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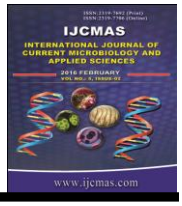

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Microbiological Safety and Physico-chemical Quality of Fountain and Public Shower Water of Mauritius

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A B S T R A C T

Man-made recreational fountains are on the rise thanks to greater urbanization and mushrooming of tourist places of attraction. There is also greater availability of communal shower facilities especially at public beaches. Public perception is that both fountain and public shower water are microbiologically safe and there is little awareness of the potential for recreational water to spread infectious diseases. This study purports to assess the microbial safety, sanitary and physico-chemical quality of water from public fountains and showers. The specific objectives were to test for the (i) level of fecal indicator bacteria (*Enterococcus fecalis* and *Escherichia coli*), (ii) presence of autochthonous waterborne pathogens (*Clostridium perfringens*, *Pseudomonas* and *Legionella*), and (iii) physico-chemical properties of water, with the view to assessing their overall compliance with legal limits. Samples were aseptically collected from five highly frequented fountains of Mauritius,and five public showers from Northern beaches of the island. Physicochemical test parameters included pH, Electrical conductivity (EC) and Total Suspended Solids (TSS). Samples were also plated on Plate Count Agar, Eosin Methylene Blue Agar, Enterococcus Agar, Pseudomonas agar, Iron Sulphite Agar and Buffered Charcoal Yeast Extract Agar for enumeration of Total Viable Counts, *E. coli*, *E. fecalis*, *Pseudomonas* spp, *C. perfringens*, and *Legionella* respectively. Values of pH, EC and TSS of fountain and shower water samples were below legal upper limits and fell in the range of 7.3-7.9, 100-375 µS/cm, 800-975 mg/L and 7.3-7.6, 200-680 µS/cm and 580-1100 mg/L respectively. *Pseudomonas spp.* was detected in all fountain water samples (1.5 – 3.0 log cfu/ml) and shower water (0.06 – 3.2 log cfu/ml) but within the tolerance range. The absence of *E. coli*, *E. fecalis*, *C. perfringens* and *Legionella* in all water samples was confirmed by culturing and molecular assays. Findings of this study indicate that most waterborne pathogens as well as fecal contaminants were undetectable in these water systems thus corroborating their safety for public use.

Introduction

Recreational water systems now play a prominent role in the life of an ever-increasing number of citizens worldwide. With urbanization, there has been a significant increase in the number of man-made recreational systems offering social

benefits, comfort and sophisticated services. These recreational activities range from whole-body water contact sports such as swimming and canoeing to non-contact sports such as fishing and walking. The public generally perceives recreational water to be safe and free from contamination and there is little awareness of the potential of chlorinated water to spread diseases.

Recent studies show that these water systems also present a degree of risk of a physical, microbiological or chemical nature (Barna *et al.,* 2012). The microbiological and physico-chemical hazards and risks associated with fountain water and public shower water systems vary from site to site and depend on the nature and the extent of exposure. Sanitary inspection and water quality assessments are important to evaluate the microbiological safety and physico-chemical quality of water. A well-conducted sanitary inspection can identify sources of microbiological hazards and estimate the risk of waterborne illnesses (WHO, 2000). Recreational Water Illnesses (RWIs) are caused by ingestion of contaminated water, inhalation of aerosols, or being in direct contact with contaminated water in swimming pools, water parks, spas, interactive fountains, ponds, lakes, rivers, or oceans. In the US, from 2005 to 2006, 78 outbreaks of RWIs have been reported, affecting 4,412 persons and resulting in 116 hospitalizations and five deaths (CDC, 2009). More than 25 000 cases of water-borne outbreaks have been registered in the US from 1999 to 2008.

