	B	C	D	E	F
Mean	20	14	20	14	17	13
Stdev	23.09	19.02	23.09	15.12	24.30	14.93
95% CI	-5.7–45.7	-6.9–35.4	-5.7–45.7	-2.5–31.1	-9.9–44.2	-3.6–29.6
Probability of having FC	0.89	0.84	0.89	0.93	0.82	0.89

For the site comparison by week, there seemed to be a weekly effect at each site. The faecal coliform count is fairly high. Thus in weeks 6, 4, and 7 are also significantly high as shown in Figure 4. On the other hand, there also seemed to be an effect of the difference in site. The different sites peak during the different weeks as shown in Figure 5.

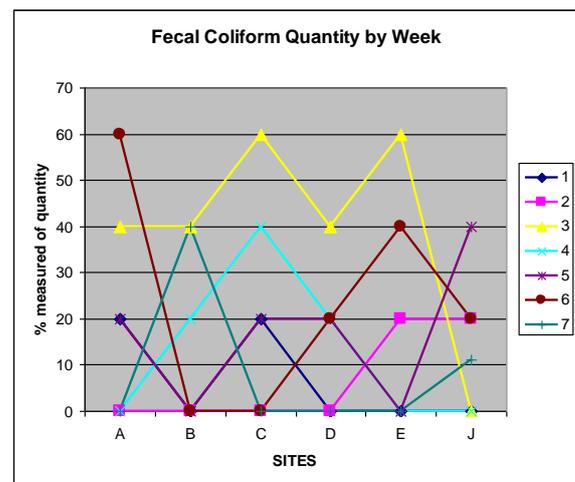


Figure 4: Site comparison by week

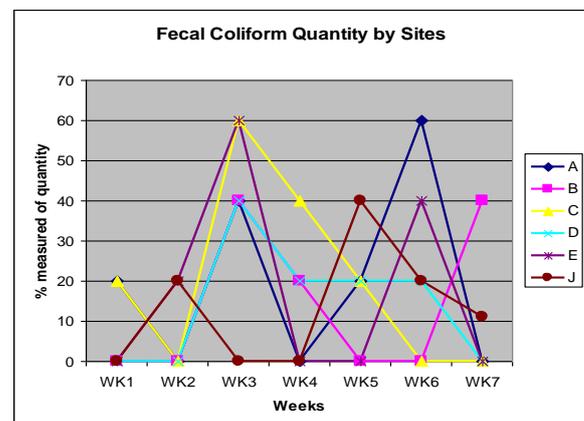


Figure 5: Weekly comparison by sites

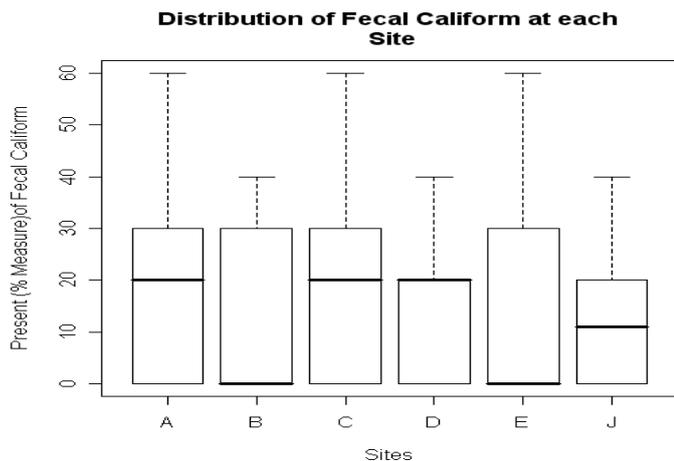


Figure 6: Faecal coliform distribution during 7 weeks at different sites

All the analysed sites show similar distributions. In sites A, C, and E revealed that faecal coliform counts are extremely high as shown in Figure 6. Unfortunately, for sites A, C, D, and J the medians are above zero and hence, central tendency is very unlikely to be zero. The statistical analysis shown below shows the present of faecal coliform by site.

```
> Summary(CFPer.aov)
      Df Sum Sq Mean Sq F value Pr(>F)
treatment  5  328.7    65.7  0.1596  0.9756
Residuals 36 14823.7   411.8
```

The ANOVA shows that there is no significant difference between sites that is all the analysed sites are equally likely to have the same faecal coliform content (the present of faecal content already shown above). Thus, the P-value is too high.