Microbiological hazards encountered in water-based recreation include viral, bacterial and protozoan pathogens. The pathogenic microorganisms that can be found in water bodies have a wide range of sources. These include sewage pollution, water environments, livestock animals and the recreational users themselves. *Enterococcus fecalis* and *Escherichia coli* are considered as fecal indicators as their presence in recreational water is indicative of the presence of fecal contaminants (Wade *et al.*, 2010). In addition, *E. coli* is an index organism, which signals the presence of enteric pathogens such as diarrheagenic *E.* coli, *Salmonella* and *Campylobacter* (Wade *et al.*, 2010). Since these enteric pathogens contaminate recreational waters as a result of human action or other, they are termed as allochthonous pathogens (Wade *et al.*, 2010).Several waterborne pathogens are also autochthonous species with freshwater systems being their natural reservoir. The objectives of the current study were therefore to test for the (i) level of fecal indicator bacteria (*Enterococcus fecalis* and *Escherichia coli*), (ii) presence of autochthonous waterborne pathogens (*Clostridium perfringens*, *Pseudomonas* and *Legionella*) and (iii) physico-chemical properties of water from several decorative fountains and public shower facilities in Mauritius, with the view to assessing the overall safety and quality.

Materials and Methods

Sample Collection

Water was collected from five communal shower facilities and five interactive or decorative fountains in Mauritius. A volume of 300ml of each water sample was aseptically collected in separate autoclaved 100ml-plastic bottles each week. Water was collected immediately after opening of the mouth of the sterilised bottles to minimise chances of contamination of samples. After collection, the water bottles were properly sealed, labelled and stored under chilled conditions and analyzed within twenty-four hours.

Physico-chemical Test of the Samples

The pH of the samples was measured at room temperature using a pH meter (Mettler Toledo).The electrical conductivity of the samples was measured at room temperature using an electric conductivity meter (Jenway 4020-series).To measure the Total Suspended Solids in the samples, filter papers were first dried for five minutes in an oven at 103-105˚C and the initial weight of each filter paper was noted. A volume of 30ml of the water sample was then passed through each filter paper and the filter paper was allowed to dry at 103-105˚C for 2.5 hours. The final weight of each filter paper was measured and the Total Suspended Solids per ml of water in each sample was calculated using the formula:

$$\text{Total Suspended Solids} = \frac{\text{(Final weight of paper- Initial weight of paper)}}{\text{Volume of water}}$$

Enumeration, Detection and Identification of Microorganisms

An aliquot of 0.1 ml and 1 ml of each sample were aseptically plated on Plate Count Agar using the spread plate technique. The plates were incubated at 37˚C for 24 hours and the number of colony forming units per ml was calculated. The method to enumerate *E. coli* was adapted from El-Hadedy *et al.* (2012). Briefly, 0.1ml and 1 ml of each sample were aseptically spread-plated on Eosin Methylene Blue agar and the plates were then incubated at 35˚C for 18-24 hours. Blue-black colonies, which produced a green metallic sheen, were identified as presumptive *E. coli*. The method to analyse *Pseudomonas* spp. on Pseudomonas agar was adapted from Ugur *et al*. (2012). An aliquot of 0.1 ml and 1 ml of each sample were aseptically plated on Pseudomonas agar using the spread plate technique. The plates were incubated at 35˚C for 48 hours. Cream colonies identified as presumptive *Pseudomonas* colonies were confirmed by biochemical tests described in Next Section.

The method to enumerate *Clostridium perfringens* on Iron Sulphite Agar was adapted from Junqueira *et al.* (2012). An aliquot of 0.1 ml and 1 ml of each sample were aseptically spread-plated on Iron Sulphite Agar followed by addition of an overlay of agar to suppress growth of aerobic microorganisms. The plates were then incubated at 35˚C for 24-48 hours under anaerobic conditions. Black colonies observed were identified as suspect *Clostridium perfringens*. The method to analyse *Legionella* on Buffered Charcoal Yeast Extract Agar was adapted from Ewann *et al.* (2006). Briefly, 100 ml of each sample was aseptically passed through a sterile membrane filter connected to a vacuum pump. The membrane filter was incubated on Buffered Charcoal Yeast Extract Agar at 35˚C for 3 days. White colonies formed were suspect *Legionella* colonies and molecular tests were carried out for confirmation. The method to isolate *Enterococcus fecalis* on Slanetz and Bartley agar was adapted from Krocko *et al*. (2007). A volume of 100 ml of each sample was aseptically passed through a sterile membrane filter connected to a vacuum pump. The membrane filter was incubated on Slanetz and Bartley Agar at 35˚C for 44 hours. Deep red colonies were confirmed as presumptive *Enterococcus fecalis* colonies.

Biochemical Confirmation of Suspected Colonies

Biochemical profiling of the microorganisms was carried out prior to microscopic examination. A piece of filter paper was soaked in oxidase reagent. A loop was then used to rub the microorganisms onto the filter paper. The paper was

observed for colour changes: a positive oxidase test was indicated by formation of a purple colour within at least 90s.A catalase test was performed by smearing a loopful of colony on a slide followed by addition of a drop of 3% H_2O_2 on the slide. The slide was then covered and observed to check for the formation of bubbles.

Molecular Confirmation of Suspected Colonies

DNA Extraction from Suspect *Legionella* Spp.

A loopful of suspected *Legionella* colony was incubated in Luria and Bertani broth for twenty-four hours in a shaker at 37˚C. An aliquot of 2 ml of the resulting solution was transferred to a 15 ml corning tube to be centrifuged at 8000 rpm for 10 minutes. The supernatant was removed and 560 µl of Tris EDTA (TE) buffer, 50 µl of 10% Sodium Dodecyl Sulfate (SDS) and 5% of proteinase K were added to the pellet. The solution formed was mixed and incubated at 55˚C for 1 hour. An equal volume of isoamyl alcohol was added and the solution was centrifuged at 8000 rpm for 15 minutes. The top layer formed was transferred to another corning tube and an equal volume of 95% alcohol was added. The tubes were stored at 20˚C overnight for DNA replication. The solution was centrifuged again at 8000 rpm for 10 minutes and the pellets formed were the DNA. The pellets were washed twice using 70% ethanol and dried at 50˚C for 20 minutes for ethanol evaporation. An aliquot of 50 µl of TE buffer were added to the pellets and the tubes were stored at 20˚C.

Polymerase Chain Reaction

The DNA extracted was used for subsequent PCR identification of the microorganisms. An aliquot of 25µl of a PCR reaction mix was made from 2.5µl of $MgCl_2$(Dream Taq buffer), 2.0µl of dNTPs, 1.0µl of forward primer (16S), 1.0µl of reverse primer (16S), 0.2 µl Taq DNA polymerase and 163µl of Millipore water. An initial denaturation was carried out for 3 minutes at 95˚C. This was followed by temperature cycles of 94˚C for 1 minute, 53˚C for 30 seconds, 72˚C for 1 minute and finally 72˚C for 30 seconds. The PCR products were analyzed using agarose gel electrophoresis using 1.5% agarose gel containing ethidium bromide and the gels were viewed. The PCR products obtained were sent for sequencing at Inqaba Biotechnology Industries (Pty) Ltd. After the sequencing process, the sequences obtained were identified through a BLAST search on the NCBI databank.

Statistical Analysis

A total of five independent trials were conducted over five weeks. A single-factor ANOVA was used to analyse the TVC and *Pseudomonas* counts for fountain and shower samples. Tukey's multiple comparisons test was carried out to compare differences among the fountain water samples or shower water samples using Minitab Inc.17 at a significance level of 5%.

Results and Discussion

Sample Collection

Results for physicochemical and microbiological analyses have no value if water samples are not properly collected and stored (WHO, 2000). In this study, autoclaved 100-ml sampling bottles containing sodium thiosulphate to neutralize any chlorine present in the water samples (WHO, 2000) were used. If the chlorine is not neutralized, microorganisms may be killed during the transit leading to erroneous results (WHO, 2000). The bottles were opened just before collection of the water samples and once the samples were

collected; the sampling bottles were properly sealed and stored in ice-proof insulated box containing ice-packs to ensure rapid cooling (1-4˚C). According to the WHO (2000), sample transportation time should not exceed two hours and the collected samples should be analyzed within twenty-four hours from time of collection. These conditions were properly applied during the sample collection process in order to avoid temperature abuse of the samples, minimize risks of contamination and maintain the initial microbial population as far as possible.