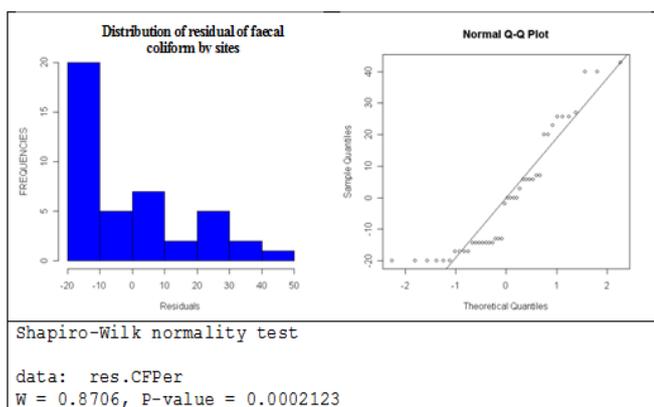


Figure 7: Distribution of residual of faecal coliform by sites

The histogram in Figure 7, gives a trend that is right skewed. Perhaps it can be approximated by the Chi-Square distribution. The Shapiro-Wilk test gives a p-value of 0.0002 which is quite small. This is indicative of a huge departure from normality. The points on the QQ-plot also confirm this. Hence, hard to affirm any difference in site – But there definitely faecal coliform in the water. In comparison, the

present of faecal coliform by week is shown in the statistical analysis shown below.

```
> summary(CFPer1.aov)
      Df Sum Sq Mean Sq F value Pr(>F)
treatment1  6 5198.2    866.4  3.0463  0.01669 *
Residuals  35 9954.2    284.4
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'
0.1 ' ' 1
```

The weekly effect is confirmed by the analysis above. This shows that the P-value of 0.01669 shows that the present of faecal coliform differ in quantity for at least one pair of weeks.

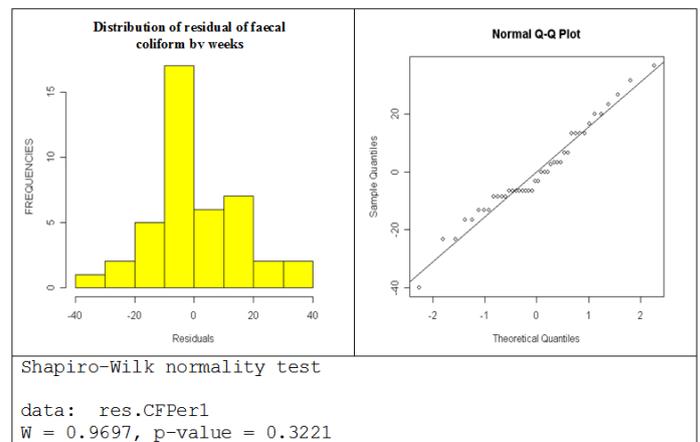


Figure 8: Distribution of residual of faecal coliform by weeks

The histogram in Figure 8 gives a trend that can be approximately normal. The Shapiro-Wilk test gives a p-value of 0.3221 which is quite large. This is indicative of the data upholding the normality assumption. The points on the qq-plot also confirm this – approximately straight. Hence, there is a significant difference in faecal coliform take at various sites in different weeks.

IV. CONCLUSION

This research discovered high levels of bacterial contamination at the 10 sites at the National University of Samoa which far exceeded WHO standards for safe drinking water in developing countries. The quality of these water sources needs to be monitored more frequently to ensure complete safety for community use. A health survey of the sites should be conducted to identify any frequent water users with possible infections from contaminated water.

ACKNOWLEDGEMENT

We are grateful to the University Research Ethics Committee (UREC) at the National University of Samoa, for the financial assistance which enabled this research to be done.