Physico-chemical Tests

pH

It is vital to maintain the proper pH in fountain water and shower water to ensure the safety of people who are directly or indirectly exposed to these water systems. Acidic pH (lower than 7.2) may cause corrosion of metals, plaster and concrete surfaces which get into direct contact with the water (Reed, 2015). When the pH of water is too high, there is a reduced ability of chlorine to kill pathogenic microorganisms which may cause infections (Reed, 2015). According to the National Health and Research Council of Australia (2008), pH for recreational water should be in the range of 6.5-8.5 for the safety of people in contact with these water systems. The pH of all the fountain water samples and the shower water samples fell in the specified range. The mean pH of the fountain water samples F1, F2, F3, F4 and F5 were found to be 7.6, 7.3, 7.8, 7.4 and 7.7 respectively (Table 1). It was observed that the pH of the water samples collected from the five fountains were not significantly different from one another ($P > 0.05$) with pH of all the samples falling in the range 7.3-7.9.The mean pH of public shower water at the five sites was found to be 7.6, 7.5, 7.5, 7.4 and 7.5 respectively (Table 1). It was observed that the pH of the water samples collected from the five public showers were not significantly different from one another ($P > 0.05$) with the pH of all samples falling in the range of 7.3-7.6.

Electrical Conductivity

Electrical conductivity measurements are very useful as they indicate the amount of dissolved organic material in water. Low electrical conductivity values signify that water samples are of high quality with low nutrient content whereas high electrical conductivity values indicate salinity, enrichment or pollution problems in water samples (WA, 2009).Even if comparatively high electrical conductivity values were obtained for some samples, these values are less than 1000 mg/L or 1000 ppm. A conductivity value of 1000 mg/L is considered the standard by the World Health Organization (WHO, 1979) and the Standard Organization of Nigeria (SON). The electrical conductivity of water from fountains (F1-F5) were 175, 380, 120, 285 and 150µS/cm respectively (Table 1). Significant differences could be observed between the electrical conductivity values of the water samples from the five fountains ($P < 0.05$). The electrical conductivity of the water samples from F1, F3 and F5 were statistically similar ($P > 0.05$) and the electrical conductivity values of water samples from F2 and F4 were statistically higher compared to the electrical conductivity of the other water samples. The Electrical Conductivity of public shower water at S1, S2, S3, S4 and S5 were 200, 200, 205, 690 and 450 µS/cm respectively. It could be observed that most of the electrical conductivity values were statistically similar ($P > 0.05$) except for S4 public shower, which was significantly higher than the rest.

Total Suspended Solids

To date, no internationally recognized standards or limits have been set for the Total Suspended Solid content in fountain or shower water. However, according to the Nigerian Standard for Drinking Water Quality, the limit for Total Suspended Solids in drinking water should be 500 mg/L (NSDW, 2007). Hence, with reference to this upper limit, the values for the Total Suspended Solids obtained in the fountain waters and shower waters seem to be acceptable since fountain and shower water are not intended for drinking. The Total Suspended Solids of fountain waterF1, F2, F3, F4 and F5 were 800, 900, 1000, 950 and 1000 mg/l respectively (Table 1). It could be observed that there were no statistically significant differences between the Total Suspended Solid contents of the five different public fountain water samples ($P > 0.05$). The Total Suspended Solids found in the shower waters at S1, S2, S3, S4 and S5 were 900, 780, 800, 1100 and 580 mg/l respectively (Table 1). There were no significant statistical differences among the Total Suspended Solid content of the five different public shower water samples ($P > 0.05$).

Enumeration, Detection and Identification of Microorganisms

Total Viable Count

The TVC values for the five fountain water samples fell in the range of 2.3-3.7 log cfu/ml with lowest and highest bacterial counts obtained for F1 (2.3 log cfu/ml) and F3 (3.7 log cfu/ml). water samples respectively (Table 2). The TVC of water samples collected from F3, F4 and F5 were comparable with mean population of 3.7 log cfu/ml, 3.6 log cfu/ ml and 3.3 log cfu/ ml respectively (Table 2). The variation in the microbial load of water sampled from the fountain waters could be due to differences in their disinfection protocols and frequencies. The mean TVC for public shower water samples fell in the range of 0.1-3.5 log cfu/ml with lowest and highest counts registered for S5 (0.1 log cfu/ml) and S2 and S3 (3.5 log cfu/ml) as indicated in Table 3. Generally low bacterial load could be attributed to regular maintenance, cleaning and disinfection of the fountains and shower-heads.

Enumeration of Presumptive *Pseudomonas*

The level of *Pseudomonas* spp. in the five fountain water samples fell in the range of 1.5-3.0 log cfu/ml with lowest and highest bacterial counts obtained for F3 (1.5 log cfu/ml) and F2 (3.0 log cfu/ml)samples respectively. The identity of presumptive *Pseudomonas* isolates from fountain and shower waters was confirmed upon streaking on Pseudomonas agar. The macroscopic morphology of the colonies, the microscopic morphology of the cells and the Gram-negative reaction observed were consistently suggestive of the genus *Pseudomonas spp* (Table 4).Negative results for the Methyl Red and Voges-Proskauer tests further corroborated the identification of *Pseudomonas spp* (Table 4).There was a significant difference in the population of *Pseudomonas* among the different public shower water samples ($P < 0.05$) (Table 4); water samples collected from S5 had a significantly lower level of pseudomonads (0.06 log cfu/ml) compared to other shower facilities (1.2-3.2 log cfu/ml). However there was no statistically significant difference ($P < 0.05$) in the mean population of *Pseudomonas* among the different fountain water samples (Table 3). The constant presence of *Pseudomonas* in the samples tested may be explained by the fact that growth of *Pseudomonas* is generally

enhanced at high temperatures in a well-aerated environment (Price *et al.,* 1988). Moreover, *Pseudomonas* spp. is known to be resistant to a wide range of antibiotics and disinfectants (WHO, 2006). Together, these factors render the environments of these water systems conducive to *Pseudomonas* proliferation given the tropical climate prevailing in Mauritius. At present, the acceptable levels of *Pseudomonas* spp. in recreational and public shower water samples have not been specified. However, Price and Ahearn (1988) showed that *Pseudomonas* spp. levels in water samples from hot tubs generally ranged from 6.6 to 10.0 log cfu/ml. Since the level of pseudomonads determined in fountain and shower water was considerably lower than reported in the literature, we can assume the results to be acceptable.

Enumeration and Detection of *Legionella* spp.

Legionella is recognized as a significant cause of sporadic and epidemic community-acquired and hospital-acquired pneumonia (Carratalà *et al.,* 2010). It is a significant health problem in many countries. In the United States, a significant rise in the number of cases of Legionnaire's disease has been reported over the past years (Carratalà *et al.,* 2010). In Germany, *Legionella pneumophila* has been found to be the leading cause of community-acquired pneumonia in hospitalized and ambulatory patients (Carratalà *et al.*, 2010).

According to the Centers for Disease Control and Prevention (CDC, 2014), Legionnaire's disease can be successfully treated with antibiotics but can sometimes be fatal. *Legionella* is naturally found in water reservoirs such as hot tubs, cooling towers, plumbing systems and decorative pools and fountains. It normally grows and propagates at high temperatures (CDC, 2014). Presumptive *Legionella* spp. was isolated from shower water at sites S2 and S3; however PCR identification of these suspect isolates revealed the absence of this pathogen in the samples tested (data not shown). The results presented in Tables 3 and 4 showed the consistent absence of *Legionella* spp. across all water samples collected at all sites. This might suggest that treatment or disinfection of fountain water and shower water is bactericidal against *Legionella*.

Enumeration of *E. coli*

E. coli was consistently undetectable, by the plating methodology, in all fountain and shower water samples collected as evidenced by the lack of dark colonies with metallic green sheen. Hence it can be deduced that all the water samples were free of *E.coli* and physical contaminants with which *E. coli* is generally associated. The primary reservoir of *E.coli* is the intestine of animals and therefore its absence in the water samples suggests that the water is free of fecal matter (Krumperman, 1983). The absence of *E. coli* in the samples might also be because of its inability to adapt and propagate in such aquatic environments (Schultz-Fademrecht *et al.,* 2008).

Enumeration of *Clostridium perfringens*

Clostridium perfringens is an anaerobic, gram-positive spore-forming pathogen; the tough and dormant spores confer protection to the bacteria by making them exceptionally resistant to unfavorable conditions in water environments, including UV irradiation, temperature and pH extremes, and disinfection processes, such as chlorination.