REFERENCES

- [1] Hrudehy S.E and Hrudehy E.J. “Published case studies of waterborne disease outbreaks-evidence of a recurrent threat”. *Water Environ Res.*, 2007, 79, pp 233-245.
- [2] Reynolds K.A, Menda K.D, Gerba C.P. “Risk of waterborne illness via drinking water in the United States”. *Rev Environ Contam Toxicol* 2007, 192, pp 117-158.
- [3] Jones A.Q, Majowics S.E, Edge V.L, Thomas M.K, MacDougall L, Fyfe M, Atashband S, Kovacs S. “Drinking water consumption patterns in British Columbia: an investigation of associations with demographic factors and acute gastrointestinal illness”. 2007, *Sci Total Environ*, 388, pp 54-65.
- [4] Jackson C. “WHO accuses Samoa of ignoring typhoid”. *New Zealand Herald* 13 February 2010.<http://www.rnzi.com/pages/news>, Accessed 17 April 2010.
- [5] Black J.G. “Microbiology: Principles and Explorations”. *John Wiley and Sons*, 2005. NY, pp 1-9.
- [6] Davies C.M, Julian A, Long H, Donald M and Ashbolt N.J. “Survival of fecal microorganisms in marine and freshwater sediments”. *Applied and Environmental Microbiology*, 1995. pp 1888-1896.
- [7] APHA, Standard Methods for Examination of Water and Wastewater – Part 900: Microbial Examination, 1999. American Public Health Association, M
- [8] Erman, A. Dilo, and P. Havinga, “A virtual infrastructure based on honeycomb tessellation for data dissemination in multi-sink mobile wireless sensor networks,” *EURASIP J. Wireless Commun. Netw.*, vol. 2012, no. 17, pp. 1–54, 2012.
- [9] Kinalis, S. Nikoletseas, D. Patroumpa, and J. Rolim, “Biased sink mobility with adaptive stop times for low latency data collection in sensor networks,” *Inf. Fusion*, vol. 15, pp. 56–63, Jan. 2014.
- [10] W. Khan, A. H. Abdullah, M. H. Anisi, and J. I. Bangash, “A comprehensive study of data collection schemes using mobile sinks in wireless sensor networks,” *Sensors*, vol. 14, no. 2, pp. 2510–2548, 2014.
- [11] Nazir and H. Hasbullah, “Mobile sink-based routing protocol (MSRP) for prolonging network lifetime in clustered wireless sensor network,” in *Proc. Int. Conf. Comput. Appl. Ind. Electron. (ICCAIE)*, pp. 624–629, Dec. 2010.
- [12] E. B. Hamida and G. Chelius, “Strategies for data dissemination to mobile sinks in wireless sensor networks,” *IEEE Wireless Commun.*, vol. 15, no. 6, pp. 31–37, Dec. 2008.
- [13] Chalermek, R. Govindan, and D. Estrin, “Directed diffusion: A scalable and robust communication paradigm for sensor networks,” in *Proc. ACM SIGMOBILE Int. Conf. Mobile Computer Network (MOBICOM)*, pp. 56–67, 2000.
- [14] M. Di Francesco, S. K. Das, and G. Anastasi, “Data collection in wireless sensor networks with mobile elements,” *ACM Trans. Sensor Netw.*, vol. 8, no. 1, pp. 1–31, Aug. 2011.
- [15] S. R. Gandham, M. Dawande, R. Prakash, and S. Venkatesan, “Energy efficient schemes for wireless sensor networks with multiple mobile base stations,” in *Proc. IEEE Global Telecommun. Conf. (GLOBECOM)*, vol. 1. pp. 377–381, Dec. 2003.
- [16] T. Banerjee, B. Xie, J. H. Jun, and D. P. Agrawal, “Increasing lifetime of wireless sensor networks using controllable mobile cluster heads,” *Wireless Commun. Mobile Comput.*, vol. 10, no. 3, pp. 313–336, Mar. 2010.
- [17] T.S. Chen, H.-W. Tsai, Y.-H. Chang, and T.-C. Chen, “Geographic converge cast using mobile sink in wireless sensor networks,” *Comput. Commun.*, vol. 36, no. 4, pp. 445–458, Feb. 2013.
- [18] W. M. Aioffi, C. A. Valle, G. R. Mateus, and A. S. da Cunha, “Balancing message delivery latency and network lifetime through an integrated model for clustering and routing in wireless sensor networks,” *Comput. Netw.*, vol. 55, no. 13, pp. 2803–2820, Sep. 2011.

AUTHORS BIOGRAPHY

Faainuseiamalie Latu is the Head of the Science Department of the Faculty of Science. He has been intensively involved in various environmental projects with the Ministry of Natural Environment in Samoa and also with regional organization such as SPREP and international universities.

Dr. Patila Amosa is the Dean of the Faculty of Science. She is the Climate Change expert. Her research interests are in the areas of marine pollution and oceanography.

Dr. Taema Imo is the Associate Professor in Environmental Science in the Faculty of Science of the National University of Samoa. Her research is geared towards environmental and marine pollution, management and toxicology.

Citation of this Article:

Faainuseiamalie Latu, Patila Amosa, Taema Imo, “Bacteriological Quality of Potable Water Supply at the National University of Samoa” Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 3, pp 19-25, March 2021. Article DOI <https://doi.org/10.47001/IRJIET/2021.503004>