Table.1 Summary of Physico-chemical Test Results of Fountain and Public Shower Water

	Fountain water					Public shower water				
	F1	F2	F3	F4	F5	S1	S2	S3	S4	S5
pH	7.6 ± 0.60	7.3 ± 0.60	7.8 ± 0.38	7.4 ± 0.47	7.8 ± 0.56	7.6 ± 0.40	7.5 ± 0.37	7.5 ± 0.40	7.4 ± 0.35	7.5 ± 0.20
Electrical conductivity (μS/cm)	172.6 ± 8.51	376.6 ± 79.21	111.7 ± 11.78	279.4 ± 66.96	159.7 ± 7.47	201.7 ± 20.27	197.4 ± 9.73	207.6 ± 40.14	673.6 ± 229.71	427.8 ± 77.39
TSS (g/ml)	806.7 ± 486.31	880.0 ± 570.00	975.3 ± 458.49	940.0 ± 377.56	996.0 ± 379.37	916.7 ± 272.92	754.7 ± 378.87	790.0 ± 392.55	1068.0 ± 508.26	580.7 ± 564.23

Table.2 Summary of Biochemical Test Results Carried out on Presumptive *Pseudomonas* Isolates

Biochemical Test	**Result**
Gram staining	Gram negative
Catalase test	Positive
Oxidase test	Positive
Methyl Red test	Negative
Voges-Proskauer test	Negative

Table.3 Bacterial Load of Water from Five Popular Decorative Fountains of Mauritius

Parameters	Log Mean Bacterial Population (log cfu/ml)				
	F1	F2	F3	F4	F5
TVC	2.3 ± 0.14^{a}	3.0 ± 0.05^{b}	3.7 ± 0.01^{c}	3.6 ± 0.05^{c}	3.3 ± 0.18^{c}
E. coli	< 0.0	< 0.0	< 0.0	< 0.0	< 0.0
Pseudomonas	2.7 ± 0.18^{a}	3.0 ± 0.46^{a}	1.5 ± 1.62^{a}	2.6 ± 0.34^{a}	1.7 ± 1.02^{a}
C. perfringens	< 0.0	< 0.0	< 0.0	< 0.0	< 0.0
E. faecalis	< 0.0	< 0.0	< 0.0	< 0.0	< 0.0
Legionellaspp.	< 0.0	< 0.0	< 0.0	< 0.0	< 0.0

Values within the same row that are significantly different from one another ($P < 0.05$) are denoted by different superscript letters

Table.4 Bacterial Load of Water from Five Popular Public Showersof Mauritius

Parameters	Log Mean Bacterial Population(log cfu/ml)				
	S1	S2	S3	S4	S5
TVC	3.2 ± 0.06^{c}	3.5 ± 0.11^{c}	3.5 ± 0.02^{c}	2.5 ± 1.00^{b}	0.1 ± 0.13^{a}
E. coli	< 0	< 0	< 0	< 0	< 0
Pseudomonas	2.0 ± 1.14^{bc}	2.2 ± 1.45^{bc}	1.2 ± 0.87^{ac}	3.2 ± 0.18^{c}	0.06 ± 0.13^{a}
C. perfringens	< 0.0	< 0.0	< 0.0	< 0.0	< 0.0
E. faecalis	< 0.0	< 0.0	< 0.0	< 0.0	< 0.0
Legionella spp.	< 0.0	0.4 ± 0.03^{b}	0.04 ± 0.13^{a}	< 0.0	< 0.0

Values within the same row that are significantly different from one another ($P < 0.05$) are denoted by different superscript letters

Although clostridia probably do not grow in surface waters, the high resistance of their spores will usually make their presence ubiquitous in environmental waters (WHO, 2008; Payment *et al*., 2003; Vilanova *et al*., 2004). Being relatively resistant to disinfection, *C. perfringens* spores must be removed by some form of filtration, as terminal disinfection is unlikely to inactivate them (Cabral, 2010). A general absence of *Clostridium perfringens* in fountain and public shower water samples tested was consistently observed suggesting that the filtration treatment process undergone is adequate. Moreover, it has been proposed that the inability to detect *C. perfringens* spores in finished water may also indicate the absence of protozoan cysts since they are likely to have been co-filtered out during the treatment process.

C. perfringens appears to be a universal component of the human and animal intestine since it has been systematically isolated from the intestinal contents of animals that have been studied (Cabral, 2010). Humans also carry *C. perfringens* as part of the normal endogenous flora (Rainey *et al*., 2009; Smith, 2003). Spores of *C. perfringens* are largely faecal in origin (Sorensen et al., 1989) and tend to be present in sewage at levels of ca. 10^4-10^5 cfu per 100 ml (Davies et al., 1995). Spores of *C. perfringens* thus also serve as good indicators for parasitic protozoa and viruses from sewage-impacted waters (Payment and Franco, 1993; Ferguson et al., 1996). Their resistance to disinfectants may also be an advantage for indexing disinfectant-resistant pathogens. Commonly used indicators of fecal contaminations such as fecal coliforms, *Escherichia coli* and enterococci are considered to be short-lived in aquatic environments (Byamukama *et al*., 2005) while *Clostridium perfringens* can survive harsh environments and may thus be used as a more reliable indicator of fecal contamination (Davies *et al.,* 1995). Their absence from the water samples further corroborate the microbiological safety and sanitary quality of fountain and public shower water.

Detection and Isolation of *Enterococcus faecalis*

Enterococci have both intrinsic and acquired resistance to antibiotics such as penicillin, chloramphenicol, tetracycline, rifampicin, fluoroquinolones, aminoglycosides and vancomycin. They are facultative anaerobes that can survive at temperatures of up to 60˚C and in high salt concentrations (Fraser, 2014). *Enterococcus faecalis* was

consistently undetectable by plating in fountain water and public shower water samples, thereby corroborating the absence of fecal traces in fountain and public shower water at the different sampling sites.

In this study, we investigated the microbial safety and sanitary quality of water from decorative fountains and public showers at popular places of attraction in Mauritius. Fecal indicator bacteria *E.fecalis* and *E. coli* and pathogens such as *C.perfringens* and *Legionella* were consistently absent in all fountain and public shower water samples tested. This indicated that all the water samples analyzed were free of physical fecal contaminants and important disease causing microorganisms. *Pseudomonas* spp. was however systematically detected in all water samples albeit at acceptable levels. The pH, electrical conductivity and Total Suspended Solid contents of all water samples were also found to be within acceptable range. Therefore this study indicates that the water of decorative fountains and public shower facilities are of sound microbiological and physicochemical quality.

References

Byamukama, D., Mach, R.L., Kansiime, F., Manafi, M. and Farnleitner, A.H., 2005. Discrimination efficiency of fecal pollution detection in different aquatic habitats of a high-altitude tropical country, using presumptive coliforms, *Escherichia coli*, and *Clostridium perfringens* spores. *Applied and Environmental Microbiology*, 71, 65-71.

Cabral, J.P.S., 2010. Water Microbiology: Bacterial Pathogens and Water. International Journal of Environmental Research and Public Health. 7(10), 3657–3703.

Carratalà, J. and Garcia-Vidal, C., 2010. An update on *Legionella*. US National Library of Medicine, *National Institutes of Health*, 23(2), 152-157.

CDC. 2013. *Legionella* (legionnaire's disease and Pontiac fever).

CDC. 2014. Healthy swimming/ Recreational water.

Cornell University, 2014. Department of microbiology-Bacterial endospores.

Davies, C.M., Long, J.A.H., Donald, M., Ashbolt, N.J., 1995. Survival of fecal microorganisms in marine and freshwater sediments. *Applied and Environmental Microbiology*, 61, 1888-1896.

El-Hadedy, D., and El-Nour S.A., 2012. Identification of *Staphylococcus aureus* and Escherichia coli isolated from Egyptian food by conventional and molecular methods. *Journal of Genetic Engineering and Biotechnology*, 10(1), 129-135.

Ewann, F., and Hoffman, P.S., 2006. Cysteine metabolism in Legionella pneumophila: Characterisation of an L-Cystine-Utilizing mutant. *Applied and Environmental Microbiology*, 72(6), 3993-4000.

Grass, J.E., Gould, L.H., and Mahon, B.E., 2013. Epidemiology of foodborne diseases outbreaks caused by *Clostridium perfringens. Foodborne Pathogens and Disease*, 10(2), 131-135.

Fraser, L.S., 2014. Enterococcal infections. *Medscape.*

Junqueira, V.C., Neto, RC., da Silva, N., and Terra JH., 2012. Comparison of methods for the enumeration of *Clostridium perfringens* spores in water. *Water Science Technology*, 65(2), 227-232.

Krocko, M., Canigova, M., and Duckova, V., 2007. Occurence, isolation and antibiotic resistance of *Enterococcus* species isolated from

raw pork, beef and poultry. *Journal of Food and Nutrition Research*, 46(2), 91-95.

Krumperman, P.H., 1983. Multiple antibiotic persistence indexing of *E.coli* to identify high- risk sources of fecal contamination of foods. *Applied and Environmental Microbiology*, 46(1), 165-170

Lebert, I., Baucour, P.,Lebert, A. and Daudin, J-D., 2004. Assessment of bacterial growth on the surface of meat under common processing conditions by combining biological and physical models. *Journal of Food Engineering*, 68, 89-98.

National Health and Research Council of Australia, 2008. Guidelines for Managing Risks in Recreational Water.

Nigerian Industrial Standard, 2007. Nigerian Standard for drinking water quality. *Standards Organization of Nigeria.*

Payment, P., Waite, M. and Dufour, A. Assessing microbial safety of drinking water: improving approaches and method. WHO & OECD, IWA Publishing; London, UK: 2003. Introducing parameters for the assessment of drinking water quality. pp. 47–77.

Rainey, F.A., Hollen, B.J. and Small, A. Genus *Clostridium*. In: De Vos P, Garrity GM, Jones D, Krieg NR, Ludwig W, Rainey FA, Schleifer K-H, Whitman WB, editors. Bergey's Manual of Systematic Bacteriology. 2nd ed. Vol. 3. Springer; New York, NY, USA: 2009. pp. 738–828.

Reed, J., 2015. Testing pool pH.

Scallan, E., Hoekstra, R.M., Angulo, F.J., Tauxe, R.V., Widdowson, M-A., Roy, S.L., Jones, J.L. and Griffin P.M., 2011. Foodborne illnesses acquired in the United States-Major pathogens. *Emerging Infectious Diseases*, 17(1), 7-15.

Schultz-Fademrecht, C., Wichern, M. and Horn, H., 2008. The impact of sunlight on inactivation of indicator microorganisms both in river water and in benthic biofilms. *Water Resources*, 42, 4771-4779.

Smith LDS. The genus *Clostridium*—Medical. In: Dworkin M, Falkow S, Rosenberg E, editors. The Prokaryotes: An Evolving Electronic Resource for the Microbiological Community. 3th ed. Springer-Verlag; New York, NY, USA: 2003. Electronic release 314.

Sorensen, D.L., Eberl, S.G. and Diksa, R.A 1989. *Clostridium perfringens* as a point source indicator in non-point polluted streams. Water Research, 23, 191-197.

Standard Organization of Nigeria, 2007. *Nigeria standard for drinking water quality*, 15-16.

Uğur, A., Ceylan, O., and Belma, A., 2012. Characterisation of Pseudomonas spp. from seawater of the southwest coast of Turkey. *Journal of Biological and Environmental Science*, 6(16), 15-23.

Vilanova X, Manero A, Cerdà-Cuéllar M, Blanch AR. The Composition and Persistence of Faecal Coliforms and Enterococcal Populations in Sewage Treatment Plants. J. Appl. Microbiol. 2004;96:279–288.

Wade, T.J., Sams, E., Brenner, P.K.,Haugland, R.,Chern, E.,Beach, M., Wymer, L., Rankin, C.C., Love,D., Li, Q., Noble, R. and Dufour, A.P., 2010. Rapidly measured indicator of recreational water quality and swimming-associated illness at marine beaches: A prospective cohort study.

Environmental Health, 9(66).
World Health Organization., 2000. Chapter 4: Water sampling and analysis. *Guidelines for drinking water quality.*
World Health Organization., 2000. Chapter 8: Sanitary inspection and microbiological water quality. Monitoring bathing waters-A practical guide to the design and implementation of assessments and monitoring programmes.
World Health Organization., 2000. Chapter 4: Water sampling and analysis. *Guidelines for drinking water quality.*

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